Australian Government

MURRAY–DARLING BASIN AUTHORITY

River Murray System Summary of River Operations

2021–2022 Water Year

July 2022

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin
The Murray−Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated.

Aboriginal people should be aware that this publication may contain images, names or quotations of deceased persons.

Executive summary

The MDBA operates the River Murray System on behalf of the Victorian, New South Wales and South Australian governments in accordance with the Murray Darling Basin Agreement (the Agreement). The Agreement requires that each year the Basin Officials Committee (the Committee) approve the "*Objectives and Outcomes for River Operations in the River Murray System*" document (the O&O). The O&O defines how the River Murray System should be operated and is published on the MBDA website. The O&O identifies that the MDBA will prepare an annual report summarising the operations of the River Murray System and its performance against both specific and general objectives and outcomes identified in the O&O. An independent advisory group will review MDBA's performance against the O&O and report back to the Committee on performance. This report is the MDBA annual report on river operations for the 2021–22 water year.

The 2021–22 MDBA water year brought above average rainfall across most the of the Murray–Darling Basin. Rainfall across much of New South Wales and southeast Queensland was 'very much above average'. Isolated areas along the eastern ranges and western slopes in the upper catchments of the Murrumbidgee, Lachlan, Macquarie, Condamine, and Border rivers recorded their highest rainfall totals on record for this twelve-month period. Rainfall across much of the Victorian southern ranges, the South Australian Riverland and the lower lakes was around average for 2021–22, whilst a small area in south-east South Australia recorded below average rainfall (**Figure 1**).

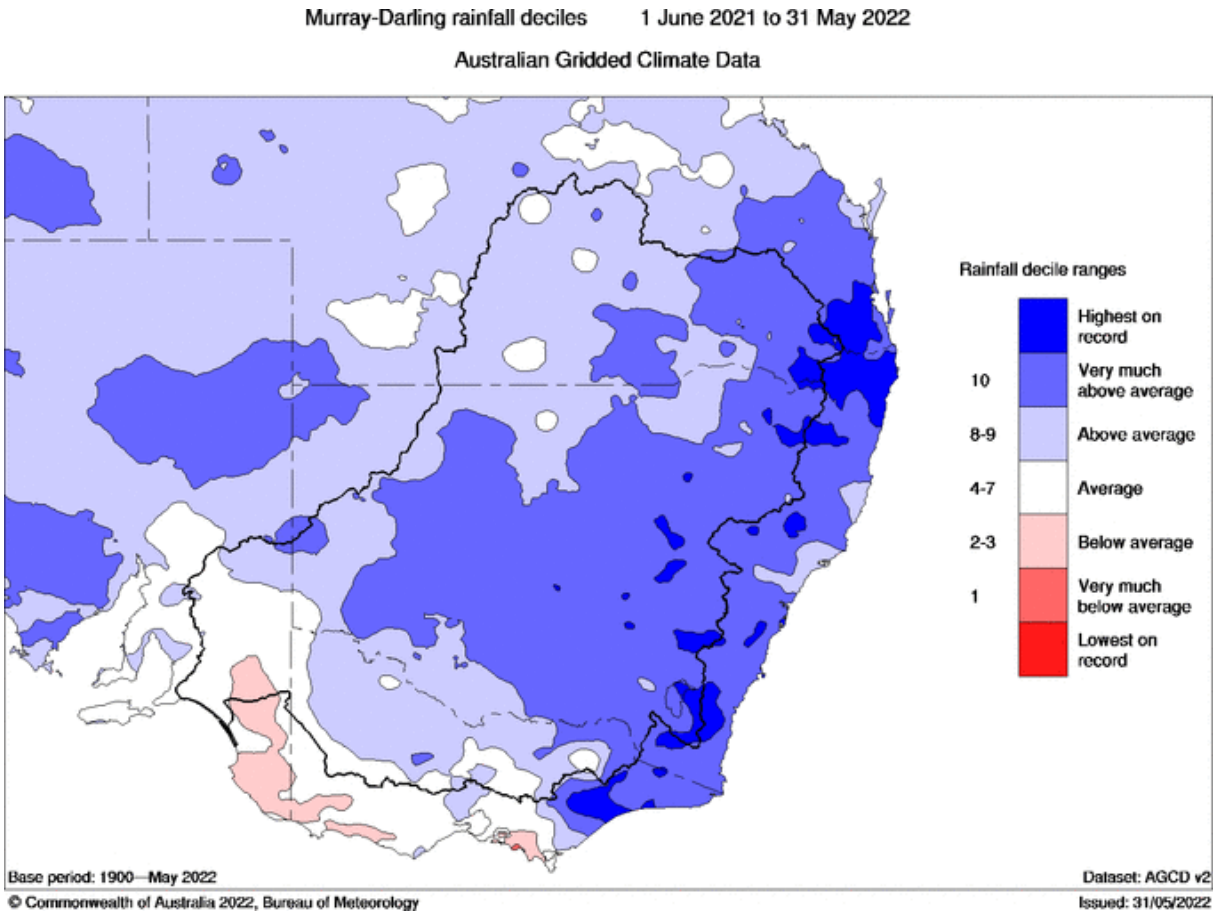


Figure 1: Murray–Darling Rainfall deciles for the period 1 June 2021 to 31 May 2022.

The year brought a consistent story of elevated inflows, full storages, and flood operations. MDBA undertook airspace releases and flood operations at Hume Dam, whilst airspace management at major Murrumbidgee system storages and the Menindee Lakes was undertaken by WaterNSW for much of the year. This drove broader system operations with persistent high inflows and unregulated flows along the River Murray heavily influencing the operation of Lake Victoria across the year.

MDBA active storage on 1 June 2021 was 4,529 GL, compared with the long-term average for that time of year of 5,089 GL (**Figure 2)**. Of this volume, 53% was held in Dartmouth Reservoir, 30% in Hume Reservoir, 4% in Lake Victoria and 13% in the Menindee Lakes system. The active storage increased over winter and spring, reaching around 8,150 GL by the end of November 2021. For the remainder of the water year the volume ranged between around 7,700 GL and 8,200 GL, well above the long-term average. At the end of May 2022, the MDBA active storage was 8,019 GL. Of this volume, 42% was held in Dartmouth Reservoir, 32% in Hume Reservoir, 4% in Lake Victoria and 22% in the Menindee Lakes system.

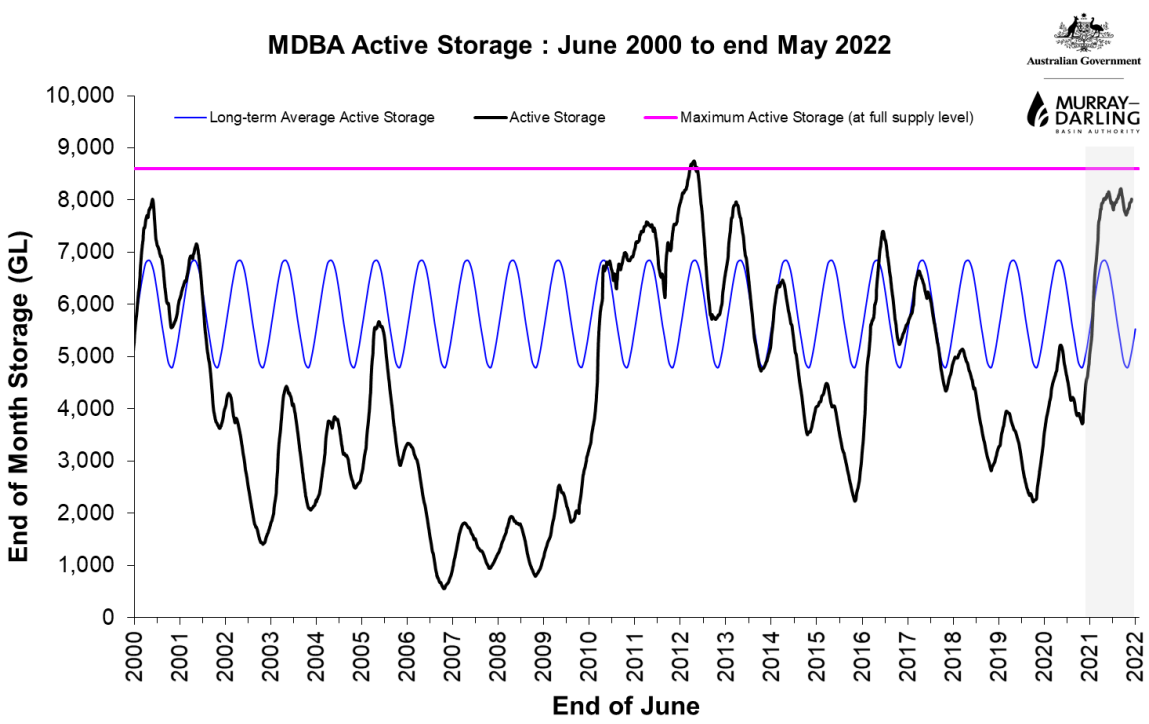


Figure 2: MDBA active storage, June 2000 to end May 2022. This graph shows the sum of active storage in Dartmouth and Hume Reservoirs, Lake Victoria and the Menindee Lakes (when part of the shared resource).

River Murray System inflows (not including releases from Snowy Hydro, IVT deliveries, managed environmental deliveries from tributaries and inflows to the Menindee Lakes) during the 2021–22 water year were approximately 10,868 GL. Monthly inflows from June to October varied around the long-term average. However, inflows from November to March were well above the long-term average for this time of year as wet conditions and regular high rainfall events persisted into summer (**Figure 3**).

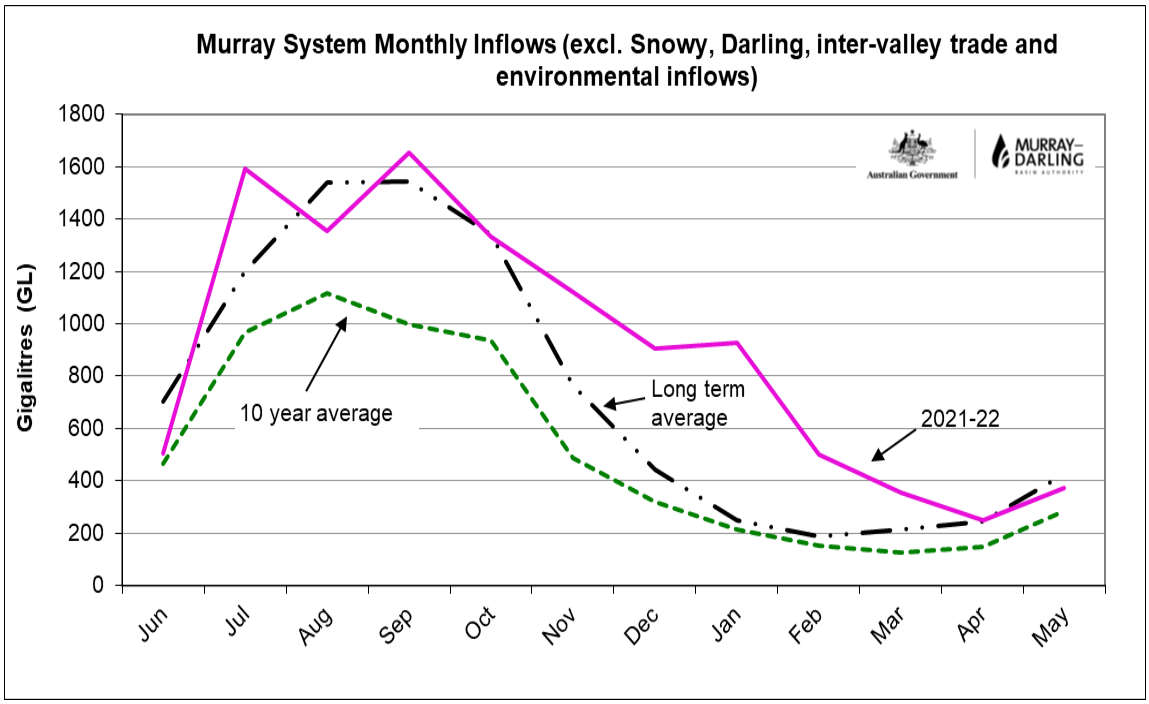


Figure 3: River Murray System inflows for 2021-22 compared with the long-term average and 10 year average.

Total inflow over the water year was in the highest 28% of annual inflows on record. This inflow volume is around double the volume recorded for the same period in 2020–21 and around 3,550 GL more than the long-term median inflow volume.

Key metrics for 2021–22

The operational metrics in **Table 1** provide a snapshot summary of river operations for the year. All figures should be considered within the context of the key drivers outlined below. Note that some variances may exist between the annual and quarterly values given within the quarterly report sections that follow due to hydrometric updates. Updates that are applied progressively throughout the year are incorporated into the annual key metrics summary (**Table 1).**

Table 1: Key metrics for River Murray System operations during 2021–22.

Metric		Annual value [i]
Total River Murray System inflows [ii]		10,868 GL (28% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 1,143 GL ↑ 1,397 GL ↑ 67 GL ↑ 895 GL.
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	145 GL 3,437 GL 275 GL 2,612 GL
	IVT Delivery	Murrumbidgee: 0 GL Goulburn: 7 GL
Total consumptive deliveries [iv]		1,233 GL Victorian Murray 1,558 GL NSW Murray
River Murray System loss [v]		1,723 GL
Environmental directed releases from Hume Dam [vi]		422.1 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	8,214 GL 696 GL 1,154 GL 83 GL 876 GL (releases and environmental trades to SA) 5,404 GL due to unregulated flows, ADF (825 GL) and forced delivery of deferred SA Entitlement.
Publication of operational information		51 MDBA Weekly Reports 25 Media Releases on 'river operations' 23 video briefings on Hume Dam operations AOO Publication Basin in Brief/Flows in the River Murray System

i. Values are provided from the River Murray System accounts at the point of time the report is written and considered as operational data. Updates to input data including changes to rating tables as well as other data changes because of hydrometric updates may result in the numbers in the above table changing.
ii. River Murray System inflows include unregulated inflows to Dartmouth, Hume and from the Kiewa, plus inflows from the NSW and Victorian tributaries excluding environmental water deliveries and IVT as well as Menindee when not part of the shared resource.
iii. Lake Victoria Net Releases refers to the net volume between inflows and outflows.
iv. Sourced from River Murray System accounts, includes all consumptive deliveries and Lindsay River allowance for Victoria.
v. River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental

water holder accounts for their specific watering actions and losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria, and Menindee Lakes System (when part of the shared resource).

vi. Sourced from River Murray System monthly environmental accounts.

vii. South Australian Environmental use – includes all environmental water that flows into South Australia.

viii. Includes changes due to rating table upgrades or subsequent hydrometric updates as well as unregulated flow, Additional Dilution Flow (ADF) and forced delivery of deferred SA Entitlement whenever these occur.

Summary of performance

General objectives and outcomes

General objectives and outcomes (GO&Os) are identified in the O&O and broadly describe system wide outcomes, relating to:

- Water storage, delivery and accounting
- RMO assets
- People and communities
- Environment
- Communication and information management

The MDBA self-assessment has identified that all GO&Os were met during the 2021–22 water year. This assessment will be independently assessed by the Independent River Operations Review Group and subsequently reported to the Basin Officials Committee (the Committee).

Specific Objectives and Outcomes

The River Murray System specific objectives and outcomes (SO&Os) for river operations provide a set of criteria that build upon established practices in relation to river operations and contemporary practice. In 2021–22, the SO&Os were found to be achieved (**Figure 4**).

Figure 4: Spatial snapshot of performance against SO&Os during 2021–22.

There are additional high-level operating requirements defined in the Murray–Darling Basin Agreement (the Agreement) that are not included in the assessment of performance against SO&Os shown in (**Figure 4).**

Contents

Introduction

Purpose of report and compliance rating system

In accordance with the document "*Objectives and Outcomes for River Operations in the River Murray System*" (the O&O) approved by the Basin Officials Committee (the Committee), the MDBA is required to prepare a report at the completion of each water year (1 June to 31 May) summarising its annual operations of the River Murray System. The O&O also identifies several general objectives and outcomes (GO&Os) and specific objectives and outcomes (SO&Os) that the MDBA must report against in detailing and assessing its performance.

This report fulfils the reporting requirement for the 2021–22 water year and provides the basis for the independent review of operations against the O&O undertaken by the Independent Review of River Operations Group (IRORG). The report includes the following sections:

1. Summary Report
    a. Overview of operational activities, including key achievements, key drivers, key metrics and month-by-month summary
2. Technical appendices[1]
    a. Performance assessment reporting against the general objectives and outcomes
    b. Performance assessment reporting against the specific objectives and outcomes
    c. Threshold Crossing Reports[2]

The performance reporting uses criteria shown in **Table 2** whilst noting that operational decisions are made based on the best available information and in the context of the operational drivers affecting the system at the time.

Table 2: Definition of ratings used in self-assessment of performance against G/SO&Os.

Performance rating against General and Specific Objectives and Outcomes			
Achieved	Qualified achievement	Not applicable	Not achieved
Operations undertaken as per the requirement of the G/SO&O for this quarter, noting there may be minor breaches of a small number and of immaterial effect.	Operations undertaken as per the requirement of the G/SO&O for this quarter with a substantial number of minor breaches or a major breach of small consequence.	The G/SO&O did not apply to this quarter.	Did not meet the requirements of the G/SO&O for this quarter.
Example: Where no issues of compliance occurred, or threshold crossings were of a minor nature.	*Example: Dartmouth dam transfers often have to balance system needs with rates of rise and fall and have a number of small – moderate threshold crossings.*	*Example: When Lake Menindee is in NSW control, or a clause is not applicable to the conditions.*	*Example: Where a clear requirement was not achieved causing a moderate-major consequence.*

[1] Summary tables only for this published version.
[2] Not included in this published version.

Summary of key external drivers that shaped river operations in 2021–22

Over the course of each water year, key external drivers shape and challenge river operations. Of these, four notable drivers played an important part in shaping and influencing river operations during 2021–22. These were:

- **Key Driver 1 - "Persistent wet conditions" –** At the end of winter, rain outlooks from the Bureau of Meteorology (BoM) continued to signal wetter conditions would persist through spring. The BoM forecasts came to fruition with the Murray–Darling Basin experiencing the 8th highest spring rainfall total on record and the highest since 2010. These wet conditions continued throughout the rest of the MDBA water year with the wettest January on record at Hume Dam. These persistent wet conditions meant long durations of storage spills and flood operations at Hume Dam and Yarrawonga Weir going on from August 2021 to February 2022. By May 2022, pre-releases had begun again in preparation for what is forecast to be another wet winter and spring. During this period, RMO undertook flexible and adaptable river operations to manage uncertainty and balance risks to flooding with the need to maintain delivery efficiency and maximise water availability.
- **Key Driver 2 – "Wet conditions in the Murrumbidgee"–** Quarter 1 saw wet conditions within the Murrumbidgee catchment with both Burrinjuck and Blowering Dams also entering winter at relatively high levels. Come July, airspace pre-releases had commenced from both storages to assist in mitigating the impacts of potential floods. These airspace releases continued for much of the coming 10 months, with the high inflows from the Murrumbidgee significantly influencing broader Murray system operations, including the development and extent of unregulated flows.
- **Key Driver 3 - "Continued filling of the Menindee Lakes"–** as Menindee Lakes storage surpassed 640 GL in early May 2021, water sharing arrangements as set out in the Murray–Darling Basin Agreement were triggered, making the storage volume a part of the shared River Murray resource. However, from Quarter two to the end of the water year, the MDBA did not call on any water from the Lakes, as significant rainfall in the Northern Basin, including some areas receiving their highest November rainfall on record resulted in flooding occurring across several Barwon-Darling tributaries. This meant a significant volume of water was passed through the Lakes as WaterNSW actively managed the storage airspace and adjusted releases to meet environmental targets and operate the system in accordance with standard operating procedures. By the end of the water year, a significant volume of water was still forecast to arrive at the Lakes, requiring WaterNSW to increase releases downstream to manage airspace and flood risk.
- **Key Driver 4 – "Persistent unregulated flows"** – In early July, inflows to Lake Victoria reached inlet capacity and unregulated flows to South Australia commenced, initially along lower Murray reaches only. As the year progressed, high flows due to flood operations at Hume Dam, alongside elevated inflows from the Murrumbidgee and Darling Rivers meant unregulated flows to South Australia continued through until the end of the water year. During the year, RMO was able to successfully manage inflows and outflows from Lake Victoria to operate the storage in accordance with the Lake Victoria Operating Strategy whilst also meeting the end of May storage target of 350 GL.

With these drivers in mind, **notable achievements** for RMO river operations in 2021–22 included:

Meeting all state water orders in 2021–22. This is a significant achievement that the MDBA endeavours to accomplish each year and was achieved despite multiple uncertainties and constraints across the River Murray System this water year.

Adapting to frequently changing conditions and kept the River Murray System on-track, under changing operating conditions, variable climate and inflows, and delivery of environmental water whilst acknowledging and addressing strong community interest in flood operations. Routine review of planning assumptions and scenario testing occurred frequently with changing conditions, and adaptive actions were implemented. RMO was responsive to the changing climate conditions, balancing flood mitigation whilst also ensuring water availability is maximised for all water users.

Communication about flood operations, which saw over 20 briefings to the public on Hume Dam operations, alongside weekly meetings with the downstream community during times when flood operations were underway.

Successful management of the unregulated flow event which entailed a careful balance of operating in accordance with the Lake Victoria Operating Strategy (LVOS) requirements, maximising available water, and the provision of timely information supporting access to significant amounts of supplementary water to licence holders.

Successful use of an updated operating arrangements to allow directed releases during the conclusion of airspace management. This year, an update to the methodology for directed releases from Hume dam enabled the delivery of environmental water on the back end of a spill event. Historically, Hume releases would sometimes be reduced quickly towards the end of a spill, to fill the storage prior to demands exceeding inflows. This could create a “unnatural hole” in the hydrograph downstream of Hume dam, that was not environmentally desirable.

The new arrangement enabled water for the environment to be delivered in October/ November and again in December to prevent an unnaturally rapid drop in downstream river levels in the final phase of storage filling. Under the new arrangements, rather than filling Hume Reservoir to 99% capacity by the end of a flood event, river operators delivered water for the environment to meet a downstream environmental flow target, so long as the Hume storage level is within 100 GL of 99%, when downstream demands (without environmental water) exceed inflows. These releases target downstream flows within existing regulated limits and provide a more natural recession that benefits the environment. RMO was able to successfully implement this provision during the year, providing good outcomes for the downstream communities, the environment and water license holders.

Efficient and effective response to the water quality issue at Hume Dam and Reservoir. RMO’s swift and thorough response entailed comprehensive communication, evaluation, monitoring and operational actions to manage and mitigate low dissolved oxygen (DO) levels immediately downstream of the Hume Dam. The water quality issues observed were like those seen 12 months prior and are understood to be linked to water quality changes from upper catchment outflow following the 2019-20 summer bushfires.

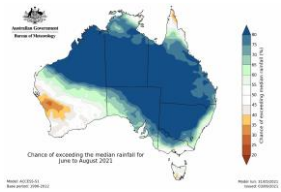
Quarter One

RMO activities for quarter one (Q1) primarily focused on the planning and preparation of the River Murray (RM) System for the coming water year (June 2021 to May 2022). The quarter saw continuous BoM forecasts for wetter than median conditions. During these months, significant focus was given to the management of storages, mainly Hume Dam, with pre-releases to manage airspace beginning in early August. Additionally, careful focus was given to the management of an extended unregulated flow period being driven initially by elevated Murrumbidgee River inflows but subsequently by high flow events from other tributaries. Between managing multiple high flow events, RMO also maintained a strong focus on the delivery of environmental water orders in August.

Q1 typically aims to capitalise on winter inflows to maximise water availability, including the re-regulation of as much tributary inflow as capacity allows in Lake Victoria. Notably, total River Murray storages began Q1 at much healthier levels than previous years.

Annual planning and preparation continued with the finalisation and publication of the *River Murray System Annual Operating Outlook* (AOO), setting out a range of possible operational futures based on six different climate and demand scenarios.

Key achievements for Q1



Publication of the Annual Operating Outlook (AOO) which provided insight into the range of possible operational activities for the water year ahead, as well as insight into possible water availability under a range of inflow and demand scenarios.

Successful management of the unregulated flow event being driven initially by Lake Victoria inlet capacity, before transitioning to a storage spill. Operations were adjusted in line with the Lake Victorian Operating Strategy (LVOS) whilst RMO provided regular, clear information regarding the duration and spatial extent of unregulated flows to support state supplementary water licence access and management of RMUF.

Management of Hume Dam airspace given the BoM wet climate outlook and above average rain across catchments during June and July. This resulted in significant winter inflows, with the storage rising towards full and the subsequent need to begin releases to manage airspace ('pre-releases') during August.

Key external drivers influencing operations in Q1

Whilst winter and spring are statistically the higher inflow periods, adaptability of operational activities and actions to changing inflow patterns during the 'filling season' is critical. In this respect, River Murray Operations recognised four **Key Drivers** that shaped Q1.

- **Key Driver 1 – "Above average winter rainfall"-** the quarter began with the BoM continuing to indicate that winter rainfall was very likely to be above average for much of northern, central, and eastern Australia. In addition, all system storages, except Lake Victoria, started the new water year at a higher level than last year, with Dartmouth at 64% capacity (compared with 51% last year) and Hume at 46% capacity (compared with 27% last year). The Menindee Lakes storage volume had exceeded 640 GL (the trigger level at which Menindee resource is shared with the Murray) in May 2021 and reached 61% (compared with 27% last year) at the beginning of June. For Lake Victoria, the storage volume was 43% capacity (compared with 62% last year). Continued rainfall through Q1 saw storages continue to fill and significant tributary inflows reaching Lake Victoria. Unregulated flows to South Australia began in mid-July due initially to Lake Victoria reaching inlet capacity before transitioning to a storage spill and the management of filling in accordance with the LVOS.
- **Key Driver 2 – "Wet conditions in the Murrumbidgee"–** Q1 saw wet conditions within the Murrumbidgee catchment with both Burrinjuck and Blowering Dams also entering winter at relatively high levels. Airspace pre-releases commenced in July from both storages to assist in mitigating the impacts of potential floods. These airspace releases continued to be made for the remainder of Q1 and helped raise the average flow at Balranald during winter to around 4,700 ML/day, well above the normal end of system target. The high inflows from the Murrumbidgee significantly influenced broader Murray system operations, including the development and extent of unregulated flows and the operation of Lake Victoria.
- **Key Driver 3 – "Continued filling of the Menindee Lakes"–** the quarter began with the continuation of modest releases from the Menindee Lakes to help meet storage requirements in Lake Victoria. By mid-July, multiple rainfall events across much of the northern Basin generated additional inflow from several Barwon-Darling tributaries and downstream into the Menindee Lakes. These inflows continued for the remainder of the quarter with the storage subsequently filling and then spilling during quarter 2.
- **Key Driver 4 – "Management of Hume Dam and downstream effects"–** By early August, wet conditions across the upper Murray during June and July had significantly increased storage in Hume Dam. Airspace analysis and storage filling forecasts supported the commencement of airspace releases from Hume Dam, which were started on 6 August at modest rates. By late August, these airspace releases were temporarily ceased due to drying catchment conditions and increased Hume releases to deliver water for the environment. These environmental water releases were a key part of the demand consideration for airspace management and simultaneously formed part of the volume of water released to achieve airspace targets. While inflows had started to recede at the end of August, the BoM outlook remained wet, indicating continued above average rainfall remained likely during spring and that further airspace management and potential flood operations would be likely during spring.

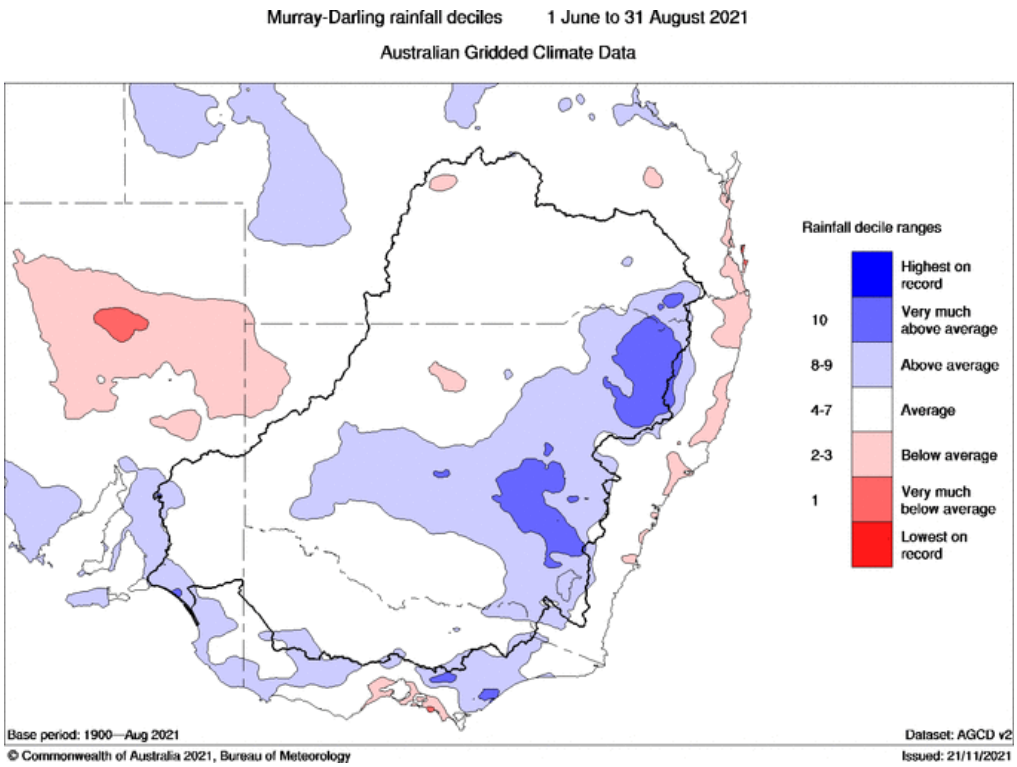


Figure 5: Murray–Darling Rainfall deciles for Q1 shows average to above average conditions across most of the southern Basin and above average to very much above average conditions for upper Murray catchments and parts of central, eastern and northern NSW.

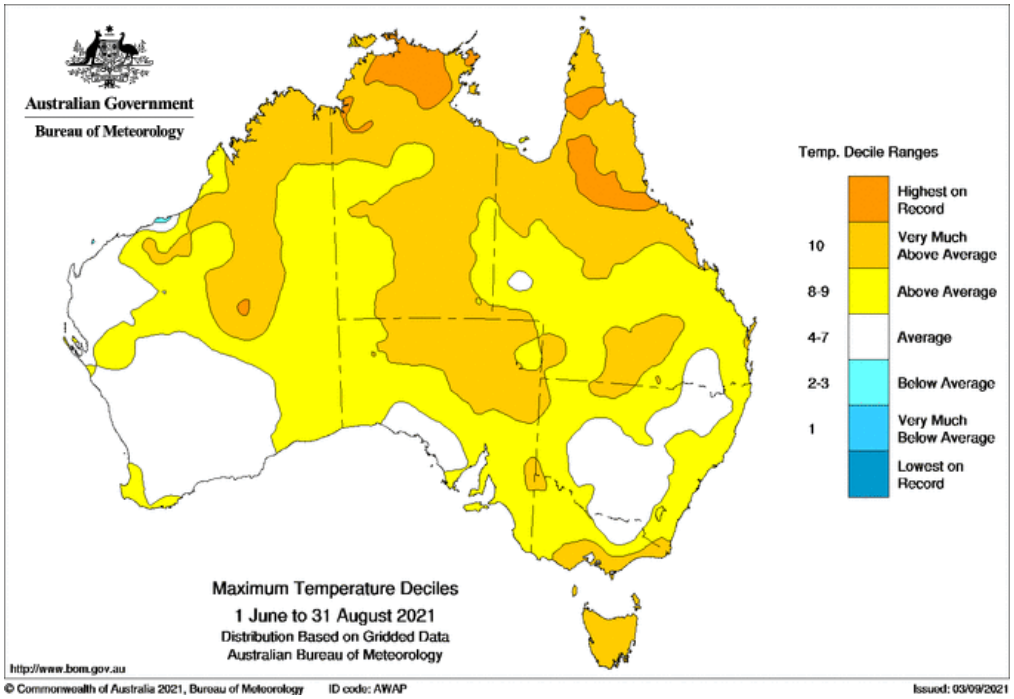


Figure 6: Maximum temperature deciles for Q1 show average to above average conditions for most of the River Murray System and central NSW, with very much above average conditions in small parts of the northern Basin and eastern South Australia and north-western Victoria.

Key metrics for Q1

The operational metrics in **Table 3** provide a snapshot summary of river operations for Q1**.** All figures should be considered within the context of the key drivers outlined above.

Table 3: Key metrics for River Murray System operations during Q1.

Metric		Quarter One [i]
Total River Murray System inflows [ii]		3,440 GL (39% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 360 GL due to capture of inflows ↑ 1,468 GL due to capture of inflows ↑ 354 GL due to capture of unregulated tributary inflows ↑ 460 due to capture of inflows
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	44 GL with AGL entitlement and minimum releases 181 GL with releases for airspace management (spill) and water for the environment. 0 GL 75 GL with releases for operational requirements and water for the environment.
	IVT Delivery	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		95 GL Victorian Murray 141 GL NSW Murray
River Murray System loss [v]		550 GL
Environmental directed releases from Hume [vi]		107 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	912 GL 174 GL 149 GL 0 GL 112 GL 477 GL due to unregulated flows, ADF (6 GL) and forced delivery of deferred SA Entitlement.
Publication of operational information		13 MDBA Weekly Reports 6 Media Releases on 'river operations' 1 Media briefing on managing high flows in the River Murray system 2 video briefings on Hume Dam operations AOO Publication Basin in Brief/Flows in the River Murray System

i. Values are provided from the River Murray System accounts at the point of time the report is written and considered as operational data. Updates to input data including changes to rating tables as well as other data changes because of hydrometric updates may result in the numbers in the above table changing.

ii. River Murray System inflows include unregulated inflows to Dartmouth, Hume and from the Kiewa, plus inflows from the NSW and Victorian tributaries excluding environmental water deliveries and IVT as well as Menindee when not part of the shared resource.

iii. Lake Victoria Net Releases refers to the net volume between inflows and outflows.

iv. Sourced from River Murray System accounts, includes all consumptive deliveries and Lindsay River allowance for Victoria.

v. River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific watering actions and losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria, and Menindee Lakes System (when part of the shared resource). Note: this is an interim loss value – refer footnote (i).

vi. Sourced from River Murray System monthly environmental accounts.

vii. South Australian Environmental use – includes all environmental water that flows into South Australia.

viii. Includes changes due to rating table upgrades or subsequent hydrometric updates as well as unregulated flow and Additional Dilution Flow (ADF) whenever these occur.

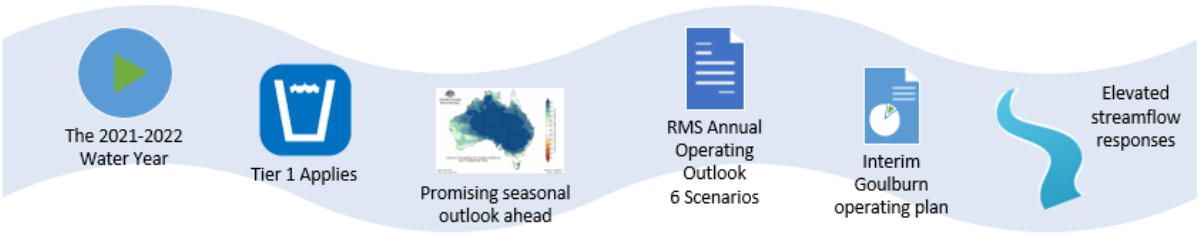
BOX 1: Status of Water Sharing and State Shares in Storage

The River Murray System started the year in 'Tier 1' water sharing arrangements, as per the criteria outlined in the Murray Darling Basin Agreement and Basin Plan. BoM's climate outlook for wetter than median conditions for the remainder of winter and early spring meant Tier 1 arrangements were expected to continue for the remainder of the 2021–2022 water year and possibly into next water year (2022–23). Tier 1 water sharing arrangements are the long standing 'normal' arrangements in the Murray–Darling Basin Agreement for sharing water in the River Murray System between the River Murray states. Tier 1 arrangements cover very wet through to very dry conditions.

Both NSW and Victoria began the water year out of Special Accounting with South Australia as per the MDB Agreement. Neither state entered a period of special accounting during Q1. State shares in storage for each month is available at https://www.mdba.gov.au/river-information/water-sharing.

Box 1: Status of Water Sharing and State Shares in Storage

June 2021



At the beginning of the water year (1 June 2021) the active storage in the MDBA's reservoirs was 4,529 GL or 53% capacity, up 19% from the same time last year. In the preceding month (May), the volume of water in the Menindee Lakes surpassed the 640 GL trigger as per the rules set out in the Agreement. This saw the portion of total storage across the River Murray system spread across the whole system, a contrast to the previous years where a significant majority of the storage volume was held in the most upstream storages of Dartmouth and Hume Dams.

Much of the Basin experienced average to very much above average rainfall for the month of June 2021. River Murray System inflows for June (excluding environmental, IVT and Snowy scheme contributions) totalled around 500 GL (47% AEP) (annual exceedance probability).

The Annual Operating Outlook (AOO) for the 2021–22 water year was completed in June and published in July 2021. The AOO is a key component of the operations planning process and uses six inflow and water demand scenarios to help outline the range of potential operational activities and flow trends expected during 2021–22 under different climatic conditions. The inflows assumed for each of the six scenarios are shown in **Figure 7**.

A key operational activity described in the AOO is the delivery of IVT to supply system demands. On 1 July 2021, Victoria introduced a new interim Goulburn to Murray trade rules with the new operating rules as part of the Victorian Government's Goulburn to Murray Trade Review. The new trade rule replaces the year-round rolling limit of 200 GL with a two-part trade rule that involves:

1. From 1 July, trade will be possible whenever the balance of the Goulburn inter-valley trade account is lower than the new limit of 190 GL; and
2. On 15 December, net trade will be capped to enable the inter-valley trade account balance to be reduced as IVT is delivered to the River Murray across the remaining year.

Accompanying the new trade rules are interim operating rules based on deliveries in the lower Goulburn River of average baseflows of 1,100 ML/day between November and April with three short freshes of up to 3,000 ML/day (or 6,000 ML/day if feasible) between December and April to minimise the damage to riparian vegetation along the lower Goulburn River. For more information see the Victorian Water Register website.

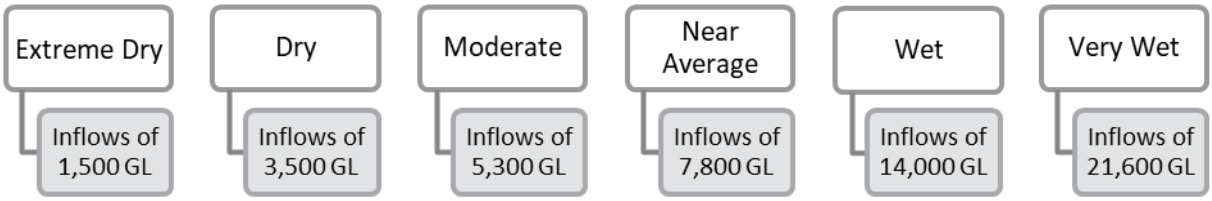
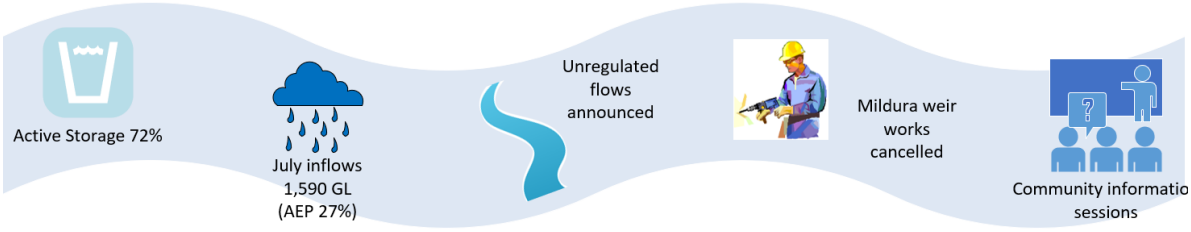


Figure 7: The six River Murray System Annual Operating Outlook (AOO) scenarios showing the volume of annual system inflow assumed in each case (Section 5.2, 2021–22 AOO).

In late June, a significant rainfall event with totals over 100 mm fell across the upper Murray catchments. The high rainfall totals resulted in significant streamflow increases in the Mitta Mitta, upper Murray, Kiewa, and Ovens Rivers. As a result, flows downstream of Yarrawonga exceeded 9,000 ML/day (approximate downstream channel capacity) and forest regulators in the Barmah and Millewa forests were opened to manage river levels. Forest managers co-ordinated the opening of several specific forest regulators on behalf of environmental water holders providing connectivity between the river and the floodplain. This action helped increase habitat for native fish and improve the transfer of valuable nutrients from the floodplain to the river. By late June, the climate outlook for the coming months forecast greater than 80% chance of exceeding median rainfall across the Basin.

July 2021



During July, the BoM forecast for wetter than median conditions was realised, with good rainfall and River Murray System inflows totalling 1,590 GL (27% AEP). This saw MDBA total active storage increase to 6,189 GL (72% capacity).

A key driver of operations throughout July and subsequent months were wet conditions in the Murrumbidgee catchment. In early July, WaterNSW advised that both Blowering and Burrinjuck Dams were effectively full. This saw releases from both storages being managed to maintain airspace for flood mitigation and environmental purposes. As a result, the flow at Balranald (the last gauge on the Murrumbidgee before it meets the Murray), increased from 1,800 ML/day on 1 July to a peak around 7,100 ML/day by late July, with high flows continuing into the coming months.

In early July, it was determined by the MDBA that inflows to Lake Victoria would reach the inlet capacity even under a conservative forecast. This meant that unregulated flows to South Australia would begin, initially along lower reaches only. As a result, the MDBA advised WaterNSW that the higher flows from the Murrumbidgee could not be re-regulated on the Murray, and in accordance with the Murrumbidgee water sharing plan, supplementary access was announced by WaterNSW for Lowbidgee entitlement holders. On 15 July, it was determined that increasing flows along the Murray were sufficient for the MDBA to extend River Murray unregulated flow from the South Australia border to the Murrumbidgee junction.

The COVID-19 global pandemic continued to provide challenges with state agency colleagues operating and working at structures needing to follow the federal and state health advice. This saw the cancellation of the planned Mildura weir maintenance works after an employee was confirmed as a close contact of a confirmed coronavirus (COVID-19) case. The works planned included commissioning a new winch and replacing three of the 24 trestles that control the water levels at the weir. As the start of the irrigation season was not far off, any delay that resulted in pushing back the scheduled completion of the works would potentially impact the region's horticultural and other industries, resulting in the works being re-scheduled for winter 2022.

During mid-late July, multiple rainfall events brought widespread rainfall totals across the upper Murray catchments. This generated decent streamflow responses in the Murray tributaries and a large rise in system inflows (**Figure 8**). During late July RMO operations focused closely on the management of a high flow event at Yarrawonga weir. Releases peaked around 27,000 ML/day as RMO operated the structure in accordance with the Objectives and Outcomes document. Which outlines during periods of Tier 1 water sharing arrangements, operations at Yarrawonga Weir do not seek to mitigate or attenuate inflow events but allow the event to pass without compromising the integrity of the structure.

As a result of continued improvements in River Murray inflows, the MDBA determined that Lake Victoria was assured of filling. Flows were sufficient to extend unregulated flow to all River Murray reaches, from the South Australian border to Hume Dam. The subsequent filling of Lake Victoria would be managed within the requirements of the Lake Victoria Operating Strategy (LVOS) and the need to bring the storage to effective full supply at the conclusion of the unregulated flow period.

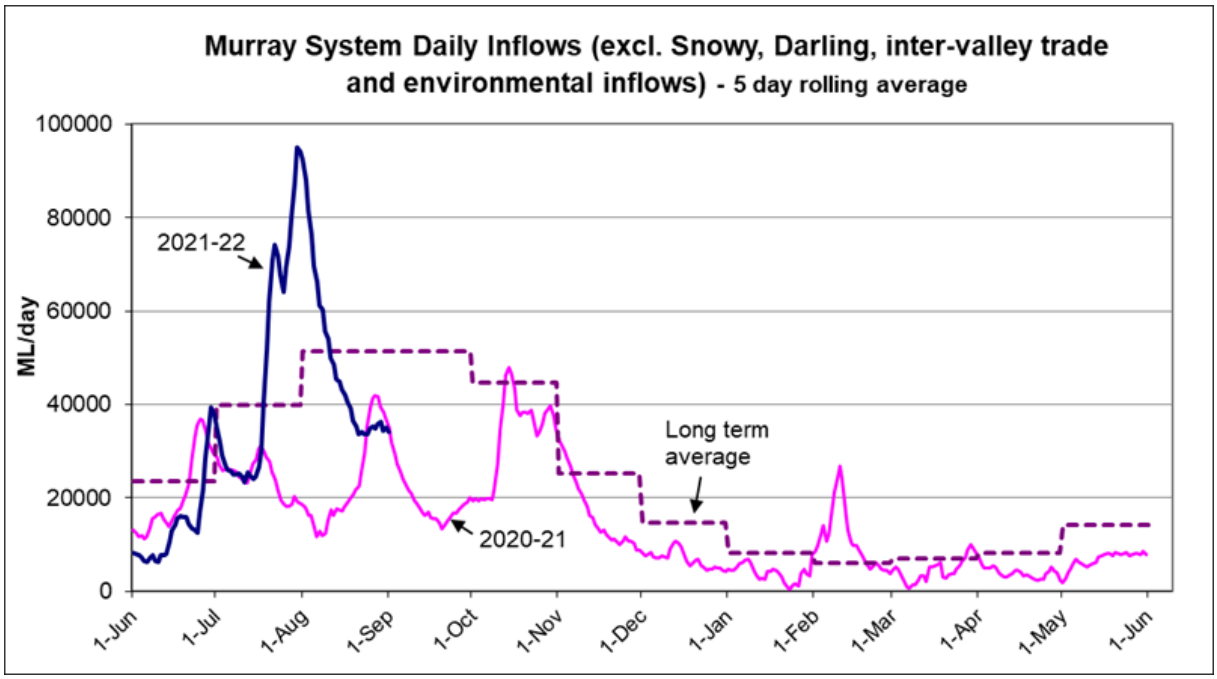


Figure 8: Murray System daily inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) until the end of Quarter 1, 2021-22.

Due to the continuing wet conditions, Hume Dam storage increased steadily towards a volume of 80% capacity by the end of July. RMO commenced 'pre-release calculations' on 22 July. These calculations form the initial stage of airspace management at Hume Dam and are used to develop a 'filling curve' and pre-release plan that enables downstream flood risks (associated with high storage levels) to be balanced against the requirement to fill the storage. Pre-release calculations during July did not support the commencement of airspace releases based on the risk profile for filling adopted by the Basin Officials Committee (BOC). However, with the Bureau of Meteorology outlook continuing to favour wetter than average conditions in winter-spring, it appeared highly likely that the commencement of airspace management was imminent.

Given the increased risk of flooding and flood operations over the coming months, RMO also focused on providing clear communication to stakeholders. This saw a Hume Dam operations section added to the RMO weekly report, alongside a media briefing on high flows in the Murray system. This was a joint briefing looking at the climate outlook and dam operations with participants from the MDBA, WaterNSW, Goulburn Murray Water, Bureau of Meteorology, and the Victorian and New South Wales state emergency services.

August 2021

River Murray System inflows for August were lower than July, with below average rainfall totals recorded across much of the system (**Figure 9**). However, the inflows totalling 1,354 GL (45% AEP) were still above median, driven by the on-going catchment yield following the good rain in July. For the three months of Q1 this brought inflows to a total near 3,440 GL, a figure that tracked between the AOO 'wet' and 'near average' inflow scenarios.

By the end of August, MDBA major storages had continued to increase, with Hume Dam at 95% capacity, Dartmouth Dam at 73% capacity and Lake Victoria and Menindee Lakes at 96% and 89% capacity, respectively. These storage levels were sufficient for Tier 1 water sharing arrangements to remain in place as expected. By the end of August, total active storage had increased significantly to 7,156 GL (87%), well above the long-term average and its highest level since early 2017 (**Figure 10**).

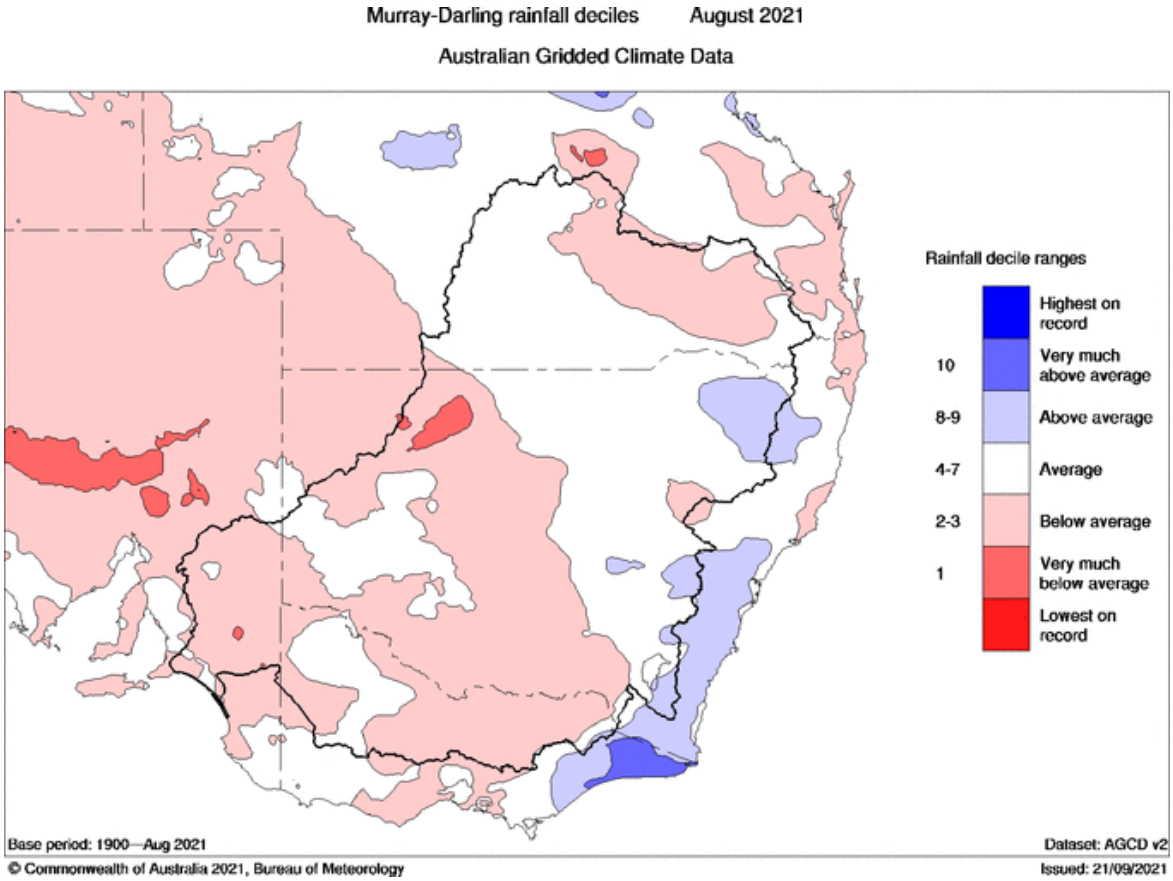


Figure 9: Murray–Darling Basin rainfall deciles for August 2021, with average to below average rainfall observed.

During August, WaterNSW continued to make significant airspace releases from Blowering and Burrinjuck Dams, resulting in flows in the Murrumbidgee at Balranald persisting at around

7,000 ML/day. This inflow along with other tributary inflows continued to drive unregulated flows along the River Murray System. In accordance with the requirements of the Lake Victoria Operating Strategy (LVOS), RMO began to delay the filling of Lake Victoria. The LVOS aims to stabilise the lake foreshore and protect cultural heritage sites by encouraging the growth of native vegetation. To help achieve this, operations aim to reduce the length of time foreshore vegetation is inundated by refilling the Lake as late as possible in spring/summer and actively drawing Lake Victoria down during late summer and early autumn, to provide a drying cycle.

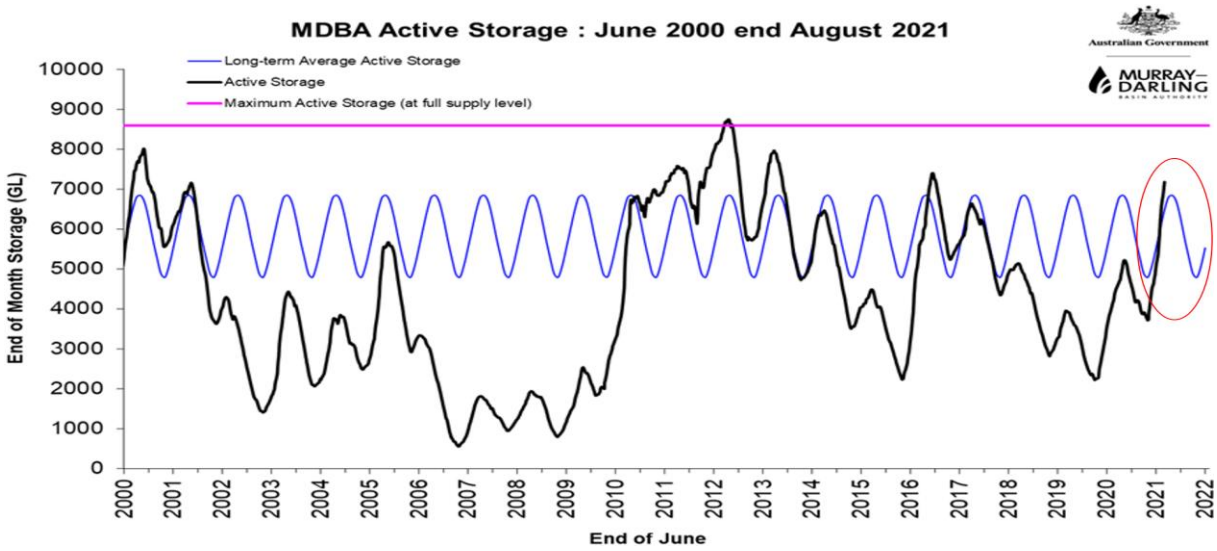


Figure 10: The River Murray System total active storage increased above the long-term average by the end of Q1.

In early August, and with Hume Dam storage steadily increasing towards 90% capacity, pre-release calculations (that consider forecasts for future inflows, demands and storage level) confirmed that the storage could be filled with a very high level of confidence. This conclusion meant that airspace management releases (for the purpose of reducing downstream flood risks as the storage approaches full) could begin, with the decision taken to commence the releases on 6 August.

From 7–15 August, an initial airspace management release of around 19 GL was made from Hume Dam. Drier conditions in early August resulted in airspace management releases from Hume Dam ceasing in mid-August. Releases then continued to meet water orders placed by environmental water holders (EWHs).

The relatively early commencement of significant releases to meet environmental orders highlighted the additional complexity and uncertainty resulting from shifting patterns of water use under the Murray–Darling Basin Plan. Forecasting the commencement of releases of water for the environment can add to the challenges of managing airspace and the process of filling the storage towards the end of the airspace management period[3].

To manage this increased uncertainty, the MDBA worked with state partners to establish and adopt a new operating provision during airspace management that would improve environmental outcomes whilst simultaneously improving the management of flood risks related to high storage levels. This

[3] *Please note, further updates in July 2022 to the methodology for directed releases have largely dealt with the additional complexities associated with the timing around the delivery of water for the environment during periods of airspace management.*

provision was noted by the Basin Officials Committee (BOC). The provision was subsequently used for the first-time during Quarter 2.

With careful planning and communication, the releases of water for the environment were managed to benefit the ecology and build resilience in Murray System ecosystems. The releases provided a low-level 'over-bank' watering of the Barmah–Millewa Forest (with accounting in accordance with the General and Specific O&Os) that started from mid-August and continued through the rest of August.

As ordered by environmental water holder water, Barmah–Millewa Forest Environmental Water Allocation (BMFEWA) was used as part of the environmental delivery during August (**Figure 11**). However, as unregulated flow were continuing at this time, RMO sought advice from the Water Liaison Working Group (WLWG) on the potential interaction of BMFEWA releases with unregulated flows upstream of Barmah–Millewa Forest (BMF). WLWG agreed that the regulated release of BMFEWA from Hume storage is for the benefit of targeted ecological objectives within the Barmah–Millewa Forest and must not therefore contribute to unregulated flow in the system until after it exits the Barmah–Millewa Forest and returns to the River Murray at Barmah and to the Edward River near Toonalook.

As the drier conditions continued in August, unregulated flows ceased along the upper reaches between Hume and Yarrawonga and in the Edward River upstream of Stevens Weir on 19 August 2021. However, the persistence of high inflows from the Murrumbidgee River meant they continued along downstream reaches.

Towards the end of August, the BoM were forecasting a cold front could deliver significant rain across south-eastern Australia with totals of between 50–100 mm across the upper Murray catchments. Forecast flow responses from this event, suggested that airspace management would likely need to re-start at Hume Dam within days.

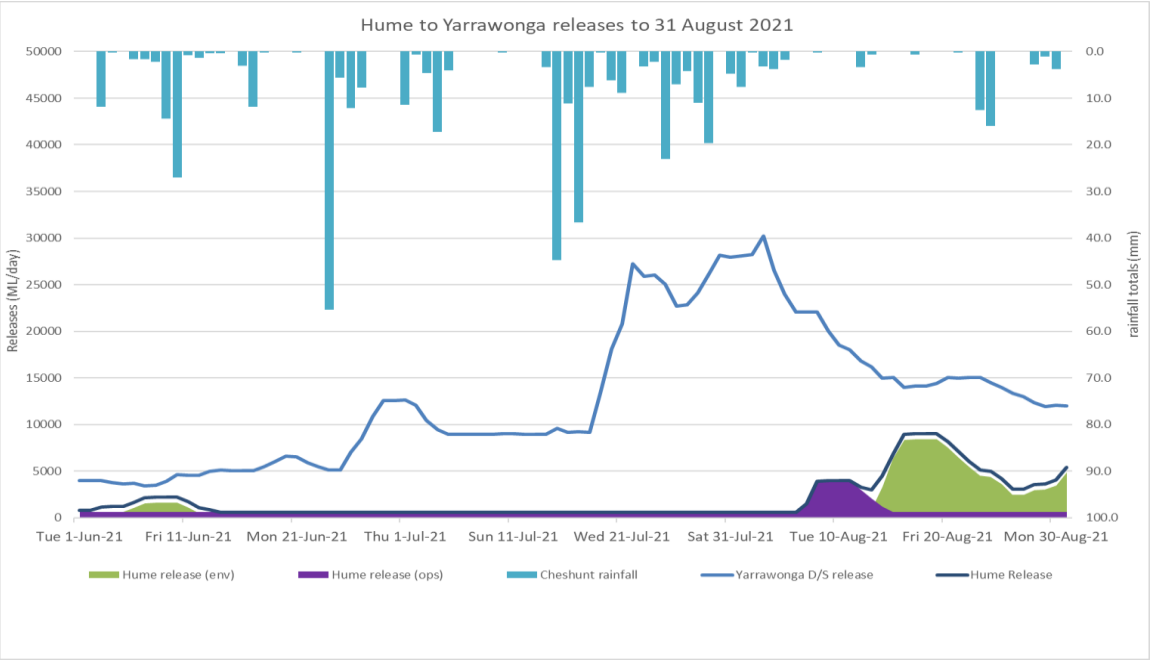


Figure 11: Operational and environmental water releases from Hume Dam compared with flow downstream of Yarrawonga Weir, June-August 2021. Unregulated tributary inflows from the Kiewa and Ovens Rivers provided a significant majority of the total flow. Hume release (ops) included both minimum release requirements and releases for airspace management during August. Hume release (env) was water released on behalf of environmental water holders to 'fill gaps' and achieve flow targets along the river downstream.

Inflows to Menindee Lakes were forecast to continue rising towards a peak at Wilcannia of around 20,000 ML/day in September. These flows were generated on the back of persistent rainfall across winter in parts of the northern Basin, with particularly good rain across north-eastern NSW that resulted in good flows through the Border Rivers and other Darling River tributaries. An updated analysis from WaterNSW indicated that the Menindee Lakes were now very likely to fill, with the possibility of a spill through spring if reasonable rain continued.

The Lakes reached a volume of 1,500 GL on 30 August and with similarly high storage levels in Hume and Dartmouth Dams, this meant that Additional Dilution Flow (ADF) was triggered. When triggered, ADF provides an additional 3,000 ML/day to South Australian Entitlement. However, as the triggering of ADF is generally linked with wet conditions in the River Murray System, the additional flow is often delivered for significant periods by unregulated flows. This was the case in August 2021 and meant that the commencement of ADF required no increase in release from headwater storage to be delivered.

The BoM published a climate outlook for September to December that indicated that spring rainfall was likely to be above median for the Basin. This included the potential for a La Niña event to begin and a weak negative Indian Ocean Dipole was forecast to continue for spring. Over the coming months, it was therefore likely that allocations would increase given the strong chance that further wet conditions and high inflows would take place.

Quarter Two

Historically during quarter two (Q2), the focus of river operations is to capitalise on healthy tributary inflows. These flows can boost storage in Lake Victoria and help set up the system for summer. If tributary inflows build further, Lake Victoria can spill, resulting in unregulated flows that can help improve environmental conditions along the system with outcomes further enhanced by the coordinated release of water for the environment. The spring of 2021–22 saw just this scenario play out. The quarter began with a significant rainfall event that saw a strong focus on flood operations at Hume Dam and Yarrawonga Weir. Over the following three months, predominantly wet conditions affected the whole Murray–Darling Basin, with very high rainfall totals across Murray system catchments and along the river. In response, storages across the River Murray system continued to fill and by the end of Q2, Hume Dam, Lake Victoria and the Menindee Lakes had all spilled.

In response to the wet conditions, operational planning was strongly focused on the management of unregulated flows and the filling of Lake Victoria. A window of drier weather during October resulted in receding inflows, unregulated flows ceasing in the upper reaches and Lake Victoria beginning to fill. However, subsequent rainfall events in November and additional airspace management releases from Hume Dam resulted in unregulated flows recommencing along all reaches of the Murray.

During Q2, RMO focused on the delivery of water for the environment between periods of flood operations of Hume Dam. This year, state resource managers agreed to implement a new operating arrangement to manage the end of a flood event at Hume Dam. The new arrangement enables water for the environment to be delivered towards the end of a period of flood operations at Hume Dam. A key aim of this arrangement is to prevent the unnatural rapid drop in downstream river levels that can otherwise occur when flood inflows recede. The approach provides similar flexibility for airspace management prior to the delivery of environmental water. The new arrangement was used for the first time during Q2.

Key achievements for Q2

Successful flood management at Hume Dam. RMO was able to provide significant flood mitigation for multiple high flow events whilst still being able to fill the storage at the conclusion of each flood, maximising water availability.

Management of unregulated flows and operation of Lake Victoria in accordance with the Lake Victorian Operating Strategy in response to evolving inflow conditions including growing spill volumes from the Darling and Murrumbidgee Rivers.

Delivery of environmental water and management of Hume Dam using the new directed release arrangement. This enabled river operators to deliver water for the environment from the dam prior to the reservoir filling at the end of the flood event. This assisted in reducing an otherwise unnaturally rapid drop in river levels that can degrade environmental outcomes.

Key external drivers influencing operations in Q2

Spring historically has seasonally high inflows. Spring 2021 provided inflows that were at or above the long-term average. As such, many of the key drivers of Q1 remained applicable or strengthened in relevance across Q2. River Murray Operations recognised four **Key Drivers** that shaped Q2.

- **Key Driver 1 - "Persistent wet conditions" –** The quarter began with the BoM forecast for above average rainfall across much of the Murray–Darling Basin coming to fruition (**Figure 12**). While September rainfall was above average or wetter for much of the Murray Darling Basin, and October was near average, November was exceptionally wet. The area average rainfall for Q2 was around 200 mm across the Murray–Darling Basin, the 8th highest spring total on record and the highest since 2010. In response, much of the focus for river operations was on the management of storages and responding to significant inflow events.

- **Key Driver 2 – "Wet Murrumbidgee catchment –** Q2 saw wet conditions in the Murrumbidgee catchment continue, resulting in releases by WaterNSW from Blowering and Burrinjuck Dams to manage elevated inflows and storage airspace. The high releases alongside elevated tributary inflows resulted in Murrumbidgee inflows to the River Murray System remaining well above the end of system target. These inflows continued to significantly influence broader River Murray system operations, including the extent of unregulated flows and the operations undertaken at Lake Victoria.

- **Key Driver 3 – "Operation of Menindee Lakes" –** The high flows in the Barwon-Darling system in August resulted in over 400 GL of inflows being recorded into the Menindee Lakes. The storage began the quarter at 89% (1,536 GL). This relatively high storage, a volume triggered Additional Dilution (ADF) Flows to South Australia. Significant rainfall in the Northern Basin was recorded during this quarter, including some areas receiving their highest November rainfall on record. This resulted in flooding across several Barwon-Darling tributaries including the Border Rivers, Gwydir, and Namoi Valleys. This meant that substantial inflows were forecast to arrive at the Menindee Lakes storage in both Q2 and Q3 (summer). In response, WaterNSW actively managed releases during Q2 to meet environmental targets and operate the system in accordance with standard operating procedures. By end of Q2, WaterNSW had advised that significant releases would be necessary from the storage to meet airspace management requirements, including raising the storage into surcharge before returning it to FSL by 1 January 2022. These high releases from the Menindee Lakes would influence broader system operations by boosting and extending unregulated flows on the River Murray heading into summer.

- **Key Driver 4 – "Continued management of Hume Dam and downstream effects"-** Q2 brought multiple significant rainfall events for the Upper Murray catchments resulting in flood operations taking place on and off during the three months. During this time, RMO was able to successfully manage multiple inflow events and provide significant flood mitigation for downstream communities, whilst maximising water availability by filling the storage at the end of each event. A strong focus was given to engagement and communication with stakeholders which included a briefing on Hume Dam operations delivered online each week. By the end of Q2, Hume storage remained high with the BoM declaring a La Niña and continuing to forecast wetter than average conditions over summer.

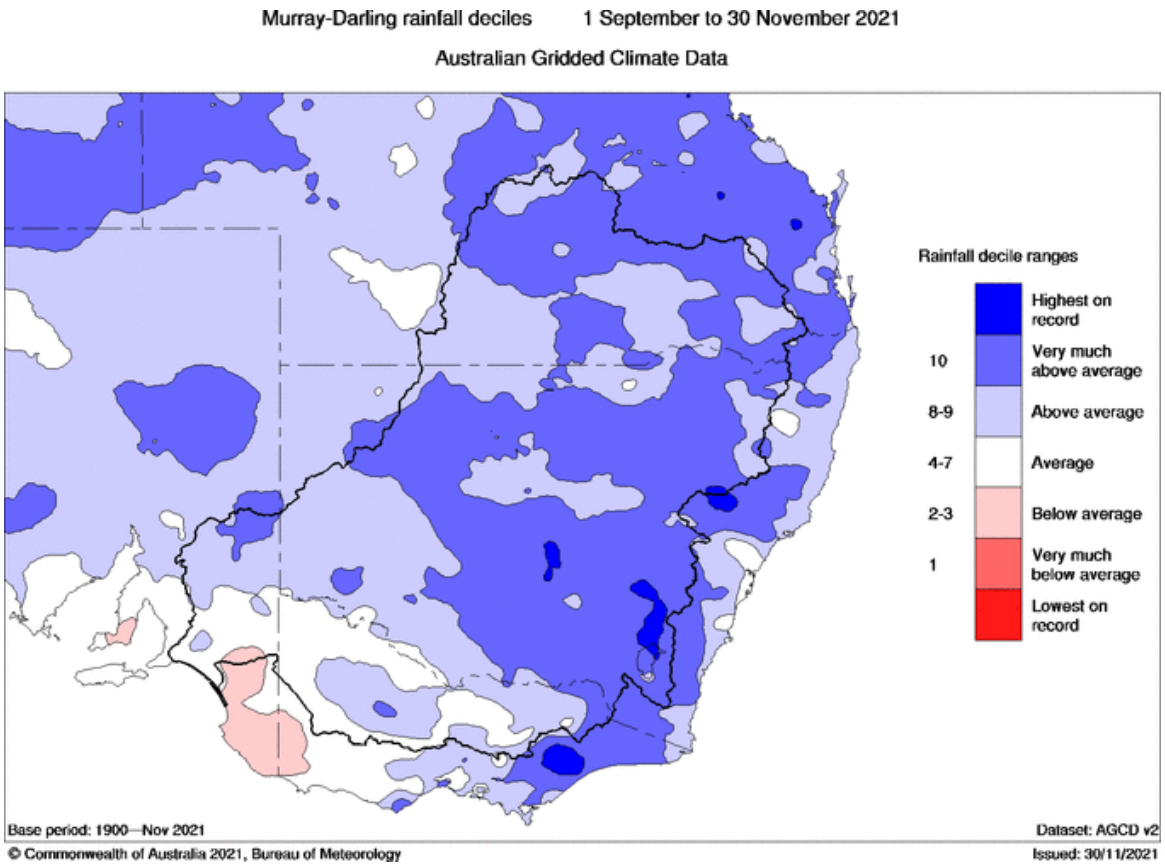


Figure 12: Murray–Darling Rainfall deciles for Q2 indicate very wet conditions across upper Murray catchments. Most of the Basin experienced above average or very much above rainfall apart from far south-western areas where rainfall was closer to average.

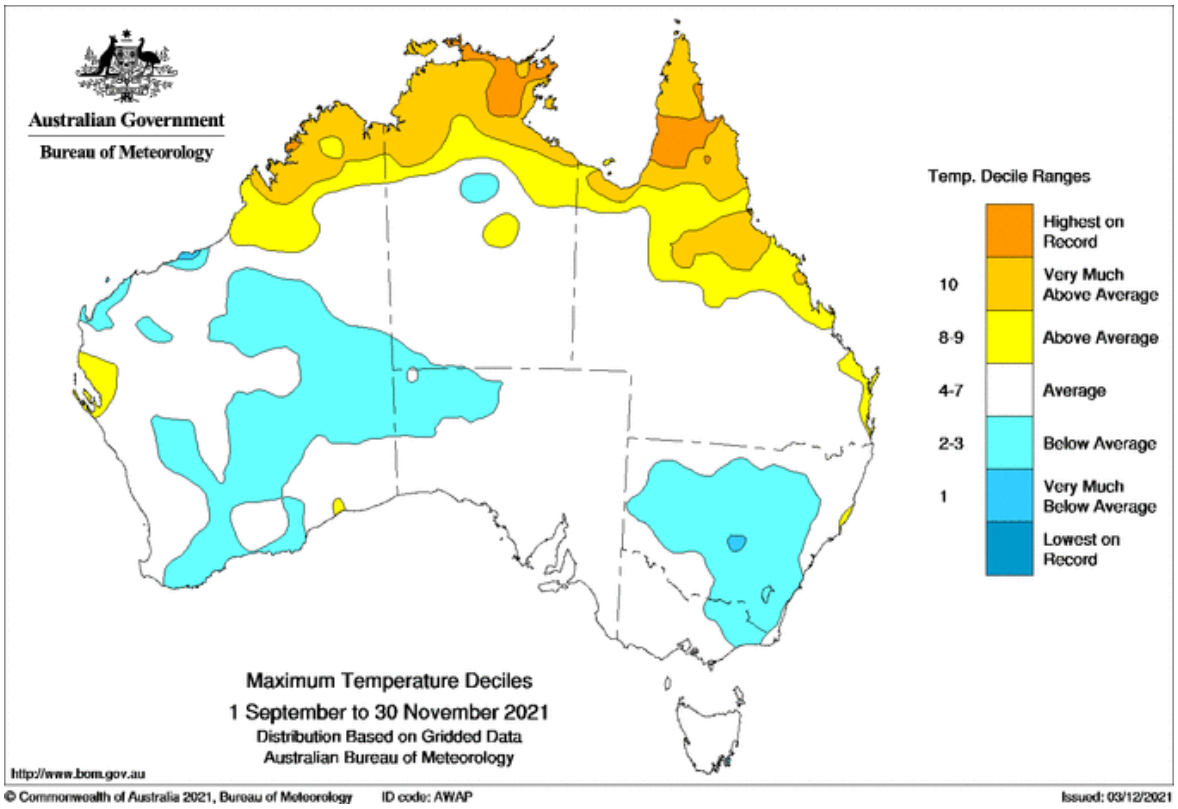


Figure 13: Maximum temperature deciles for Q2 show average to below average conditions across the River Murray System.

Key metrics for Q2

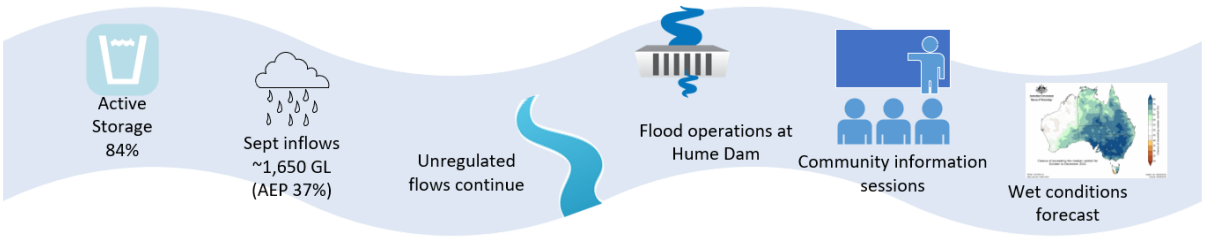
The operational metrics in **Table 4** provide a snapshot summary of river operations for Q2**.** All figures should be considered within the context of the key drivers outlined above.

Table 4: Key metrics for River Murray System operations during Q2.

Metric		Quarter Two [i]
Total River Murray System inflows [ii]		4,108 GL (33% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 479 GL due to capture of inflows ↑ 144 GL due to capture of inflows and airspace management (spill) ↓23 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS) ↑ 375 GL due to capture of inflows and airspace management releases (spill)
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	18 GL comprising AGL entitlement releases (power generation) and minimum releases 1,585 GL comprising releases for airspace management (spill) and delivering water for the environment 39 GL due to the management of storage filling (spill) and the LVOS during unregulated flows 190 GL releases to the lower Darling River comprising operational releases, including spill and releases of water for the environment. 73 GL released to the Great Darling Anabranch for airspace management (spill)
	IVT	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		320 GL Victorian Murray 353 GL NSW Murray
River Murray System loss [v]		664 GL
Environmental directed releases from Hume [vi]		184 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	2,596 GL 174 GL 312 GL 6.4 GL 338 GL 1,765 GL due to unregulated flows and additional dilution flows (273 GL).
Publication of operational information		13 MDBA Weekly Reports 9 Media Releases on 'river operations' 13 video briefings on Hume Dam operations Basin in Brief/Flows in the River Murray System

i. Values are provided from the River Murray System accounts at the point of time the quarterly report is written and considered as operational data. Updates to input data including changes to rating tables as well as other data changes because of hydrometric updates may result in the numbers in the above table changing.
ii. River Murray System inflows include unregulated inflows to Dartmouth, Hume and from the Kiewa, plus inflows from the NSW and Victorian tributaries excluding environmental water deliveries and IVT as well as Menindee when not part of the shared resource.
iii. Lake Victoria Net Releases refers to the net volume between inflows and outflows.
iv. Sourced from River Murray System accounts, includes all consumptive deliveries and Lindsay River allowance for Victoria.
v. River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific watering actions and losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria, and Menindee Lakes System (when part of the shared resource). Note: this is an interim loss value – refer footnote (i).
vi. Sourced from River Murray System monthly environmental accounts.
vii. South Australian Environmental use – includes all environmental water that flows into South Australia.
viii. Includes changes due to rating table upgrades or subsequent hydrometric updates as well as unregulated flow and Additional Dilution Flow (ADF) whenever these occur.

September 2021



At the start of spring, the active storage in the MDBA's reservoirs was at 84% capacity (7,183 GL), up significantly from 53% at the same time last year. In most years, September is one of the higher inflow months that generally sees storage volumes and water resources increase. This remained the case for September 2021, with average to very much above average rainfall recorded across much the Basin, including over the upper Murray catchments (**Figure 14**). By the end of the month, River Murray System active storage had climbed significantly. System inflows for the month totalled around 1,650 GL (37% annual exceedance probability (AEP), well above the September average of 1,543 GL.

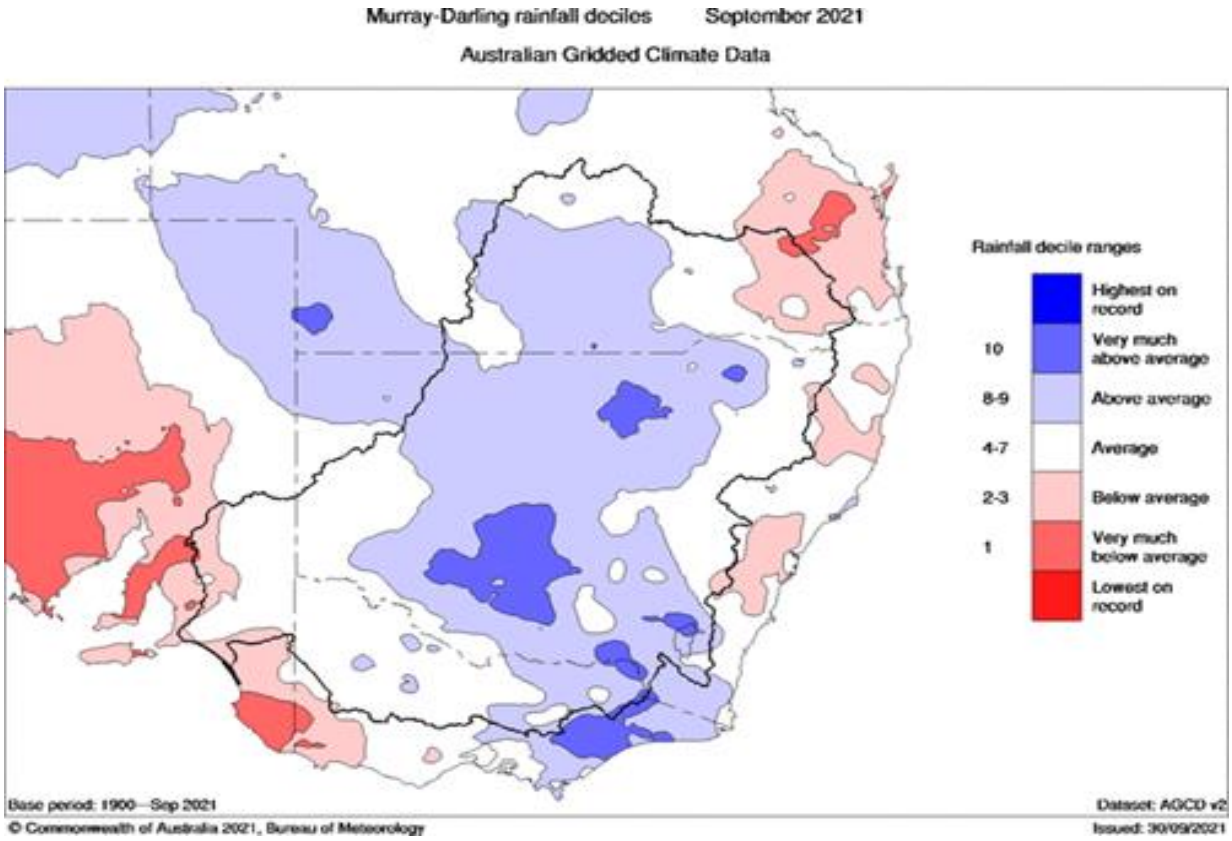


Figure 14: : September 2021 Murray–Darling Basin rainfall deciles showing mostly above average to very much above average conditions.

Starting in early August, releases from Hume Dam totalling around 130 GL had been made to both supply downstream demands and for airspace management. However, with conditions starting to dry off and inflows receding as August progressed, operations remained aware of the need to meet storage filling requirements whilst continuing to prepare for the possibility of heavier rain returning in spring. This balancing act meant that an airspace volume of around 160 GL was available for flood mitigation purposes as spring arrived.

In the second week of September, a strong cold front delivered rain across south-eastern Australia with totals over 100 mm recorded across the upper Murray, Ovens and Kiewa catchments (**Figure 15**). Forecast rainfall and stream flow scenarios provided by the BOM indicated that modest increases in releases would be most likely sufficient to manage the likely volumes of inflow. However, actual rainfall reached totals near the top end of forecast scenarios, meaning some upstream gauges reached their highest levels to date for 2021. This resulted in the commencement of flood operations with Hume inflows peaking at close to 75,000 ML/day and moderate flooding along the Murray upstream of Hume Dam.

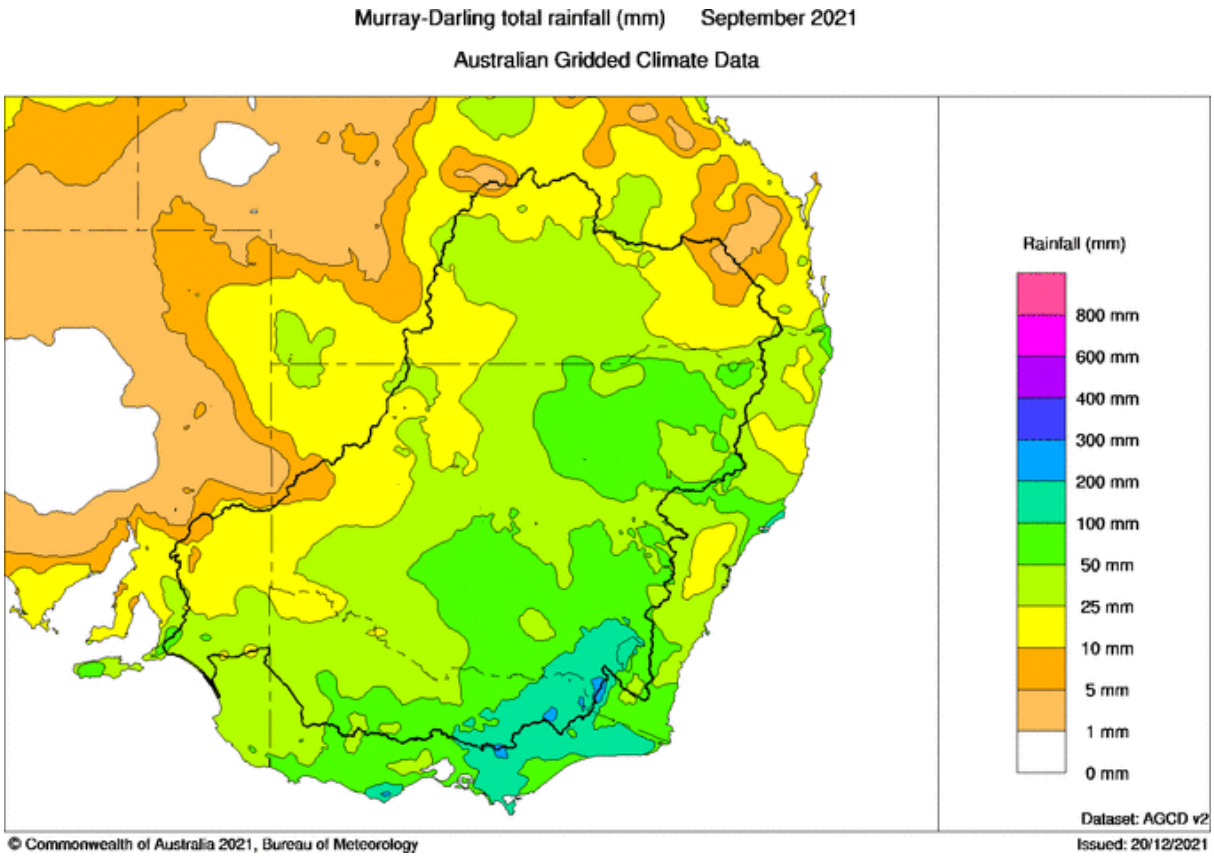


Figure 15: Murray–Darling Basin total rainfall for September 2021

Despite inflows reaching the higher end of the forecast range, the available airspace in Hume Dam meant the event was comfortably managed. Peak releases of 31,000 ML/day were required, which provided significant downstream flood mitigation (i.e., compared with peak inflows of 75,000 ML/day). River levels at Doctors Point and Albury peaked well below the minor flood level with peak flows of around 38,000 ML/day due to the addition of elevated Kiewa River inflows (Kiewa inflows exceeded 7,000 ML/day at the Bandiana gauge). Flows at Doctors Point remained above channel capacity (25,000 ML/day) for around 10 days, whilst downstream at Corowa, the river reached the minor flood level.

As the river downstream reached levels not observed for some years, inconsistencies between the gauged flow (at the Heywoods gauge) and the measured release from the dam (that were previously not observed) became evident. In particular, the flow measurement based on the Heywoods rating appeared higher than the targeted release rate based on outlet settings at the dam. In response, the MDBA worked with WaterNSW to arrange flow gauging's at key gauges. Gauges included Heywoods, Doctors Point, Corowa and Bandiana on the Kiewa River. This action resulted in an updated rating

table for Heywoods, which upon implementation provided more consistency in release measurement. Heywoods is known to be a challenging location to accurately gauge flow due to several factors such as weed growth. RMO noted that further work would be required at the completion of flood operations to re-check flow ratings at critical gauges as well as the release measurement based on outlet settings at the dam to confirm the accuracy and consistency of release measurements at different flow rates.

In addition to utilising existing communication avenues such as the River Murray weekly report and media releases, River Murray operations initiated an online weekly Hume Dam operations briefing aimed at keeping downstream community stakeholders informed and up to date. These briefings covered catchment conditions, water releases, forecast rainfall, inflows, and the management plans for the coming week. An additional weekly video update was also published on the MDBA website which summarised the content of the briefings. Thirteen Hume Dam updates were provided during Q2, which were delivered in collaboration with flood forecasters from the BOM. Positive feedback was received from the community on the format and information provided, which aimed to improve understanding of flood risks and the need to be prepared for possible flooding both upstream and downstream of Hume Dam. While this community provided positive feedback on the proactive nature of the briefings, they expressed concern over MDBA airspace management. Specifically, they advocated for greater airspace to mitigate potential downstream flooding. The MDBA acknowledge the community concerns noting that airspace management decisions were made consistent with the specific objective and outcome 2.6 and this limited the airspace that could be targeted.

In addition to high flows from the upper Murray, elevated flows continued to occur from the Murrumbidgee and Barwon-Darling rivers. In response to the continued rainfall and elevated inflows in the Murrumbidgee catchment, WaterNSW continued to actively manage airspace at Blowering and Burrinjuck Dams. Persistent spill from these dams meant inflows from the Murrumbidgee to the Murray was also significantly increased. At the Balranald gauge, flows during September averaged around 9,800 ML/day, well above the end of system target flow for September of 1,330 ML/day.

Similarly, WaterNSW had been closely monitoring the Barwon-Darling flows and assessing the capacity to store all inflows in the Menindee Lakes. As rain fell in the northern Basin, revised flow forecasts indicated that increasing flows in transit were likely to exceed the Maximum Induced Surcharge Volume (MISL) in early October unless airspace releases were implemented. In response, WaterNSW commenced airspace management releases into both the lower Darling River as well as the Great Darling Anabranch (via the Lake Cawndilla outlet). As well as benefits for flood mitigation, the releases targeted environmental benefit to the Anabranch, which had previously remained dry over several years.

As a result of high flows throughout the River Murray System and increased releases for airspace management at Hume Dam, unregulated flows extended along the entire river downstream from Hume Dam, including in the Edward-Wakool System.

In South Australia, forecasts for increasing flows into the lower Murray raised the opportunity for South Australia to undertake a lake level cycling operation in the Lower Lakes (**Figure 16**). Lake level cycling is undertaken to improve salinity conditions by drawing higher salinity water out of Lake Albert before re-filling with fresher water from the Murray during periods of high flow. Barrage releases were increased from late August to decrease lake levels, which were subsequently refilled as unregulated flows increased over the ensuing weeks.

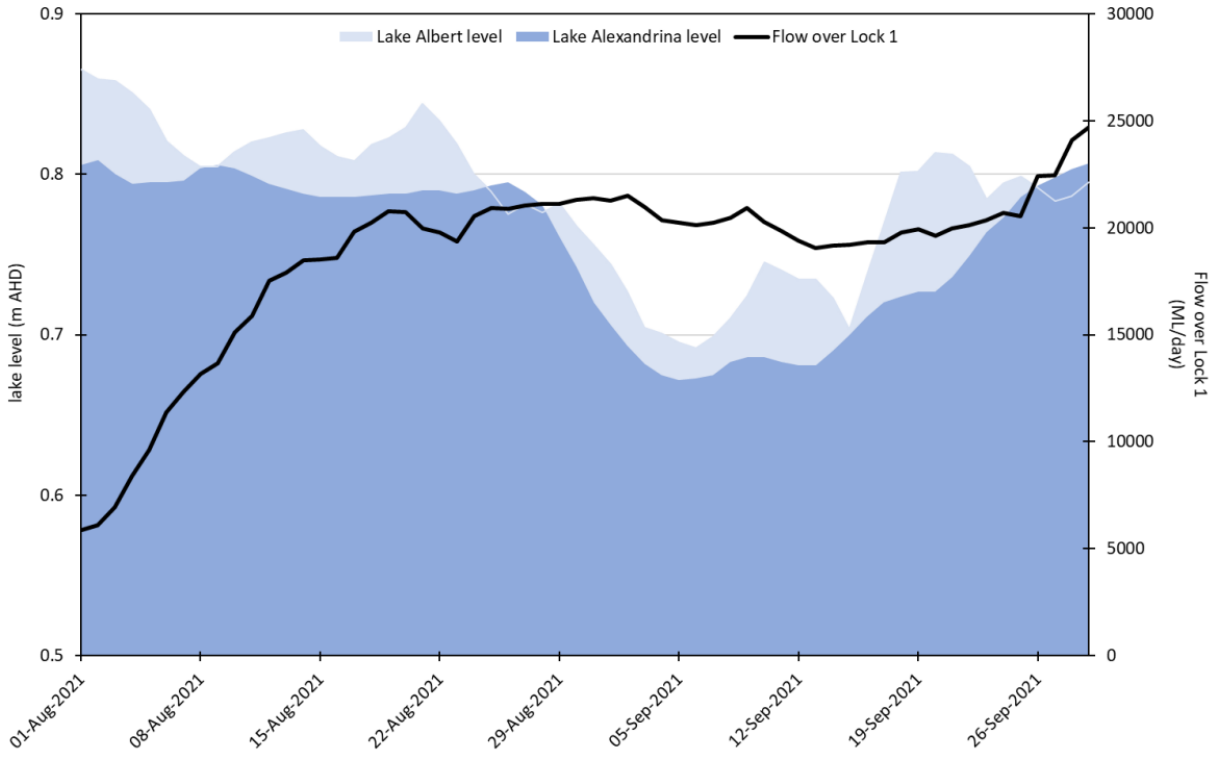
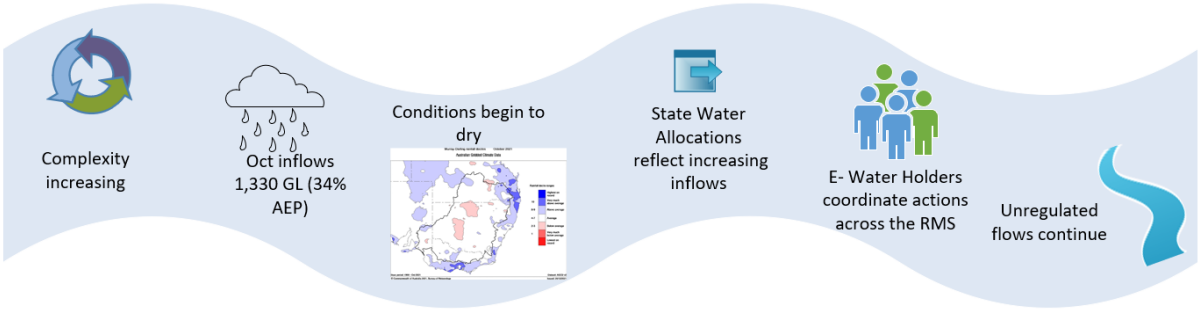


Figure 16: High upstream flows have enabled lake level cyling of Lake Albert.

Towards the end of September, the BoM were forecasting a low pressure trough with thunderstorm activity to bring heavy rainfall across the Upper Murray catchments. In response, releases at Hume Dam focused on generating additional airspace. As such, releases from Hume were stepped up to 21,500 ML/day. This action generated additional airspace ahead of forecast rain while maintaining the downstream flow at Doctors Point within channel capacity (25,000 ML/day).

October 2021



Conditions were drier during October, although rainfall remained close to the long-term average for most of the Murray Valley (**Figure 17**) and River Murray System inflows totalled around 1,330 GL. The inflow volume was slightly under the long-term October mean of 1,340 GL, but still well above the last 10-year October mean of 920 GL.

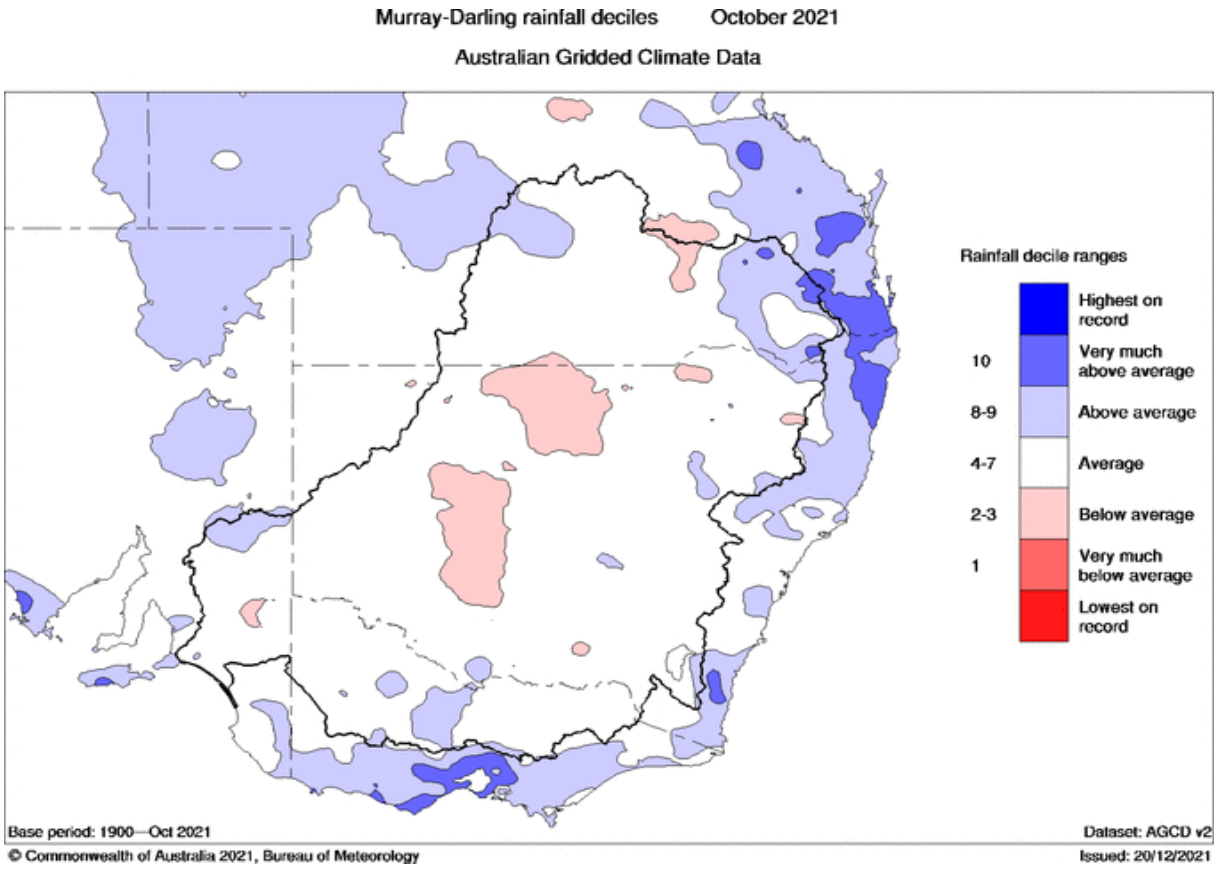


Figure 17: October 2021 Murray–Darling Basin rainfall deciles showing mostly average conditions.

During October the MDBA had access to water at Hume, Dartmouth, Menindee Lakes and Lake Victoria storages. As the month progressed, storage levels at Dartmouth continued to steadily rise, while releases from Hume Dam were managed to steer the storage towards effective full. Lake Victoria also approached effective full supply level as unregulated flows continued to be captured. As a result, MDBA active storage (**Figure 18**) increased to levels above the peak volume reached in 2017 (following the 2016 floods) with 2021 volumes boosted by the additional volume stored in the Menindee Lakes.

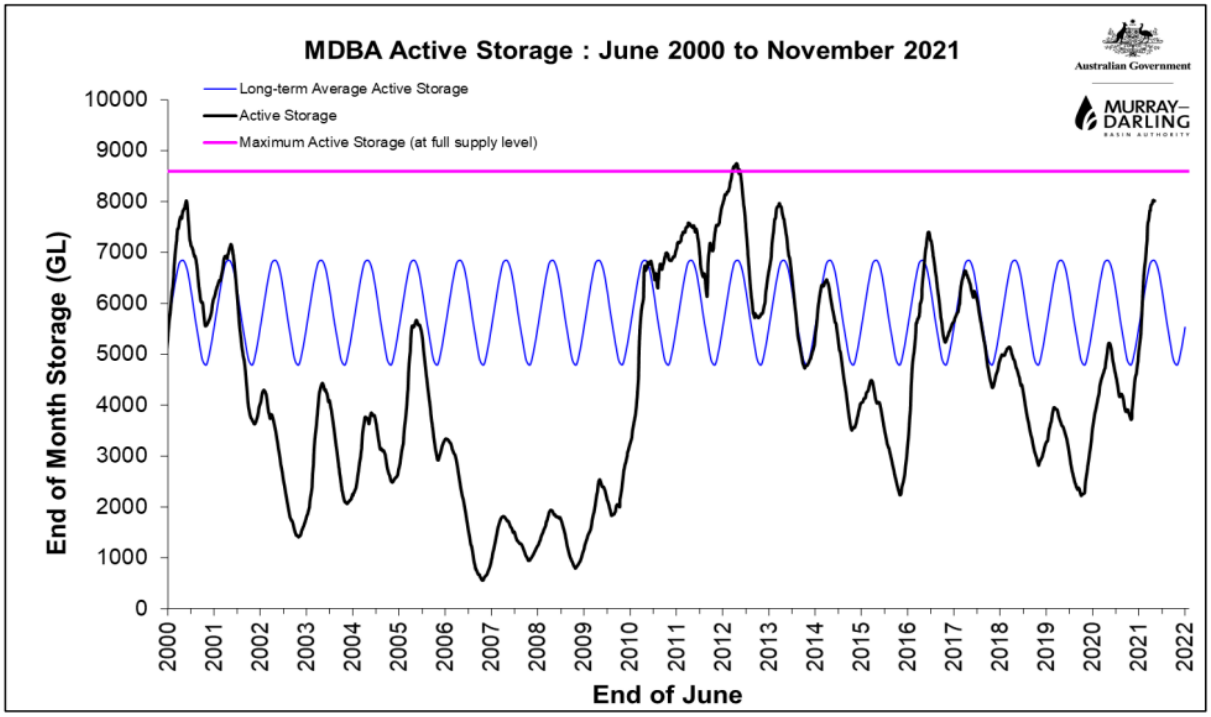


Figure 18: Murray–Darling Basin Active Storage levels to end of October 2021.

October began with a significant inflow to Hume Dam in response to heavy falls across the upper Murray Catchments. In response, airspace releases were stepped up once again, reaching a peak release of 29,000 ML/day on 2 October. With contribution from local run-off and the Kiewa River peaking at around 5,500 ML/day, flows exceeded downstream channel capacity at Doctors Point (25,000 ML/day) for around a week with a peak flow of around 36,000 ML/day.

In accordance with the Objectives and outcomes for river operations in the River Murray System, operations at Yarrawonga Weir do not seek to mitigate or attenuate inflow events from any of the Kiewa, Ovens and Upper Murray rivers, but rather, allow the event to pass without compromising the integrity of the structure. As such, releases downstream of Yarrawonga Weir were increased to a peak of 41,000 ML/day as high flows from Hume Dam, the Kiewa River and Ovens River arrived. This flow provided environmentally beneficial moderate floodplain and wetland inundation across the Barmah–Millewa Forest.

By the start of October, approximately 700 GL had been released from Hume Dam since airspace management commenced in early August.

During October, continued wet conditions in the Murrumbidgee catchment resulted in flows to the Murray averaging 10,500 ML/day, well above the end of October system target of 1,030 ML/day.

Similar wet conditions continued to drive Menindee Lakes operations where inflows above 10,000 ML/day persisted into early October. In response, WaterNSW managed the lakes in accordance with the Menindee Lakes surcharge rules. The Menindee Lakes has additional surcharge capacity in the order of 300 GL, which can be used to help manage high inflows and downstream flood risk as well as to maximise water resource when safe to do so. However, operating rules for the use of Menindee Lakes surcharge require the storage to return to the nominal FSL (1,730 GL) by 1 January in any given year. This is to assist with dam safety and flood risk associated with potential heavy monsoonal rain and flood inflows that typically take place during summer and early autumn.

The Menindee Lakes storage exceeded FSL (1,730 GL) during September and reached a peak storage volume of 1,980 GL (116% of active capacity) in the second week of October. The storage was then gradually lowered as WaterNSW made releases to the lower Darling and the Great Darling Anabranch, which averaged about 2,500 ML/day and 1,200 ML/day respectively during October. The BoM outlook indicated that the chance of exceeding median rainfall was very high across most of NSW during October and the following three months. This outlook foreshadowed the possibility of renewed inflows across the Barwon-Darling catchments and underlined the likely need for additional airspace management releases in the months ahead.

On the Goulburn River, environmental water holders undertook a spring pulse during October. This saw the flow at McCoys Bridge (the last gauge on the Goulburn River) peak around 8,000 ML/day. This flow contributed to a substantial pulse of water along the River Murray where flows met with elevated releases from Yarrawonga weir. This resulted in the flow at Torrumbarry Weir peaking near 24,500 ML/day. These higher flows provided an overall boost to river levels along the length of the river, from Yarrawonga Weir to the Coorong in South Australia.

As the month progressed without any further significant rainfall, operations at Hume Dam aimed to raise the storage to effective full supply (99% capacity). Filling targets are required to be met as downstream demands emerge to maximise stored water in the system. During Q2, the MDBA implemented the new operating arrangement for directed releases of water for the environment during airspace management at Hume Dam. The arrangement uses a new accounting provision that lets operations steer Hume storage to effective FSL in a modelled 'without environmental water' scenario. The arrangement helps improve environmental outcomes as well as airspace management for flood protection. More information can be found in **Box 2**.

With storages continuing to fill and water availability increasing, there were corresponding rapid improvements to state water allocations for Murray entitlement holders (**Table 5**). In addition, during October, the MDBA facilitated an online webinar highlighting how water allocations are managed and distributed across state river systems, with representatives from New South Wales, Victoria and South Australia also presenting.

Table 5: Allocations during 2021–22 on the River Murray.

Mid- Month Allocation	SA High - Class 3	Vic Murray High Reliability	Vic Murray Low Reliability	NSW Murray High Security	NSW Murray General Security
July 15	100%	31%	0%	97%	10%
August 16	100%	52%	0%	97%	30%
September 15	100%	77%	0%	97%	44%
October 15	100%	100%	0%	100%	110%
November 15	100%	100%	0%	100%	110%

BOX 2: Updated post flood operating arrangements to improve environmental outcomes whilst still optimising resources for all entitlement holders

As part of its flood management priorities, MDBA has obligations to maximise water availability at Hume Dam. Under previous operating arrangements to manage the end of a flood event the MDBA aimed to fill Hume Dam to at least 99% capacity. To achieve this, the MDBA would capture the last inflows into the storage before downstream demands emerged. This previous arrangement typically caused an unnatural rapid drop in the river level downstream of Hume Dam as releases were reduced. This unnatural drop can cause bank erosion and impede important ecological processes that are triggered by the preceding higher flows, such as native fish breeding.

This year, state resource managers have agreed to an updated operating arrangement to manage the end of the flood event at Hume Dam. The new arrangement enables water for the environment to be delivered to prevent the unnatural rapid drop in downstream flows.

Under the new arrangements, rather than filling Hume Reservoir to 99% capacity by the end of a flood, river operators may deliver water for the environment to meet a downstream environmental flow target, so long as the Hume storage level is within 100 GL of 99% when downstream demands (without environmental water) exceed inflows. These releases target downstream flows within existing regulated limits. The volume debited against water for the environment accounts is calculated as the difference between the release made to meet the environmental demand and the release that would have been needed to meet all other requirements. This accounting arrangement ensures there is no impact to the overall water resource, while optimising environmental outcomes.

State water managers from Victoria, NSW and South Australia have agreed that this new operating arrangement allows the MDBA to continue to achieve flood priorities set in the Objectives and Outcomes for River Operations in the River Murray System, specifically, improved environmental outcomes and the optimisation of the water resource for all entitlement holders. The new arrangements will be reviewed in due course. (Note that in July 2022, some details of the method were updated further with the support of the jurisdictions.)

Box 2: Updated operating arrangements during the conclusion of airspace management to improve environmental outcomes whilst optimising resources for all entitlement holders.

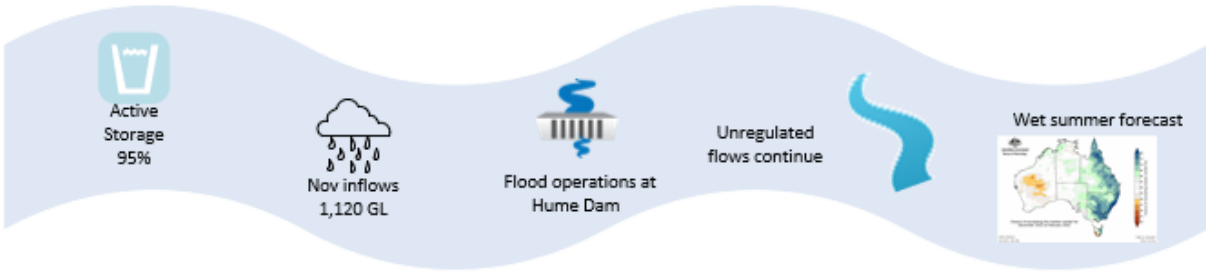
As conditions continued to dry off towards the end of October, environmental water deliveries from Hume Dam resumed, progressing the combined EWH's Southern Spring Flow as per the RMC Delivery Plan. By 31 October 2021, access to unregulated flows had ceased in the upper-mid reaches but were continuing in the mid-lower reaches, including the lower Darling River, driven by continuing high inflows from the Murrumbidgee River and continuing spill from the Menindee Lakes.

During October, the MDBA led a four-day Shortfall Exercise to test version 2 of the *River Murray Shortfall Response Plan* (now available on the MDBA website). Attendees included the Joint Governments, infrastructure managers, the Commonwealth, communications and media representatives, and Capacity Policy Working Group Independent Expert Panel members. The exercise was designed to test the latest version of the Shortfall Response Plan which now includes

Delivery Shortfall with Menindee Lakes available as a shared resource. The scenario tested the ability to implement rationing and understand its implications, and further develop processes for the internal and external communications required for managing an increasing shortfall risk. At the conclusion of the exercise attendees agreed to the approach outlined in version 2 of the *River Murray Shortfall Response Plan*. Each of the Joint Governments will continue to develop and refine their state-based shortfall response plans to complement the overarching *River Murray Shortfall Response Plan*. The MDBA will continue to run regular Shortfall Exercises; and work to incorporate System Shortfall planning. Throughout 2021–22, the MDBA undertook delivery shortfall monitoring using the Source model software and reported the risk of a delivery shortfall in the River Murray between Wakool Junction and the SA border in the weekly report in line with the shortfall response plan.

At the end of October, the BoM climate outlook suggested the chance of La Niña developing over the coming months had increased, meaning conditions were likely to be wetter than average over the remainder of the year. With storages already full, and some continuing to spill, it was likely that wet conditions would drive operations for the remainder of Q2.

November 2021



November 2021 was a very wet month across the Murray–Darling Basin and for Australia as a whole. The BoM reported that nationally, it was the wettest November in 122 years of record, surpassing the record set in November 1973. It was also the wettest November on record for the Basin, and for New South Wales and South Australia. It was amongst the ten wettest Novembers for Queensland.

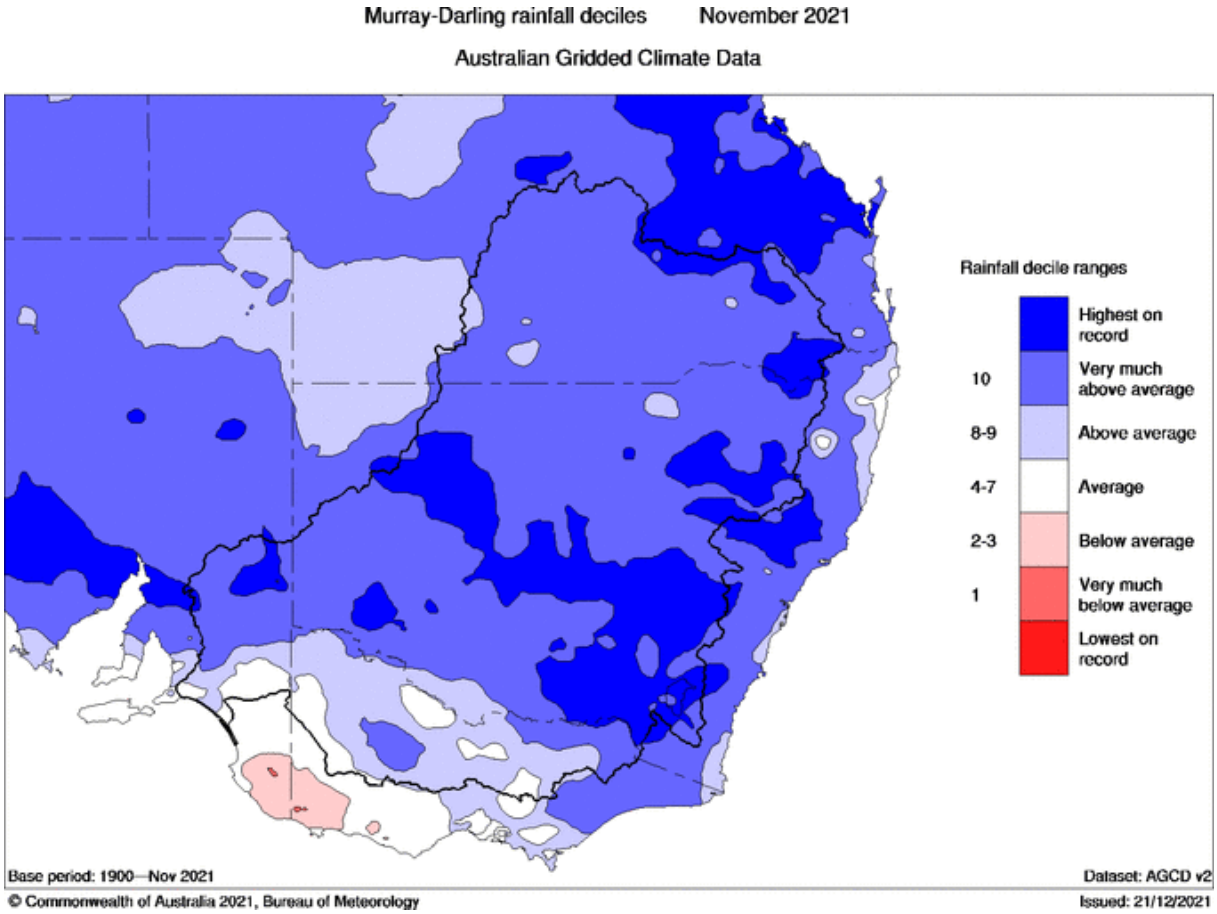


Figure 19: November 2021 Murray–Darling Basin rainfall deciles show wetter than average conditions across the Basin.

The BoM reports that the November area-averaged rainfall total for the Basin was 121 mm, which is 201% above the mean. The rainfall deciles for November show that rainfall across the Basin was predominantly 'very much above average' to 'highest on record', with some small patches of 'average' rainfall in the far south (**Figure 19**).

Temperatures across the Basin in November were mostly below average to very much below average. For Australia as a whole, temperatures were observed to be 0.63°C cooler and it was the coolest November this century. Australia's mean maximum temperature for November was 1.22 °C cooler than average and the mean minimum temperature was 0.06 °C cooler than average.

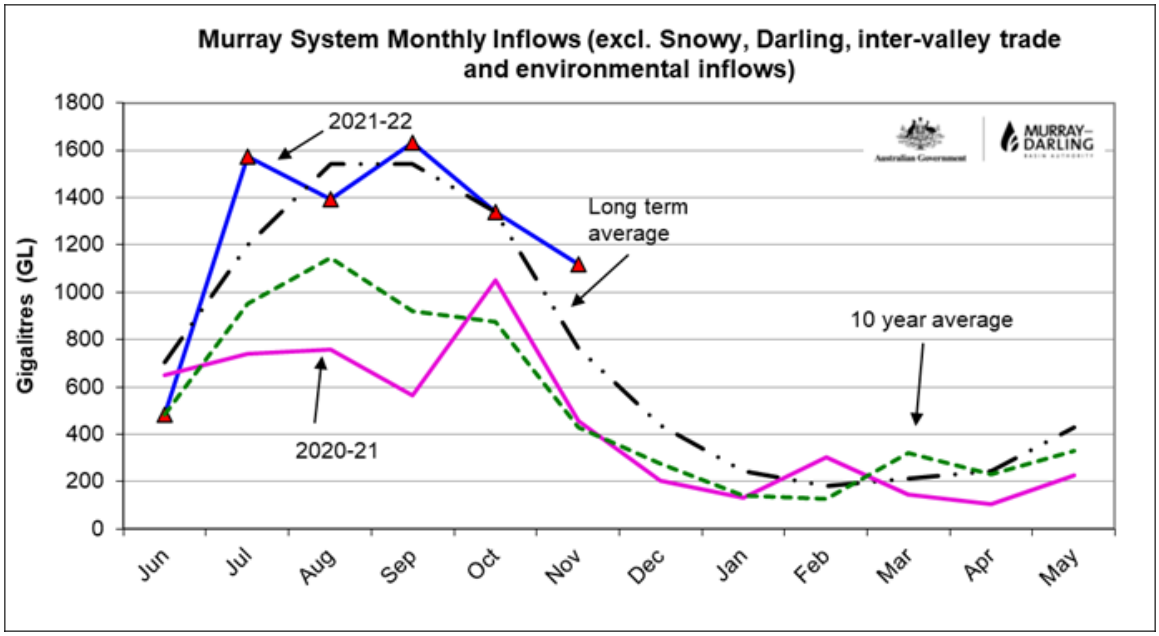


Figure 20: Murray System monthly inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) until the end of Quarter 2, 2021-22.

During November these climatic conditions affected inflows into storages. System inflows during November (calculated excluding inflow contributions from deliveries of water for the environment, IVT, Darling inflows and Snowy scheme releases) totalled around 1,120 GL, well above the long-term mean of about 760 GL (**Figure 20**).

By the end of November, total inflows for the year to date had reached 7,556 GL (38% AEP), tracking between the near average and wet inflow scenario of the AOO. River Murray system active storage totalled 8,127 GL (95% capacity) by the end of the month.

At the end of November, Dartmouth Reservoir was at 86% capacity, Hume Reservoir at 99%, Lake Victoria at 91% and Menindee Lakes storage was surcharged at 110% capacity. The transfer of water from Dartmouth Dam to Hume Reservoir was not required during Q2. Releases from Dartmouth therefore remained at the minimum rate, meaning just 18 GL was released for the quarter.

November started with dry conditions that saw releases from Hume Dam increasing to meet system demands. As a result, unregulated flows ceased in the upper reaches of the Murray. However, by the second week of the month, the BoM were forecasting widespread rain over the upper Murray catchments. With Hume Dam at around 98% capacity (around 70 GL of airspace) and irrigation demands remaining low, releases were stepped up to manage airspace and increase potential for mitigation of peak inflows. However, with observed rainfall over this period being towards the lower end of forecast ranges, releases were able to be reduced again, with the flows downstream remaining well within channel capacity. Nonetheless, the increased releases, supported by high flows

from downstream tributaries were sufficient to trigger unregulated flows again along the whole River Murray System.

As RMO continued to undertake flood operations at Hume Dam, WaterNSW was managing the high flows in the Barwon-Darling system. By mid-November there was growing confidence that significantly higher releases from the Menindee Lakes would be required to manage the storage below full supply level. Consultation was undertaken by WaterNSW with environmental water managers, fisheries, entitlement holders and other members of the community and plans were developed to initiate higher releases from Weir 32 and into the Great Darling Anabranch as necessary over the coming months.

Throughout October and November, WaterNSW continued to make significant releases at Blowering and Burrinjuck Dams to manage airspace in response to forecast and observed rainfall. As a result, elevated inflows from the Murrumbidgee River to the Murray continued throughout November and were forecast to persist well into December.

Due to elevated flows continuing throughout the system, RMO continued to closely manage operations at Lake Victoria. By early November, conservative forecasts suggested that the whole River Murray system may return to fully regulated conditions by December. In response, RMO looked to raise the level of Lake Victoria to reach effective full supply level (99%) at the conclusion of the unregulated flow period. At the same time, RMO received an order from environmental water holders for a directed release from Lake Victoria. This order looked to slow recessions, boost flows and maintain target flow levels through till December. RMO was able to meet this order with increased releases from Lake Victoria, which in addition to already natural high flow saw flows to South Australia exceed 30,000 ML/day for nearly a month. This provided increased water inundation and ecological benefits for floodplains and wetlands in South Australia.

By late November, the BoM were forecasting more widespread rainfall over the Upper Murray catchments with totals of 50-100 mms expected. Ahead of the rainfall, RMO increased releases from Hume Dam to manage airspace and provide flood mitigation where possible.

The already wet catchments of the upper Murray tributaries responded strongly to the rainfall. Upstream of Hume Dam the Murray River at Jingellic reached minor flood level with a peak flow of around 40,000 ML/day. Total inflows to the storage peaked at around 50,000 ML/day. However, careful airspace management meant releases could be limited to a peak of 33,000 ML/day, meaning significant flood peak mitigation was once again achieved. Flows at Doctors Point peaked at around 37,000 ML/day and remained above channel capacity for around 9 days but well below minor flood level at Albury.

The elevated releases from Hume again resulted in unregulated flows becoming available across the whole River Murray system and allowed a further delay to the filling of Lake Victoria. As such, RMO looked to lower the Lake Victoria storage level in accordance with the Lake Victoria operating strategy (LVOS) as specified in the Objectives and Outcomes for River Operations in the River Murray System. The LVOS aims to stabilise the lake foreshore and protect cultural heritage sites by encouraging the growth of native vegetation. To help achieve this, operations aimed to reduce the length of time the foreshore vegetation is inundated. The storage is then operated to maximize water availability by the end of the unregulated flow event.

Due to unregulated conditions, delivery of IVT from the Murrumbidgee and Goulburn rivers was not required for Q2.

By the end of Q2, the BoM issued a climate and water outlook from December 2021 to March 2022. It was reported that the La Niña has become established in the tropical Pacific with indications it would remain active until at least late summer. In combination with Australia's other climate drivers, the outlook indicated that rainfall was likely to be above average for parts of eastern Australia. Additionally, December to February maximum temperatures were likely to be above median for most of Australia, with below median daytime temperatures likely for eastern NSW (**Figure 21 and Figure 22**).

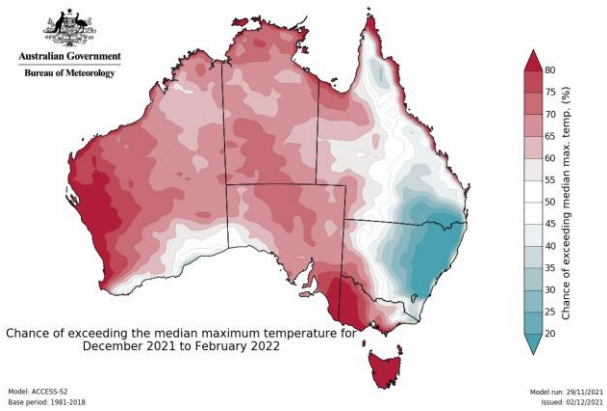


Figure 21: Chance of exceeding the median rainfall for December 2021-February 2022.

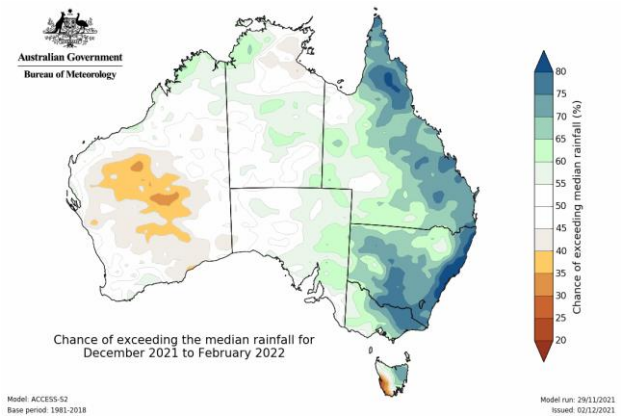


Figure 22: Chance of exceeding the median maximum temperature deciles for December 2021 – February 2022.

This outlook meant that the summer ahead was likely to require a high level of adaptability of operations and continuous adjustment of operational planning. Given storages across all the River Murray system remained high or spilling, further flood operations and elevated flows through the system remained highly likely.

Quarter Three

Like much of Q1 and Q2, a key focus of quarter three (Q3) was continued management of full storages, with River Murray Operations (RMO) safely passing multiple floods at Hume Dam and Yarrawonga Weir. January brought record breaking rainfall for areas across the upper Murray catchments, and cycles of intense thunderstorms in and around the upper Murray region that required careful forecasting and a strong consideration of airspace and risk management. The wet conditions resulted in Hume Dam storage reaching 99% capacity during January – only the 4th time this has occurred since the 1960s (when the dam was expanded to its current size). The previous occasion was 28 years ago in January 1994.

Traditionally, summer is the peak irrigation season with high demands that require careful planning of releases and system transfers to manage risk of shortfall and ensure supply. However, due to unusually high inflows to the system this year driven by storage spills and unregulated inflows from the Murrumbidgee and Darling systems, unregulated flows on the Murray persisted into summer. This significantly reduced the requirement for regulated releases from Hume Dam or delivery of IVT to meet system demands. By the end of Q3, drying conditions saw unregulated flows conclude along the system's upper reaches whilst elevated inflows from the Murrumbidgee and Darling River started to ease.

During Q3, significant focus was given to the management of water quality including low dissolved oxygen (DO) levels downstream at Hume Dam. This issue has been driven by enhanced concentrations of bushfire residue entering the lake over the past few years, and complex physical and chemical processes in the water column that have lowered dissolved oxygen in deeper parts of the lake near the outlets. RMO worked closely with WaterNSW and power station owners, Meridian Energy to actively manage downstream water quality impacts from this situation as conditions changed in the lake. This included steps to improve dissolved oxygen (DO) levels downstream by varying the combination of outlets used to deliver the required release. Releases through the valves helped increase aeration, as did the addition of compressed air to releases through the power station. This adaptive management approach was supported by active water quality monitoring and engagement with key stakeholders such as fisheries and town water supply agencies. Significantly improved DO levels ensured conditions remained favourable for fish and other aquatic animals.

In early December, the MDBA published the **end October update** to the *River Murray System Annual Operating Outlook (AOO) 2021–22*. This provided a revised analysis and update to the trajectories of the AOO planning scenarios based on how conditions had tracked up until late spring. The update included revised assumptions and the outlook for summer and autumn including the likelihood of continuing wet conditions indicated by BoM climate outlooks, including the establishment of La Niña conditions.

Key achievements for Q3

Continued successful management of Hume Dam and subsequent flows downstream, during a long period of flood operations. This was driven by the wettest January on record at the dam. January rainfall of 318 mm exceed the previous record of 213 mm recorded in 1974. During Q3, spills occurred at Hume Dam until early February, an unusual situation so far into summer.

Management of unregulated flows and Lake Victorian Operating Strategy requirements in response to changing inflow forecasts with high flows in the lower Darling River due to the management of the Menindee Lake system together with releases by WaterNSW to manage storage airspace within the Murrumbidgee system.

Efficient and effective response to water quality issues at Hume Dam associated with bushfire impacts to catchment inflows from the upper Murray following the 2019-20 summe bushfires. RMO worked closely with stakeholders to adaptively manage the situation and trialled a variety of release configurations to help improve dissolved oxyger levels immediately downstream of the dam.

Key external drivers influencing operations in Q3

During summer the following key drivers influenced river operations:

1. **Key Driver 1 – "Wet conditions, summer storms, heavy and unpredictable rain, continuing spill from Hume Dam"-** Quarter 3 brought multiple rain events and storm cycles that led to recurrent high inflow events at Hume Dam (**Figure 23**). RMO safely managed these events by adjusting Hume Dam airspace and releases to meet flood operations priorities. This included appropriate consideration of dam safety, maximising stored water at the end of the flood period, and providing downstream flood mitigation and environmental benefit where possible. Significant forecasting uncertainties associated with storm-based rainfall challenged flood operations and RMO worked closely with the BoM to assess future rain and likely streamflow responses from evolving forecasts to inform operational decisions and understand overall risks. Despite these challenges and record January rainfall around the dam, releases were able to be maintained at rates close to channel capacity or below.

- **Key Driver 2 – "Continuing high unregulated inflows into summer"-** During Q3, elevated flows from River Murray tributaries continued to supply large parts of the system, drive broader system operations, and suppress requirements for Hume Dam releases and IVT delivery. During summer, flows from the Murrumbidgee River averaged around 9,500 ML/day due to airspace management releases from upstream storages. This is considerably above the average end of system target of around 200 ML/day. Similarly, WaterNSW continued to manage significant flood inflows to the Menindee Lakes. This saw airspace management releases into the lower Darling River reach a peak flow of 18,000 ML/day at Weir 32. At the end of February, the release at Weir 32 was reduced to 9,000 ML/day, whilst generally drier conditions resulted in regulated flows returning to River Murray reaches upstream of the Murrumbidgee junction.

  Key Driver 3 – "Water quality issues within Hume Dam and elsewhere"- Q3 brought water quality challenges across multiple areas of the River Murray system. During early January, dissolved oxygen (DO) levels downstream of Hume Dam were observed to fall below critical thresholds for aquatic animals. The observed changes were like those seen 12 months prior and were understood to be linked to water quality changes from upper catchment stream flow following the 2019-20 summer bushfires. This also changed some chemical and physical characteristic of the water column. In response, RMO worked closely with key stakeholders to scale up water quality monitoring and manage water quality risks. The operational response involved the use of various release combinations (spillway gates, irrigation valves, power station) to help improve dissolved oxygen levels to within healthy limits. RMO helped coordinate other response activities including engagement with environmental experts and town water managers. In addition, Q3 saw water quality impacted in other parts of the Murray system including elevated Blue-Green Algae in various locations and low DO in parts of the northern Basin as flood flows mobilised large amounts of organic material from the floodplains. Agencies and scientific experts worked together to monitor water quality and advised the best operational measures to mitigate the risk to aquatic life as much as possible.

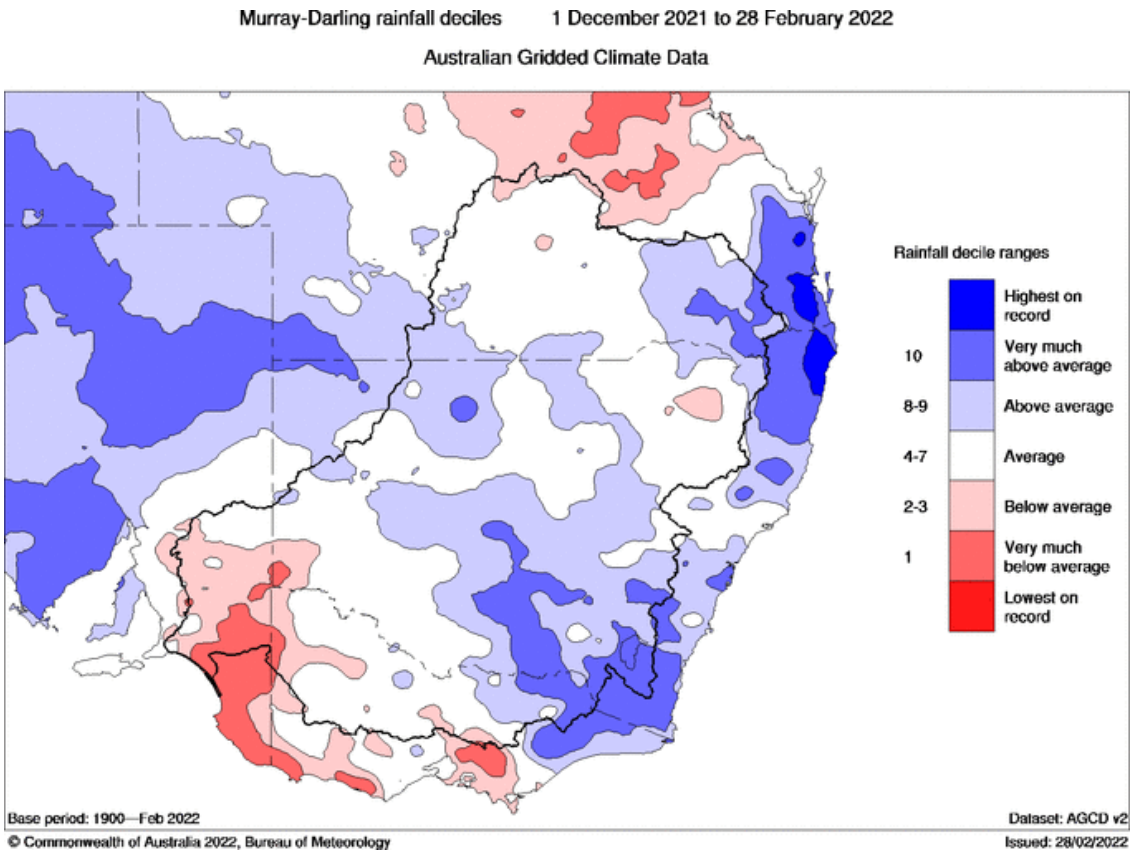


Figure 23: Murray–Darling rainfall deciles for Q3 show varied conditions across the River Murray System with above to very much above average rainfall in north-east Victoria, south-east NSW and south-east Queensland; and average to below average rainfall towards the far south-west of the Basin.

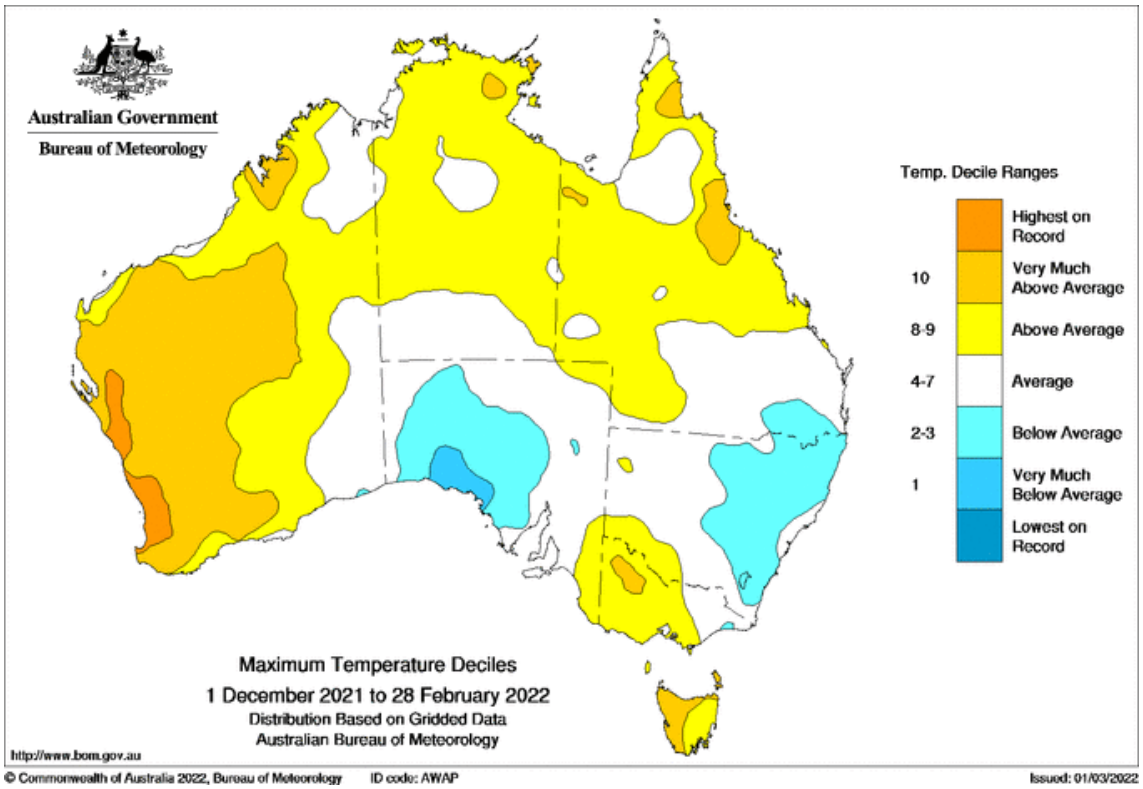


Figure 24: Maximum temperature deciles for Q3 show average to below average temperatures across the east of the Basin, with above to very much above average temperatures across western Victoria, south-west NSW and eastern South Australia.

Key metrics for Q3

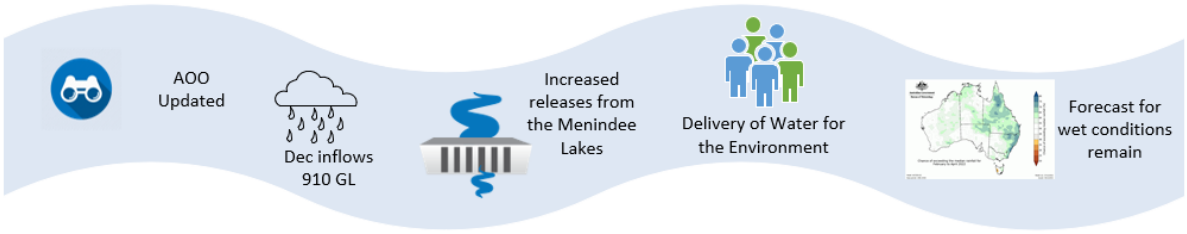
The operational metrics in **Table 6** provide a snapshot summary of river operations for Q3. All figures should be considered within the context of the key drivers outlined above.

Table 6: Key metrics for River Murray System operations during Q3.

Metric		Quarter Three [i]
Total River Murray System inflows [ii]		2,334 GL (3% AEP)
Storages	Net change at Dartmouth	↑ 272 GL with high inflows and no system transfers required
	Net change at Hume	↓ 143 GL due to releases for downstream demands
	Net change at Lake Victoria	↓ 69 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS)
	Net change at Menindee Lakes	↓ 13 GL due to airspace management by WaterNSW
Storage releases	Dartmouth Releases	22 GL comprising AGL entitlement releases (power generation) and minimum releases
	Hume Releases	1,024 GL comprising releases for airspace management (spill) and releases to meet downstream demands
	Lake Victoria Net Releases [iii]	61 GL due to the management of storage filling (spill) and the LVOS during unregulated flows
	Menindee Lakes Releases	1,385 GL released to the lower Darling River comprising operational releases (including spill) and releases of water for the environment. 174 GL released to the Great Darling Anabranch for airspace management (spill)
	IVT	Murrumbidgee: 0 GL Goulburn: 7 GL
Total consumptive deliveries [iv]		530 GL Victorian Murray 654 GL NSW Murray
River Murray System loss [v]		368 GL
Environmental directed releases from Hume [vi]		130 GL
Flow to SA	Total SA Flow	2,665 GL
	Dilution & Loss	174 GL
	Entitlement Flow	454 GL
	Consumptive trade deliveries	39 GL
	Environmental water deliveries [vii]	240 GL
	Rolling Adjustment [viii]	1,757 GL due to unregulated flows and additional dilution flows (270 GL).
Publication of operational information		12 MDBA Weekly Reports 4 Media Releases on 'river operations' 7 video briefings on Hume Dam operations Basin in Brief/Flows in the River Murray System

i. Values are provided from the River Murray System accounts at the point of time the quarterly report is written and considered as operational data. Updates to input data including changes to rating tables as well as other data changes because of hydrometric updates may result in the numbers in the above table changing.
ii. River Murray System inflows include unregulated inflows to Dartmouth, Hume and from the Kiewa, plus inflows from the NSW and Victorian tributaries excluding environmental water deliveries and IVT as well as Menindee when not part of the shared resource.
iii. Lake Victoria Net Releases refers to the net volume between inflows and outflows.
iv. Sourced from River Murray System accounts, includes all consumptive deliveries and Lindsay River allowance for Victoria.
v. River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific watering actions and losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria and Menindee Lakes System (when part of the shared resource). Note: this is an interim loss value – refer footnote (i).
vi. Sourced from River Murray System monthly environmental accounts.
vii. South Australian Environmental use – includes all environmental water that flows into South Australia.
viii. Includes changes due to rating table upgrades or subsequent hydrometric updates as well as unregulated flow and Additional Dilution Flow (ADF) whenever these occur.

December 2021



At the beginning of Q3, MDBA published the **end of October update of the AOO** which included updated analyses and forecasts based on system conditions in late spring. Typically, most of the year's inflows have been received by the end of October and so a clearer picture of the likely path of storage levels, system demands, and flows can be determined. The document also provided a revised analysis of the climate and system drivers that had shaped and were expected to continue shaping river operations activities for the remainder of the water year. Key information included that:

- River Murray System inflows had tracked between the wet and near-average scenarios during the first 5 months of 2021–22 water year and unregulated flows had occurred across the system for much of this period, including in the lower Darling system during spring.
- Looking forward, the Hume Dam storage level across the remainder of 2021–22 was likely to remain relatively high compared to levels observed over the last 2 years, although a return to persistent drier than average conditions could see it drawn down to a volume below 50% capacity. As such, it was highly unlikely that bulk transfers from Dartmouth to Hume would be required for the remainder of 2021–22.
- Lake Victoria storage level remained high and was expected to remain so for summer. This meant that the likely commencement of transfers from upstream storages remained delayed and any actual transfer commencement would depend on the timing of any shift to drier conditions and a return to regulated conditions in the coming months.
- Operational risks and potential challenges for the rest of the 2021–22 water year included significant flooding in the River Murray system, the operation of Menindee Lakes and water quality issues including blue green algae, blackwater and anoxic conditions in Lake Hume.

December 2021 rainfall varied significantly across the Murray–Darling Basin (**Figure 25**). Areas of South Australia and far western Victoria and New South Wales experienced dry conditions with rainfall deciles below average to very much below average. Whilst in the mid-Murray and upper Murray rainfall deciles were around average or above. Temperatures across the Basin for December were generally close to average.

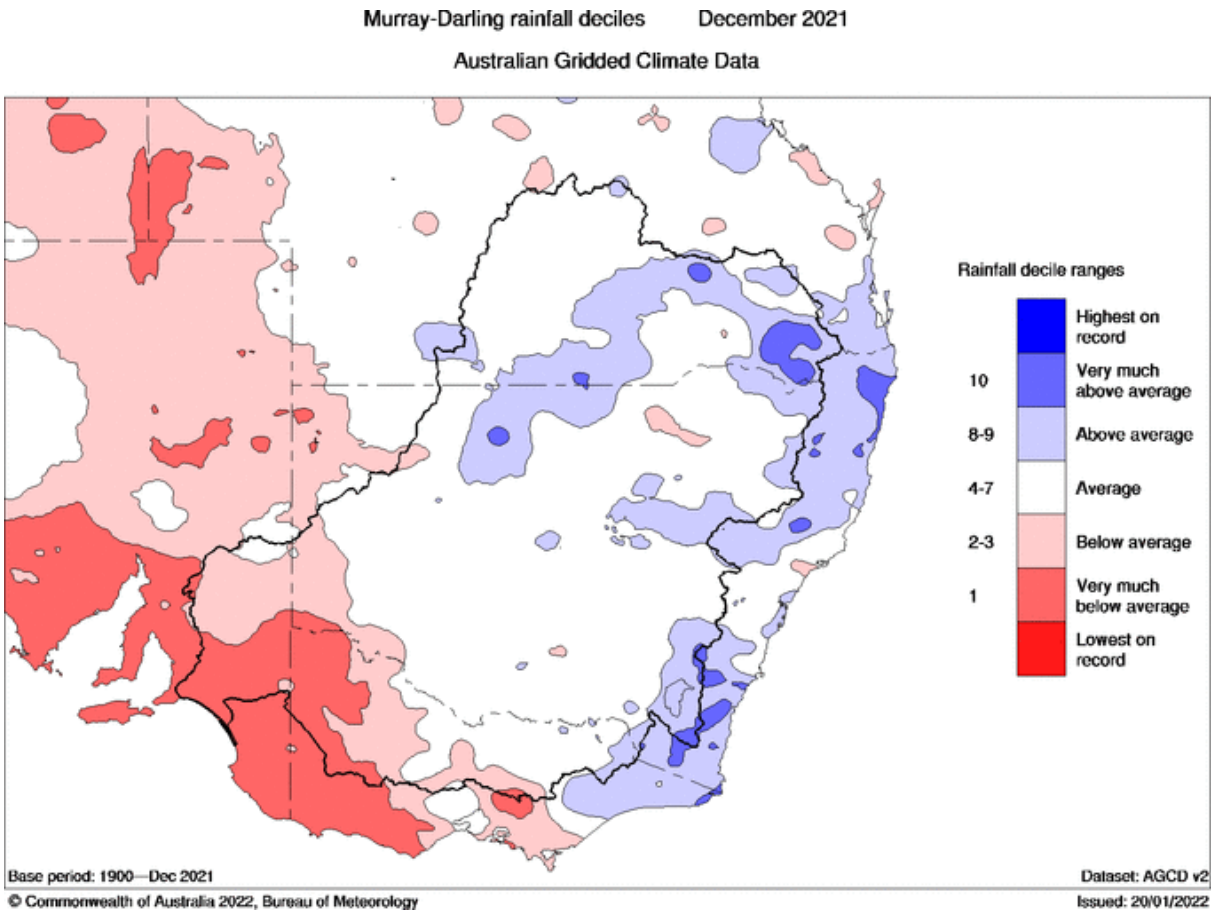


Figure 25 – Murray–Darling Basin rainfall deciles for December 2021.

River Murray system inflows for December 2021 (excluding Snowy, Darling, IVT and environmental inflows) were around 910 GL, which is within the highest 10% of 129 years of record for December.

The month began with Hume Dam at 99% capacity and flood operations taking place following heavy rain in late November that delivered inflows peaking at 54,000 ML/day.

By the second week of December, releases from Hume Dam had been decreased to meet downstream demands including the continued delivery of water for the environment. This saw the Yarrawonga downstream release target a flow of near 8,500 ML/day. In response to drier condition, lower inflows from the Ovens and Kiewa rivers, and increasing demands, unregulated flows in the Hume to Yarrawonga reach ceased on 12 December but continued to occur further downstream.

During December, RMO also focused on the delivery of environmental water in the form of a directed release from Lake Victoria. This saw additional releases from Lake Victoria to build on the significant pulse passing Wentworth. This boosted the flow to South Australia and provided a range of benefits for the environment in South Australia including things such as: 'flowing water habitat' to benefit native fish, animals and plants in the River Murray channel that have adapted to a riverine environment, including supporting conditions that favour spawning and recruitment of golden perch and Murray cod.

At Menindee Lakes, the storage volume continued to be reduced by WaterNSW ahead of significant flows that were in transit along the Barwon-Darling River. The total storage volume decreased over December from near 1,900 GL at the beginning of the month to 1,630 GL by the end. The airspace generated in the Menindee Lakes by this action increased potential flood peak mitigation for high

inflows that were in transit from the northern Basin following very heavy rain in November. Menindee Lakes releases were increased at Weir 32 from 4,000 ML/day to a peak of 18,000 ML/day during December, whilst flows from the Cawndilla outlet to the Great Darling Anabranch targeted 2,000 ML/day. The release plan was prepared by WaterNSW in consultation with stakeholders including DPE Water, DPI Fisheries and the Lower Darling River Operations Stakeholder Consultation Committee (ROSCCo).

During December, a continuation of airspace releases from Burrinjuck and Blowering Dams resulted in additional Murrumbidgee inflow to the Murray. Balranald flows remained at around 9,000 ML/day, which continued to drive unregulated flow conditions in the lower reaches of the Murray. Significant flows were forecast to continue from the Murrumbidgee catchment over the coming months, driving broader operations including the management of Lake Victoria.

By mid-December, a cloud band with embedded thunderstorms that stretched from central New South Wales to eastern Victoria brought rainfall across areas of Queensland, most of New South Wales, Victoria and parts of South Australia. The heavy rainfall over the upper Murray generated renewed streamflow responses in the upper tributaries. In the upper Murray, the flow at Jingellic peaked at over 19,000 ML/day. Hume releases were gradually reduced to 6,500 ML/day during the event as demands fell away due to 'rain-rejection', as available airspace was sufficient to fully capture and store the event. This resulted in the storage returning to effective full supply with a peak level of 99.3% capacity observed on 25 December when demands exceeded inflows again.

The rain-rejection event downstream caused Mulwala Canal diversions to drop to a low of 2,900 ML/day, 2,000 ML/day below orders; whilst diversion to Yarrawonga Main Channel dropped below 600 ML/day before gradually increasing. This significant demand decrease plus heavy rain on the river resulted in surplus water arriving at Lake Mulwala. In response, the release from Yarrawonga Weir was increased for a short period up to 10,000 ML/day.

Whilst flows at this rate were manageable at the time with some Barmah–Millewa Forest regulators already open, it did require further consideration of forest regulator settings and the 'fish exit strategy' implemented by forest managers following an extended period of forest inundation. In an effort to minimise environmental risks, MDBA requested surplus water to be redirected through Mulwala Canal and escaped into the Edward River, Wakool River, Billabong Creek and Murray further downstream. This action also helped improve water quality in these systems. Additionally, Lake Mulwala was temporarily surcharged above the normal operating range (124.6 to 124.9 m AHD) to re-regulate as much flow as possible.

Towards the end of December, a period of hot and dry weather arose, with temperatures reaching near 40 degrees across the southern Basin by the New Year. As downstream irrigation diversions increased in response, Hume Dam releases increased to a peak near 15,300 ML/day, and the storage started to draw down.

By the end of December, the BoM continued to report a climate outlook that predicted January to April 2022 rainfall was likely to be above average for parts of eastern Australia, particularly northern Queensland and coastal NSW (**Figure 26**), with a positive ENSO (La Niña) phase established in the Pacific and forecast to be maintained until the end of summer.

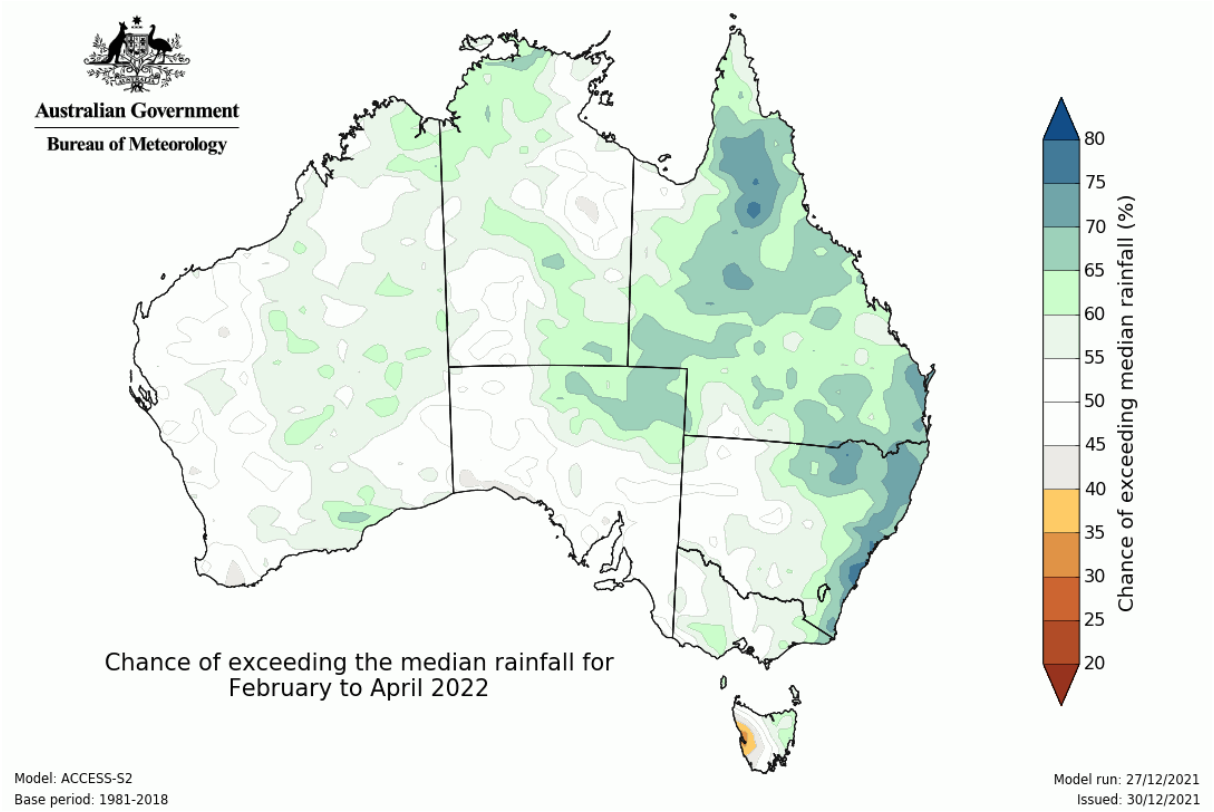
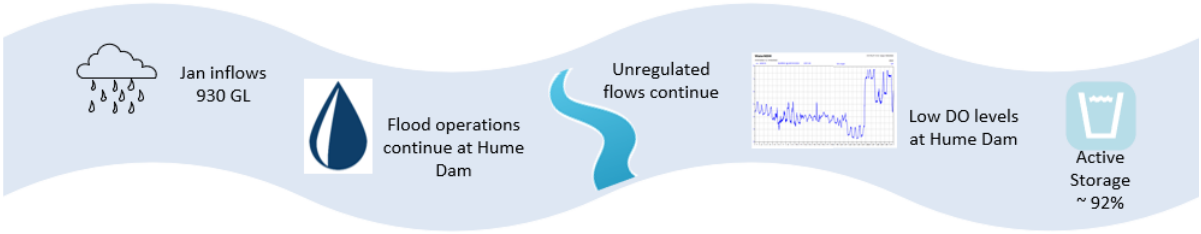


Figure 26: BoM published outlook showing the chance of exceeding the median rainfall for February to April 2022.

January 2022



January 2022 was dominated by record-breaking rainfall over parts of north-east Victoria and southern NSW linked to incursions of tropical moisture and characterised by repeat cycles of severe thunderstorm activity across south-eastern Australia. Whilst rainfall across the broader Murray–Darling Basin was 30% above average, it was the 4th-highest on record for South Australia, and the 8th-highest for Victoria. Moreover, rainfall exceeded the previous monthly record for January by a significant margin at several locations directly on and around Hume Dam and the upper Murray catchment (**Figure 27**).

Moisture associated with ex-tropical cyclones Seth and Tiffany also contributed to the weather conditions during January. For example, two-day totals of 50 to 100 mm during January 7 and 8 over inland New South Wales occurred as moisture from ex-tropical cyclone Seth moved south and interacted with a low-pressure trough and cold front that crossed southern Australia. Several sites in south-eastern New South Wales, north-eastern Victoria and East Gippsland observed daily rainfall records for January during this event and there was flash and major riverine flooding along parts of the upper Mitta Mitta River valley. Similarly, moisture associated with ex-tropical cyclone Tiffany contributed to very intense storms and several daily rainfall records observed mid-month.

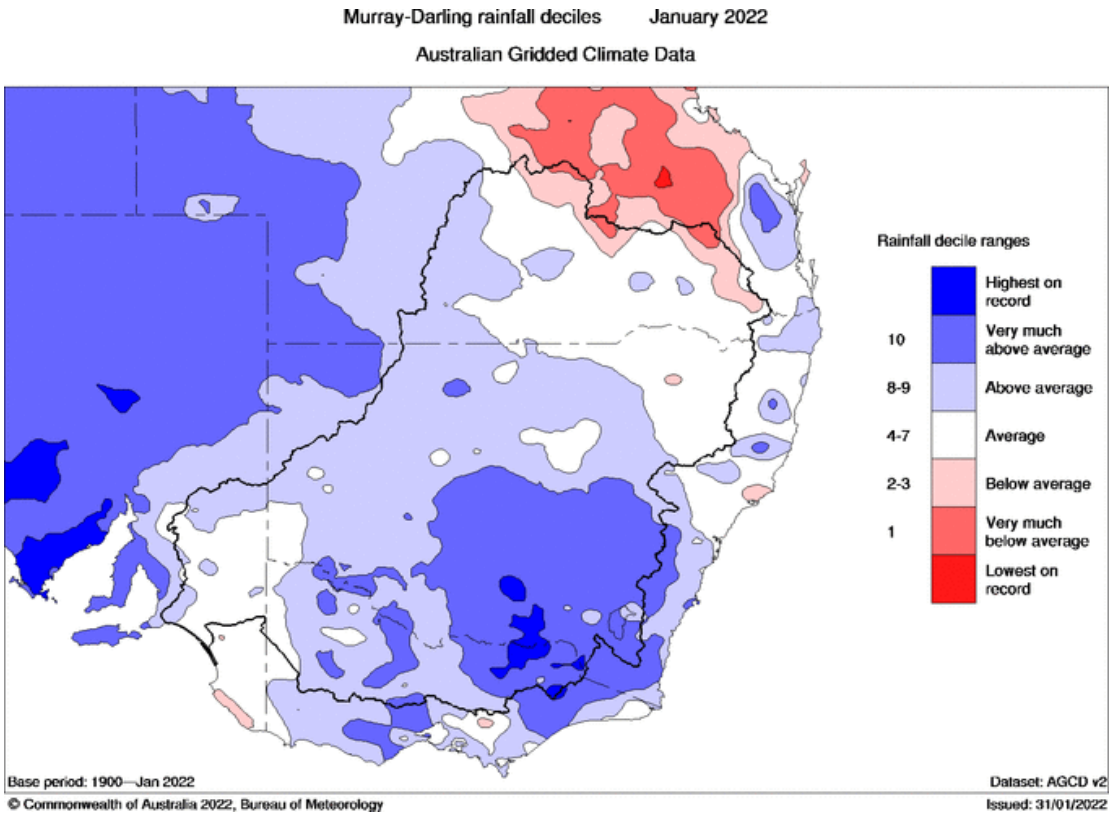


Figure 27: Murray–Darling Basin rainfall deciles for January 2022

Murray system inflows for January 2022 (excluding Snowy, Darling, IVT and environmental inflows) were well above average and some of the highest ever observed for January, totalling around 930 GL (2% annual exceedance probability) (**Figure 28**). Unregulated inflows to Hume Dam were the second highest ever recorded for January, exceeded only by the inflows of January 1974; whilst January inflows to Dartmouth Dam of 150 GL were the highest ever recorded.

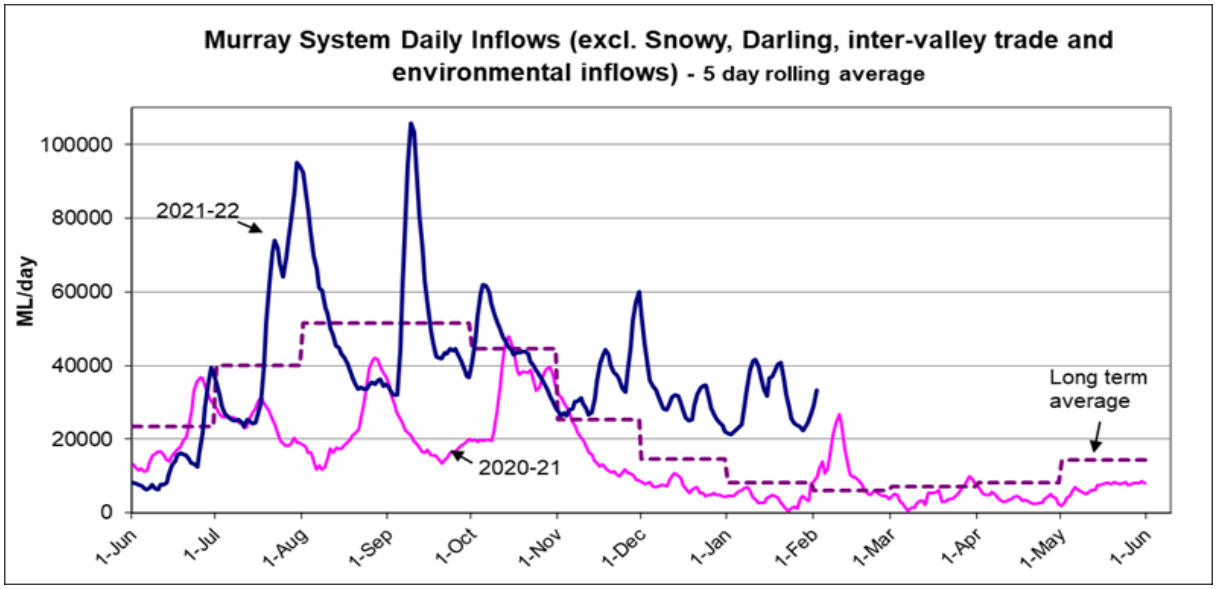


Figure 28: Murray System Daily Inflows at 02 February 2022.

After a warm and dry start to January, unstable conditions and the first round of storms set in from 5 January over the south-eastern Basin. However, the localised nature of storm activity, meant some locations received very heavy rain whilst other areas recorded much less. For the week ending January 12, Hume Dam received a total of 161 mm, whilst further upstream parts of the Dartmouth dam catchment received totals around 120 mm. In response, Hume inflows increased to a peak of 18,000 ML/day on 8 January. This rainfall event saw Hume Dam once again reach 99% capacity and reinstated a period of unregulated flow between Hume Dam and the South Australian border.

Further storm events took place through the middle of January and again towards the end of January. Releases to manage airspace recommenced on 10 January and increased to 17,000 ML/day a few days later; and then to 19,000 ML/day following another round of heavy rain mid-month that included a January daily record of 95 mm at Hume Dam on 15 January.

A final round of heavy storms over the final few days of January was linked to a trough that extended from central to south-eastern Australia and brought thunderstorms, showers, and tropical humid conditions across much of eastern Australia for close to a week. This event saw Hume Dam inflows increase again, reaching 22,000 ML/day on 1 February, whilst releases were once again increased to 19,000 ML/day to manage airspace. By the end of January, Hume Dam returned to 99% capacity, with releases steadily reduced back to regulated rates in early February.

Despite the repeat rain and flooding upstream of Hume Dam across the month and the relatively small volume of available airspace, downstream of the dam, the flow downstream of the Kiewa River junction at Doctors Point only briefly exceeded channel capacity on one occasion late in the month.

This occurred mostly because of very heavy localised rain and flash flooding around Albury that temporarily boosted the river height downstream.

Due to the increase in releases from Hume and tributary inflows, releases from Yarrawonga Weir increased to a peak of 17,500 ML/day on 20 January, with low-level over-bank flows through the Barmah–Millewa Forest. RMO once again liaised with forest managers to adjust forest regulators and pass the unregulated flows through the Barmah–Millewa Forest. RMO also requested surplus water to be redirected through Mulwala Canal and escaped into the Edward River, Wakool River and Murray further downstream to minimise risks to water quality associated with water entering the forest during summer. Flows at Yarrawonga Weir increased again late in the month as further spill arrived from Hume Dam.

During mid-January, dissolved oxygen (DO) levels immediately downstream of the Hume Dam began decreasing at the Heywoods gauge. The observed changes were like those seen 12 months prior and were understood to be linked to water quality changes from upper catchment outflow following the 2019-20 summer bushfires, which also changed some chemical and physical characteristic of the water column. In response, RMO worked closely with key stakeholders to scale up water quality monitoring and actively manage water quality risks to the extent possible with dam operations. The operational response involved the use of various release combinations (spillway gates, irrigation valves, power station) to help improve dissolved oxygen levels back to within healthy limits (**Figure 29)**. RMO also helped coordinate other response activities including engagement with environmental experts and town water managers to help adaptive management and fine tune the approach to manage associated changes to water chemistry.

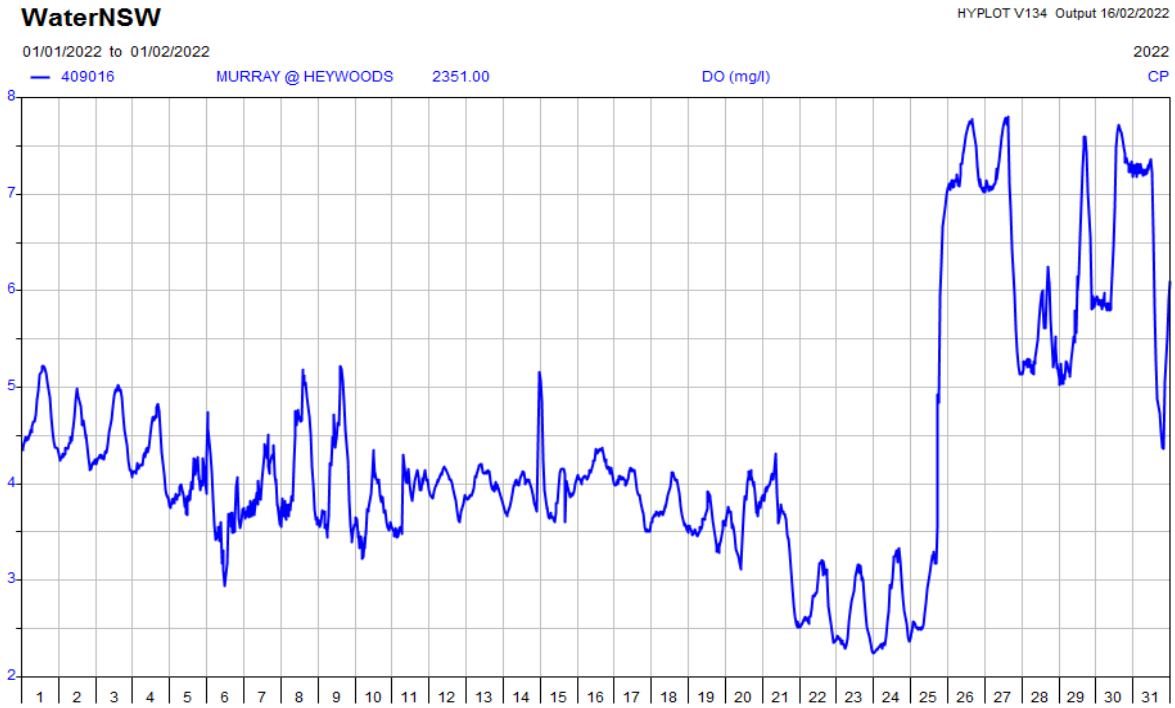


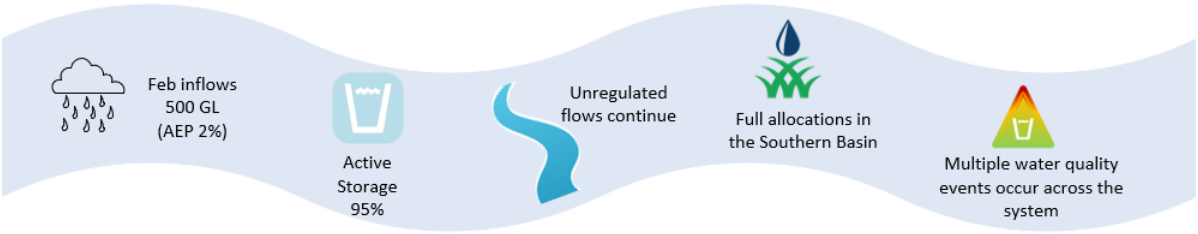
Figure 29: River Murray at Heywoods dissolved oxygen levels during January 2022 (Figure couresy WaterNSW).

Unregulated inflow from the Murrumbidgee River continued at rates above Murrumbidgee channel capacity throughout January. This continued to drive unregulated flows on the Murray downstream.

Releases to the lower Darling River (measured at Weir 32) remained at 18,000 ML/day during January as WaterNSW continued to manage airspace in the Menindee Lakes. Releases from Lake Cawndilla (part of Menindee Lakes) into the Great Darling Anabranch also continued at around 2,000 ML/day. These releases helped decrease the Menindee Lakes storage slowly to a low of 1,582 GL during January to provide airspace to manage peak inflows from the Darling River expected during February following widespread flooding in the Northern Basin during late 2021. Downstream on the lower Darling River, the flow at Burtundy increased slowly throughout the month and reached 14,100 ML/day, which helped to further drive unregulated flows on the Murray into South Australia.

By the end of January, water stored in River Murray system storages was well above the long-term average with Dartmouth Reservoir at 92%, Hume Reservoir 99%, the Menindee Lakes at 94% and Lake Victoria decreasing to 76%. Lake Victoria operations continued to be managed in accordance with the Lake Victoria Operating Strategy (LVOS) requirements. Given the BoM was indicating an increased chance that February to April rainfall would be above median for parts of eastern and central Australia, there remained a good chance that elevated flows could persist through parts of the system into autumn.

February 2022



February 2022 brought average rainfall for much of the Murray–Darling Basin and a comparatively drier end to a generally wetter than average summer for the Basin as a whole. February rainfall deciles show the contrasting conditions between the southern and northern Basin (**Figure 30**). The north saw average to well above average rainfall driven by exceptional, record-breaking rain along the south-east Queensland and northern New South Wales coast late in the month extending into the Basin to some extent. In contrast, southern parts of the Basin were relatively dry. The national mean temperature for summer was 0.73 °C above the 1961–1990 average, however the maximum temperature deciles in the Murray–Darling Basin were below average to the east and above average in the south-west.

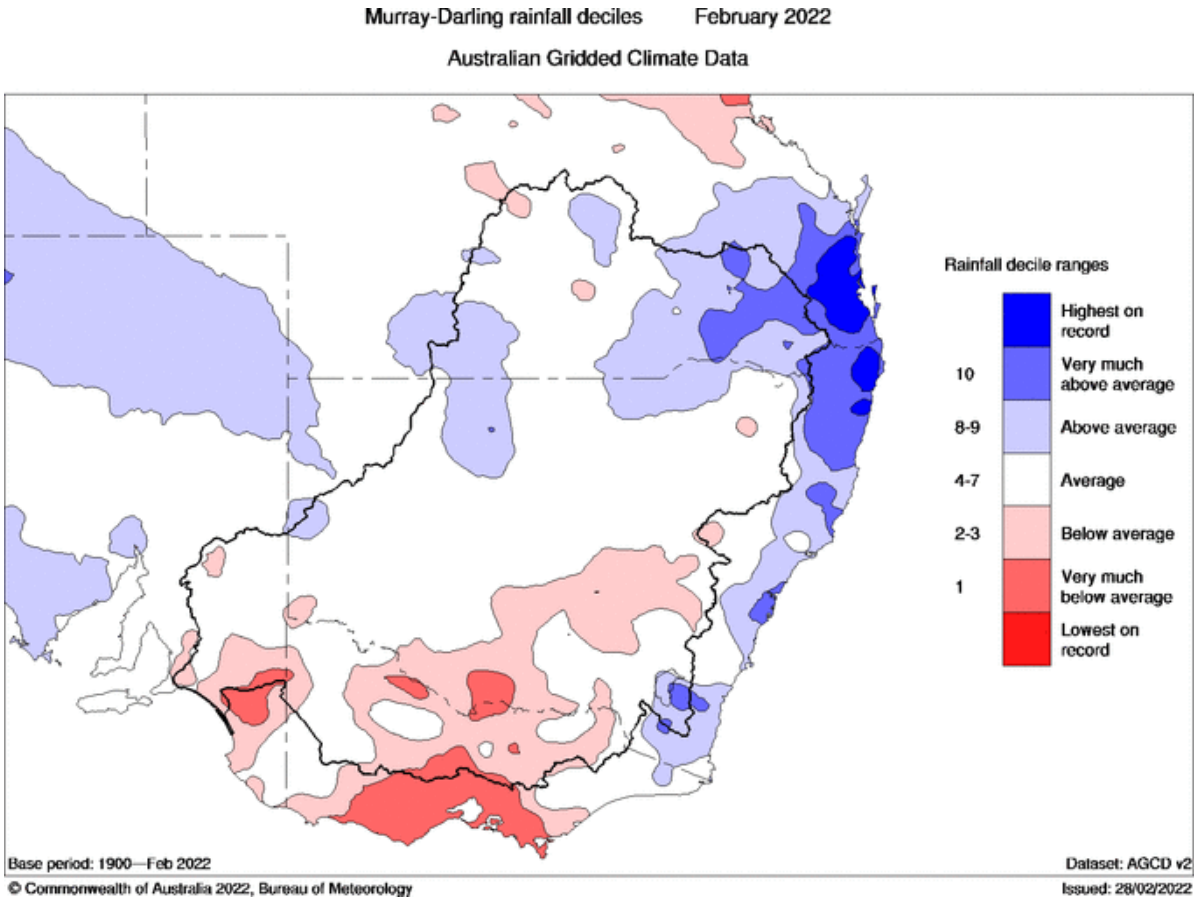


Figure 30: Murray–Darling Basin rainfall deciles for February 2022

River Murray system inflows for February 2022 (excluding Snowy, Darling, IVT and environmental inflows) were around 500 GL (2% Annual exceedance probability), driven mainly by continuing catchment outflow from heavy rain during January.

February began with Hume Dam storage at 99% following heavy rain late in January. Regulated releases to supply downstream demands began on 4 February as inflows receded. Downstream at Yarrawonga Weir, the Hume Dam airspace releases combined with elevated tributary inflows from the Ovens and Kiewa Rivers to generate a peak release of 26,000 ML/day on 2 February. Additional Barmah–Millewa Forest regulators were opened to manage river levels through the Choke as the elevated flows moved downstream. As the high flows subsided, forest managers managed a gradual closure of most forest regulators.

Yarrawonga releases returned to the regulated target of 8,500 by 8 of February. This included the delivery of water for the environment to slightly boost flows during February. During this period, several smaller regulators remained open to the Barmah–Millewa Forest to support critical water bird nesting habitat.

On the Murrumbidgee River, inflows to the Murray also started to decrease. Since July 2021, elevated flows from the Murrumbidgee River had driven broader River Murray system operations and persistent unregulated flow conditions downstream. By the end of February, flows had reduced to around 3 GL/day with a forecast for flows to fall away to an environmental water order target rate during March.

On the Darling River system, the flow just upstream of the Menindee Lakes at Wilcannia peaked on 16 February 2022 and the total lake storage reached the full supply level (1,730 GL) on 19 February 2022. By the end of February, the lake storage was continuing to rise, but as the inflows receded the lake level was expected to peak in the first week of March. WaterNSW closely monitored the upstream flows to manage the releases from the Menindee Lakes storage, so that inflows could be safely captured and stored at levels no higher than the Maximum Induced Surcharge Level (MISL) of 2,039 GL. In addition to managing inflows, WaterNSW alongside other agencies undertook operations to reduce the effect of Blackwater coming down the system **(Box 3)**.

BOX 3 – Managing hypoxic water at the Menindee Lakes

The high flows continuing down the Darling River had mobilised large amounts of organic material from the floodplains. The breakdown of this material caused dissolved oxygen (DO) levels to drop along the river below critical levels for fish health. Although this is a naturally occurring process in Australian rivers, it can also lead to fish deaths if better aerated refuges are not easily accessible for fish to move to.

Agencies and scientific experts work together to continually monitor the dissolved oxygen levels throughout the Barwon-Darling River system and advise the best operational measures at the Menindee Lakes to mitigate the risk to aquatic life as low DO water arrives from upstream. Operational options include transferring water between the lakes to mix the low dissolved oxygen water with better quality water, adjusting the timing, size and location of releases from the Lakes into the lower Darling to mix the water quality in the main river and provide refuge areas of better-quality water.

Box 3: Water quality event at the Menindee Lakes.

Around February 11, WaterNSW began to reduce the release at Weir 32 from 18,000 ML/day to 9,000 ML/day. This flow rate was maintained until the end of February. At the Lake Cawndilla outlet,

releases to manage storage airspace into the Great Darling Anabranch were also wound back over a week to a rate of 150 ML/day by the end of February. However, Environmental Water Holders were planning a potential water order for Lake Cawndilla releases in the range of 100 to 500 ML/day starting during March 2022, which was likely to be maintained until at least the end of autumn 2022. In addition, further significant rain and resultant inflows from the northern Basin would be likely to require a return to airspace management releases.

Noting the dynamic state of inflows and operations at the Menindee Lakes, the MDBA maintained its involvement in the *Lower Darling River Operations Stakeholder Consultation Committee (ROSCCo)*, coordinated by WaterNSW. This enabled the MDBA to update the community on current operational considerations in the River Murray and evolving plans for releases into the lower Darling River.

Following Victoria's mid-February water availability announcement, Victorian Murray low reliability water shares (LRWSS) increased to 100% allocation. Since the introduction of the current entitlement products in 2007, the last (and only) time there was a low reliability allocation at this time of year was in 2017 (5% allocation).

By the end of February, storages remained exceptionally high for this time of the year (**Figure 31**). Total active storage remained around 95% with Dartmouth reservoir holding around 3,580 GL (93%), Hume reservoir at 2,838 (95%), Lake Victoria sitting at 554 GL (82%) and the Menindee Lakes surcharged at 1,908 GL (110%).

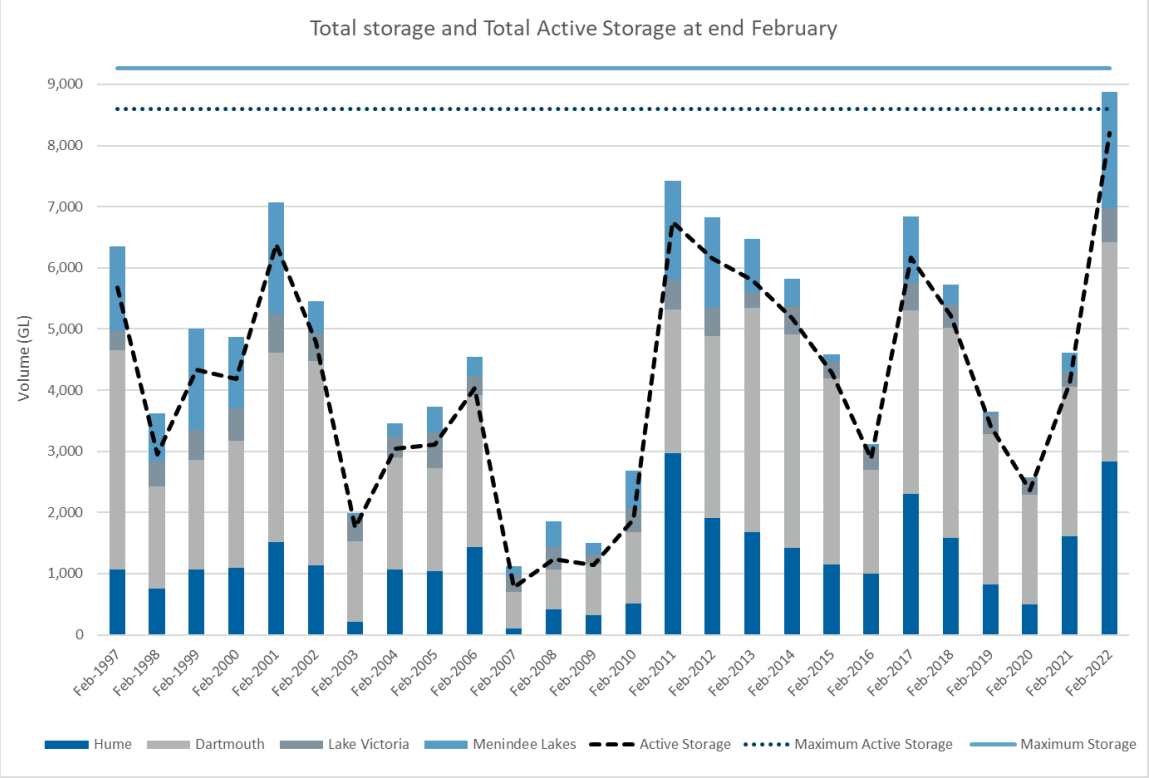


Figure 31: Total storage (solid lines) and total active storage (dashed lines) at end February over the previous 25 years.

Additional Dilution Flow (ADF) to South Australia continued to be triggered. The unregulated flows into South Australia meant that no additional releases from storages were needed to meet ADF during February, which had been the case since ADF was triggered during August 2021.

With more typical summer conditions forecast in the short-term, Hume storage was expected to continue falling into autumn. This would see the downstream flood risk ease further in the short-term. However, with the relatively high storage level in both Dartmouth and Hume Dams, the likelihood of airspace management (or 'pre-releases') taking place by the coming winter-spring was relatively high. This potential was likely enhanced by the fact that the BoM three-month rainfall outlook indicated an increased chance of rain exceeding median across autumn. River operations planning therefore had a focus on the potential need for and timing of airspace releases and preparation for flood operations in the coming months. Concerns about the potential for high dam levels and flood risk in the coming winter-spring had been raised by local community members and would be a focus of river operations communication efforts in the coming months for both the Murray and lower Mitta Mitta Rivers.

Quarter Four

The primary focus for River Murray Operations' activities for quarter four (Q4) was to balance continuing wet conditions and elevated inflows whilst continuing to ensure water availability was maximised for all water users.

The BoM reported for the Murray–Darling Basin, autumn brought an average of 176 mm of rainfall, or the 10th wettest autumn from 123 years of history. This was in part driven by persistent heavy rainfall during March that also resulted in catastrophic and widespread flooding across coastal New South Wales, and parts of south-east Queensland at the end of March.

This 'autumn break' combined with easing irrigation demands, meant towards the end of Q4, RMO commenced small airspace management releases from Hume Dam. The decision to release water then, with the dam around 90 percent full, was in line with the rules set by Basin governments for dam management. The MDBA cannot make releases to create additional airspace unless there is a very high likelihood the dam will fill before demand exceeds inflow.

Like much of the water year, storage spills and unregulated inflows from the Murrumbidgee and Barwon-Darling systems meant unregulated flows on the Murray persisted through until the end of autumn. During May, WaterNSW had indicated the Menindee Lakes system was forecast to receive additional inflows of around 1,150 – 1,550 GL expected by the end of July. This led to a revised release plan to increase the flow at Weir-32 to target 23,000 ML/day and held for some weeks. This flow, in addition to that already on the Murray, meant flows to South Australia would be above 30,000 ML/day as winter arrived.

During Q4, water quality issues at Hume Dam continued to persist. This required operational changes to the release outlet configurations to improve dissolved oxygen levels. By early April, water quality monitoring had indicated that the storage was beginning to de-stratify and over the coming month, the release outlet configuration was progressively transitioned back to default arrangements that allowed full use of the power station.

By the end of Q4, the BoM was forecasting winter rainfall was likely to be above median for much of the Basin, with indications of an 80% chance or more of exceeding median rainfall for much of the River Murray system, but a lower chance for areas in the far south. Moving into winter, with most storages spilling and others quite full, a key focus for RMO was on the potential further need for and timing of airspace releases and preparation for flood operations.

Key achievements for Q4

All 2021–22 state water orders were met. This is a significant achievement that the MDBA endeavours to accomplish each year and was achieved despite multiple uncertainties and variables across the River Murray System.

Achievement of good outcomes at Lake Victoria by managing the lake in accordance with the LVOS, whilst meeting the end of May 350 GL storage target, in a year that saw mostly unregulated flows to South Australia.

Successful management of water quality issues at Hume Dam, that through adaptive management saw no significant water treatment issues for Albury City Council or North-East Water, while providing improved conditions for downstream aquatic animals.

Key external drivers influencing operations in Q4

Adaptability of operational activities to constantly changing inflow patterns was key during the autumn of 2022. River Murray Operations recognised two **Key Drivers** that would shape the fourth quarter.

- **Key Driver 1 – "Continuing wet conditions and elevated inflows"** – Autumn brought persistent rainfall across much of the Murray–Darling Basin, with above average conditions experienced across most of the River Murray system aside from some areas in north-east Victoria/south-east NSW and western South Australia. In response, systems inflows for autumn were around 976 GL, or 26% annual exceedance probability. High rainfall across the northern Basin meant that renewed inflows to the Menindee Lakes continued throughout Q4, driving additional releases from the Lakes to maintain airspace consistent with relevant operating rules and procedures. Additionally, the wet conditions and easing demands meant Hume Dam ceased its drawdown at a relatively high level around mid-April and then began re-filling during the second half of autumn. In response, pre-releases from Hume Dam were commenced around mid-May. These releases aimed to maintain airspace to buffer against large rain events and reduce the risk of flooding over the coming winter-spring, whilst ensuring filling requirements could be met with very high confidence later in the season.
- **Key Driver 2 – "Continuing unregulated flows and reaching the target level at Lake Victoria"** – Although drier conditions during April meant flows from the Murrumbidgee River reduced through the month, by May airspace releases had begun again at Blowering and Burrinjuck dams. Resulting in flows at Balranald remaining well above the end of system target and contributing to unregulated flows on the Murray. Furthermore, flows on the lower Darling at Weir 32 averaged around 10,500 ML/day during Q4, further driving unregulated flows along the Murray. Despite the high flows, RMO was able to manage inflows and outflows from Lake Victoria to draw down the storage successfully meeting the end of May target of 350 GL.

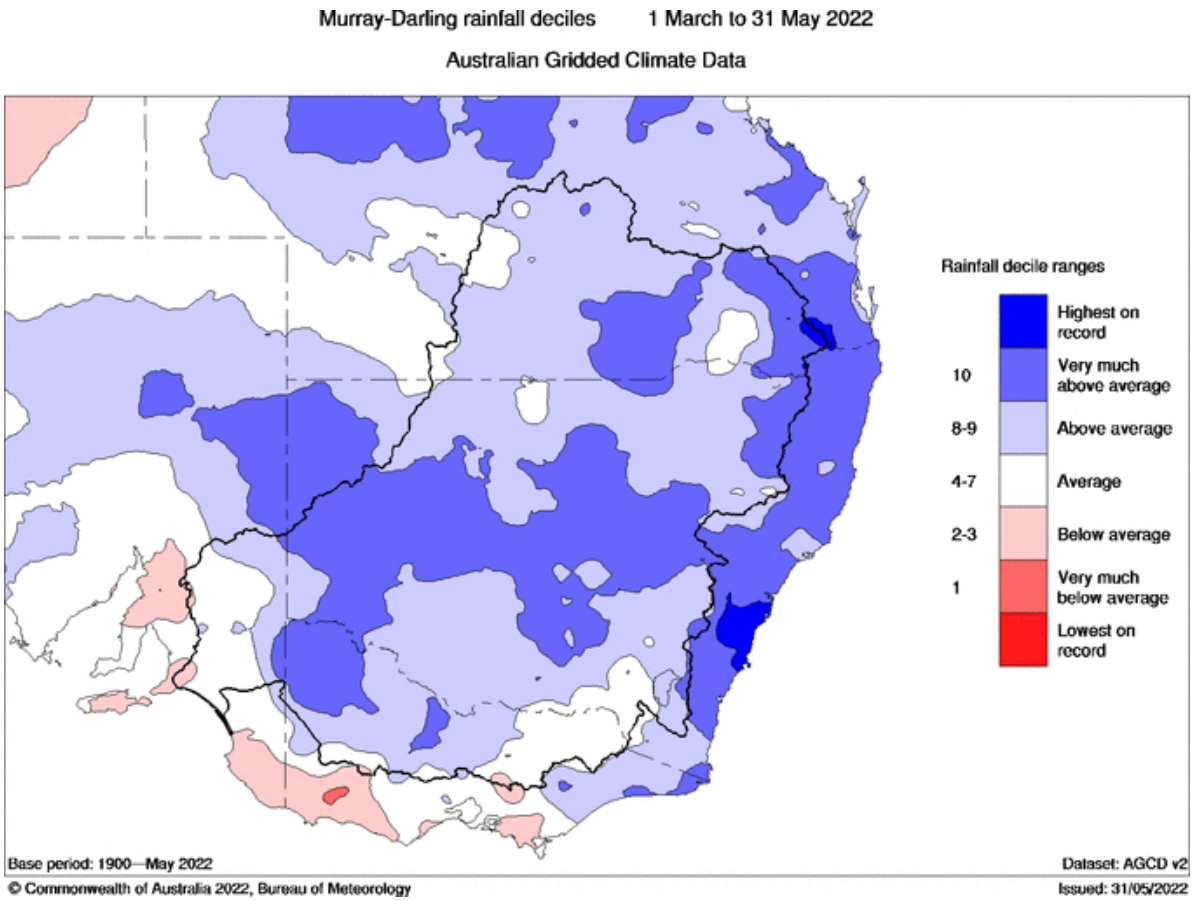


Figure 32: Murray–Darling rainfall deciles for Q4 show above to very much above average rainfall across much of the Murray–Darling Basin, with 'highest on record' rainfall for parts of the Condamine catchment in the north-eastern Basin and average rainfall across the upper Murray catchements.

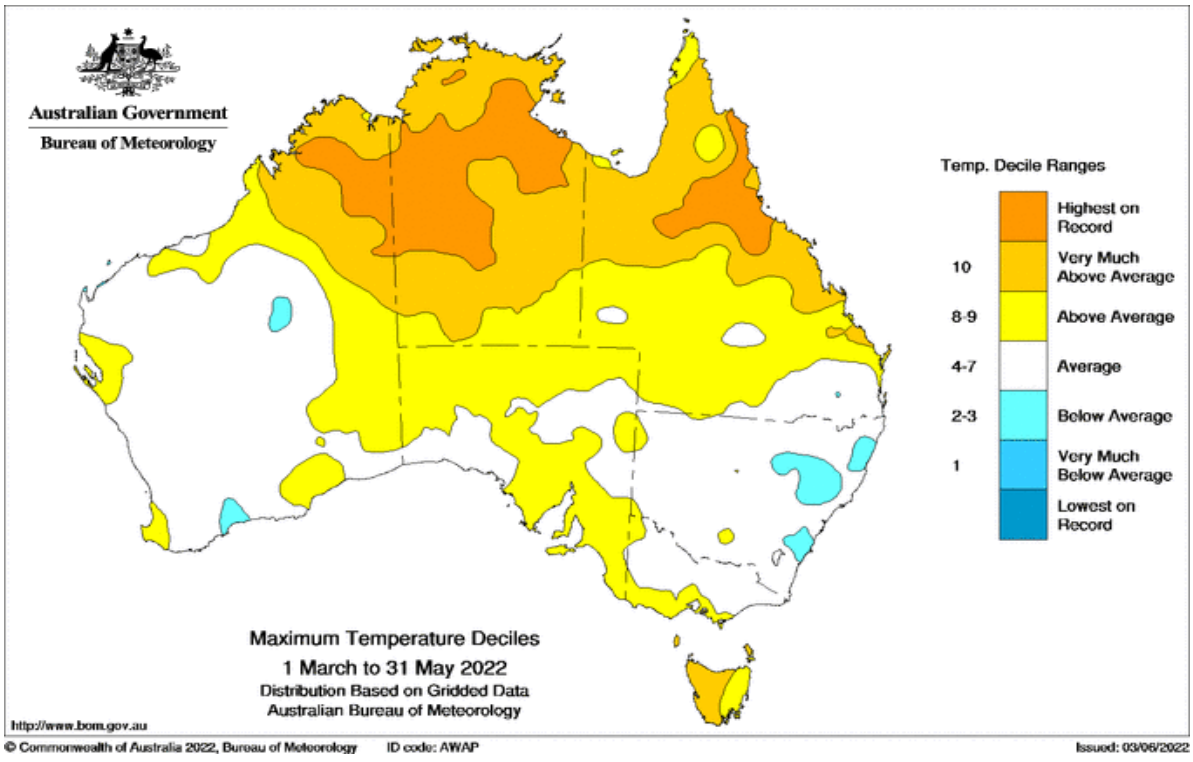


Figure 33: Murray–Darling maximum temperature deciles for Q4 show predominantly average temperatures for most of the River Murray System, with the South Australian Murray experiencing above average temperatures.

Key metrics for Q4

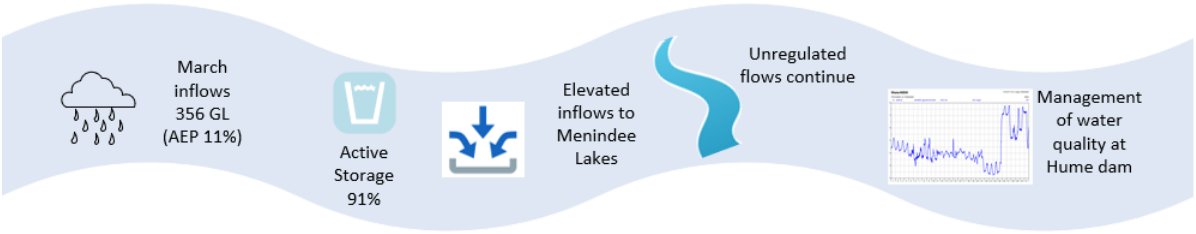
The operational metrics in **Table 7** provide a snapshot summary of river operations for Q4. All figures should be considered within the context of the key drivers outlined above.

Table 7: Key metrics for River Murray System operations during Q4.

Metric		Quarter Four [i]
Total River Murray System inflows [ii]		976 GL (26% AEP)
Storages	Net change at Dartmouth	↑ 31 GL with no system transfers required
	Net change at Hume	↓ 71 GL due to releases for downstream demands and airspace management (spill)
	Net change at Lake Victoria	↓ 196 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS)
	Net change at Menindee Lakes	↑ 74 GL due to management of the Menindee Lakes
Storage releases	Dartmouth Releases	61 GL comprising AGL entitlement releases (power generation) and minimum releases
	Hume Releases	647 GL comprising releases for downstream demands, airspace management ('pre-release' spill) and delivering water for the environment
	Lake Victoria Net Releases [iii]	175 GL due to the management in accordance with the LVOS during unregulated flows.
	Menindee Lakes Releases	961 GL released to the lower Darling River comprising operational releases, including airspace management (spill). 141 GL released to the Great Darling Anabranch for airspace management (spill)
	IVT	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		288 GL Victorian Murray 411 GL NSW Murray
River Murray System loss [v]		141 GL
Environmental directed releases from Hume [vi]		0.5 GL
Flow to SA	Total SA Flow	2,041 GL
	Dilution & Loss	174 GL
	Entitlement Flow	240 GL
	Consumptive trade deliveries	38 GL
	Environmental water deliveries [vii]	184 GL
	Rolling Adjustment [viii]	1,404 GL due to unregulated flows and additional dilution flows (276 GL).
Publication of operational information		13 MDBA Weekly Reports 6 Media Releases on 'river operations' 1 video briefings on Hume Dam operations Basin in Brief/Flows in the River Murray System

i. Values are provided from the River Murray System accounts at the point of time the quarterly report is written and considered as operational data. Updates to input data including changes to rating tables as well as other data changes because of hydrometric updates may result in the numbers in the above table changing.
ii. River Murray System inflows include unregulated inflows to Dartmouth, Hume and from the Kiewa, plus inflows from the NSW and Victorian tributaries excluding environmental water deliveries and IVT as well as Menindee when not part of the shared resource.
iii. Lake Victoria Net Releases refers to the net volume between inflows and outflows.
iv. Sourced from River Murray System accounts, includes all consumptive deliveries and Lindsay River allowance for Victoria.
v. River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific watering actions and losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria and Menindee Lakes System (when part of the shared resource). Note: this is an interim loss value – refer footnote (i).
vi. Sourced from River Murray System monthly environmental accounts.
vii. South Australian Environmental use – includes all environmental water that flows into South Australia.
viii. Includes changes due to rating table upgrades or subsequent hydrometric updates as well as unregulated flow and Additional Dilution Flow (ADF) whenever these occur.

March 2022



The Bureau of Meteorology (BoM) reports that for March 2022 rainfall was average to above average across much of the Murray–Darling Basin (**Figure 34**). Above average rainfall was recorded in south-east Queensland's Darling Downs districts, in New South Wales along the slopes and ranges, the central north, parts of the Riverina and the lower western districts, and across much of Victoria.

Across the Basin as a whole, the BoM reported an area-average rainfall for the Murray–Darling Basin in March totalling 47.8 mm. This is 12% above the long-term average for the Basin.

River Murray system inflows for March (excluding Snowy, Darling, IVT and environmental inflows) were around 356 GL, which is well above the month's long-term median of 148 GL. In comparison with the historical record since 1891, only about 11% of previous monthly totals for March have been higher than the inflows observed in March 2022.

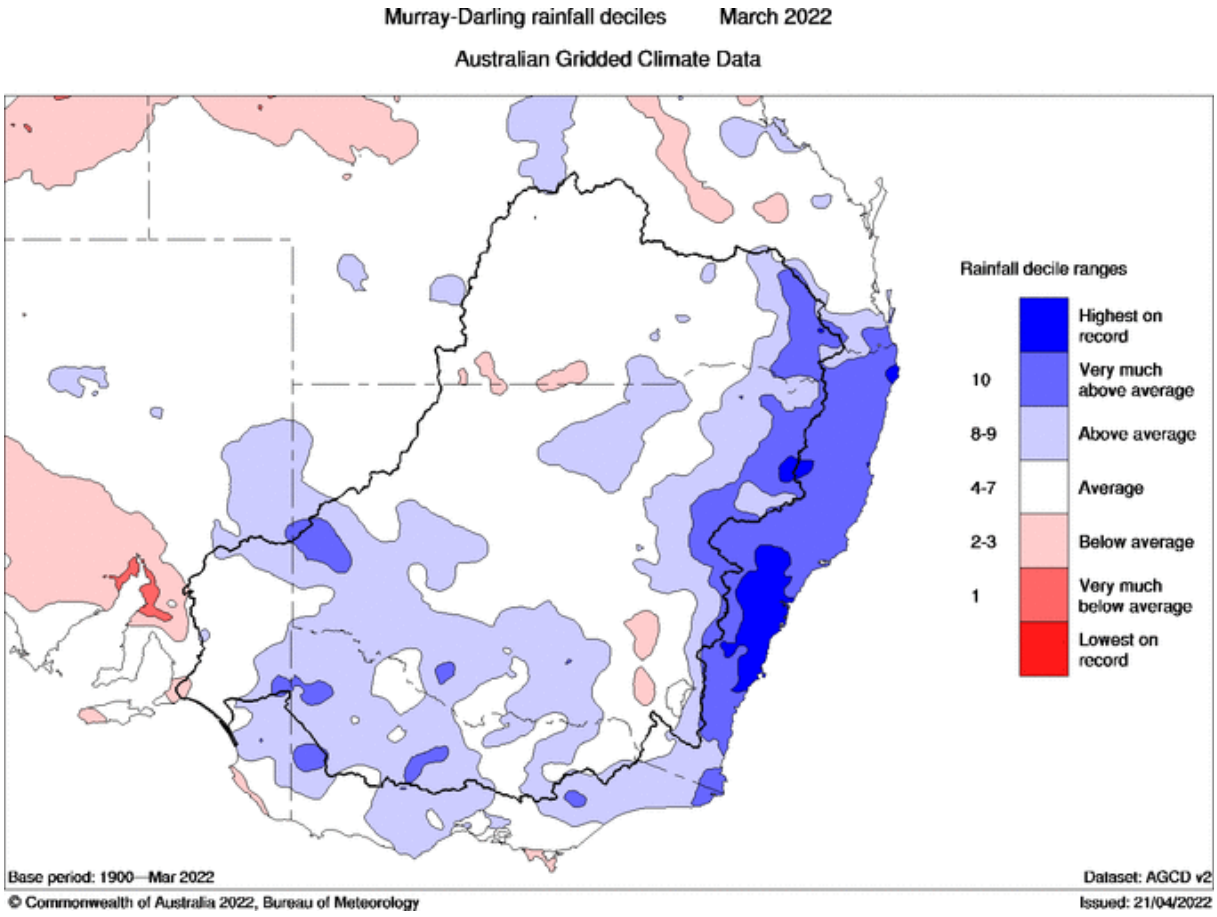


Figure 34: Murray Darling rainfall deciles for March 2022 shows rainfall was average to above average across much of the Murray–Darling Basin.

The month of March began with the return of wet conditions. The north-eastern fringe of the Basin recorded falls of more than 200 mm due to the intense rain system that generated destructive flooding along the Queensland and New South Wales coastal catchments pushing over the Great Divide. Rain fell over the Upper Murray catchments in early March. This generated a modest inflow response but also this caused a reduction in downstream demands with Hume Dam releases wound back in response.

Throughout March, water quality issues including low dissolved oxygen levels downstream of Hume Dam remained. This required an adaptive response and a number of changes to the release outlet configuration to improve dissolved oxygen levels and help aquatic animals downstream of the dam to breathe.

During March, operators trialled a variety of configurations to optimise the approach in response to water quality observations and discussions among stakeholder agencies and water quality experts. Adjustments were made dependant on the impacts of water storage chemistry and physical processes that affect a range of water quality indicators, including oxygen levels and other naturally dissolved compounds. During March, a suitable outlet combination was found using releases through the power station and cone valves at the base of the dam wall with occasional use of the gated spillway. By undertaking these actions, dissolved oxygen levels were maintained above the critical threshold required for aquatic animal survival, whilst also assisting North-East Water and Albury City Council with their water treatment processes.

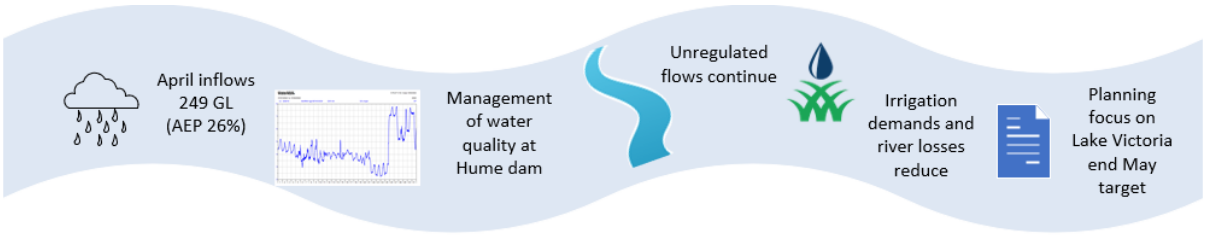
Further down the system, Torrumbarry weir pool was raised back to full supply level during March. The weir was lowered for over a month to help determine if a drawdown could reduce the rate of erosion and notching during summer (a period coinciding with peak boating activity, hot weather and desiccated dispersive bank sediments), compared to maintaining the weir pool at FSL.

On the Murrumbidgee river, flows measured at Balranald continued to build during the month in response to wet conditions. By the end of the month, flows had risen from a low of near 2,500 ML/day to around channel capacity at 8,000 ML/day. During March, releases from Hume Dam to the Murrumbidgee junction were regulated, however, elevated flows downstream of the Murrumbidgee junction continued to drive unregulated flows in the lower reaches of the system.

In the Barwon-Darling system, March began with decreasing inflows to the Menindee Lakes storage. In response, WaterNSW looked to continue reducing the releases from Weir 32 to capture as much water in the storage as operationally practical in the event that inflows continued to recede. As such, releases reduced from a high of 9,000 ML/day to 6,000 ML/day over the month. However, renewed northern Basin rainfall during the month had soon generated further tributary inflows that were forecast to bring about 450 - 750 GL into the Menindee Lakes by the end of May. The plan by the end of March was to extend the period of releases at 6,000 ML/day for an additional 5-6 weeks. From the second week of May, if forecast inflows did not increase, the releases would then be gradually reduced to about 500 ML/day in accordance with minimum release requirements.

RMO is required to operate Lake Victoria in accordance with the Lake Victoria Operating strategy. Under this strategy, commencing in February, Lake Victoria is to be drawn down over the coming months. As such, during March, releases into and out of the lake were managed to draw the storage down from 81% to 68%.

April 2022



The Bureau of Meteorology (BoM) reports that for April 2022 rainfall was average to above average across much of the Murray–Darling Basin (**Figure 35**). Rainfall in the upper Murray catchment was mostly around average. Across the Basin the BoM reported an area-average rainfall for the Murray–Darling Basin in April totalling 53.9 mm. This was 40% above the long-term April average.

River Murray system inflows for April (excluding Snowy, Darling, IVT and environmental inflows) were around 250 GL, which is well above the month's long-term median of 164 GL. In comparison with the historical record since 1891, only about 26% of previous monthly totals for April were higher than the inflows observed in April 2022.

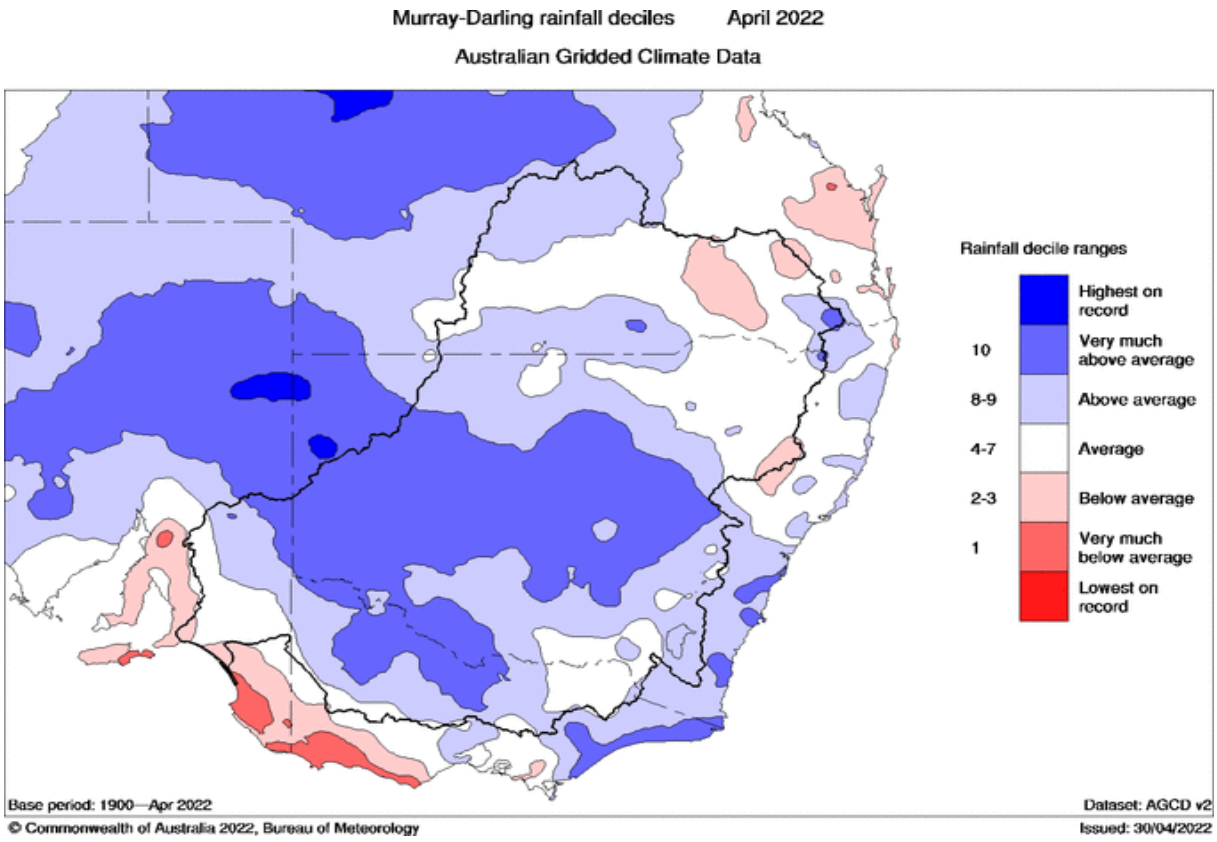


Figure 35: Murray–Darling rainfall deciles for April 2021 showing above average rainfall conditions being expereinced for much of the Basin.

At the beginning of the month, a deep low-pressure system off the southern coast of New South Wales and a high-pressure system centred south of South Australia funnelled a moist south-to-south-easterly flow over south-eastern New South Wales and eastern Victoria that brought rainfall across both the upper Murray catchments and then further inland over irrigation areas.

In response irrigation demands were supressed across the River Murray system leading to reduced releases from Hume Dam. The volume of water stored in Hume Dam started to level off following many weeks of drawdown to supply autumn demands. By the end of the month, releases were expected to reduce close to minimums for the remainder of the irrigation season, with Hume storage forecast to gradually increase into May with further rainfall.

During early April, monitoring by WaterNSW suggested that dissolved oxygen levels within Hume Dam were beginning to improve. This was because the water column had mixed or 'de-stratified', in response to cooler minimum air temperatures and windy conditions over previous weeks (**see Figure 36 vs Figure 37**). Stratification is a well-known process in dams where, during summer, a warmer layer of water develops within the storage sitting above a cooler bottom layer with relatively little mixing between the two layers. In response to the mixing of the lake during April, the release configuration was gradually adjusted to favour releases for hydro-power generation.

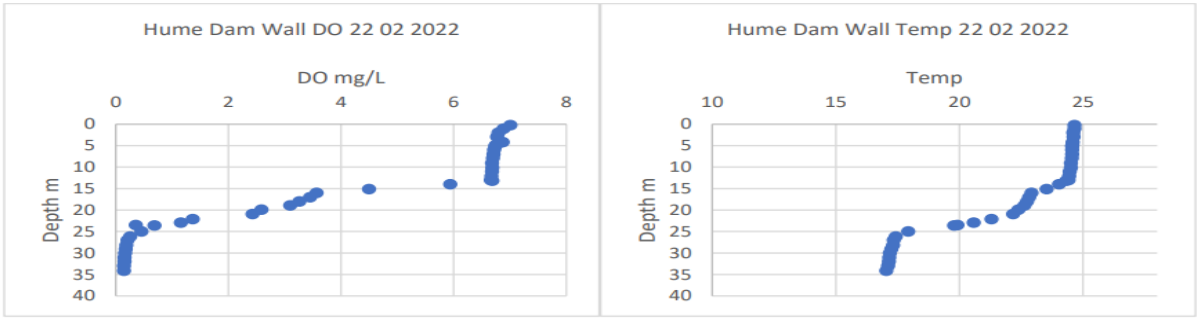


Figure 36: Temperature and oxygen profiles recorded on 22 February at Hume Dam wall sample site. The data shows a warmer, oxygenated surface layer down to about 15 metres depth, sitting above a cooler, low oxygen bottom layer. Data courtesy of WaterNSW.

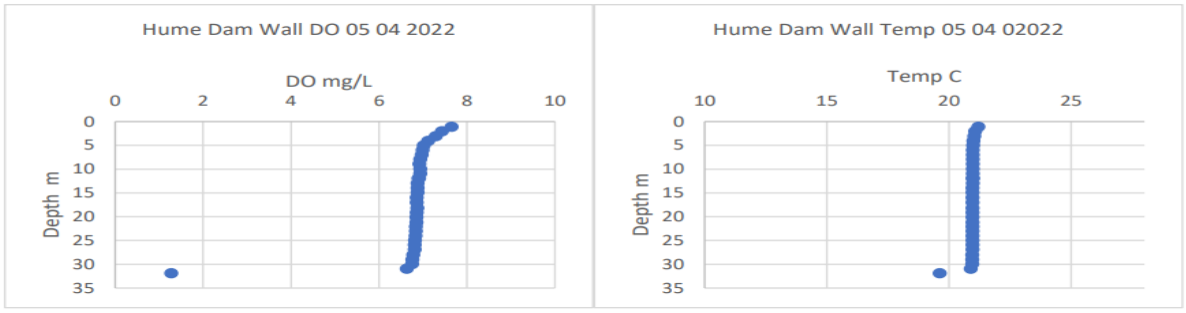


Figure 37: Temperature and oxygen profiles recorded on 5 April at Hume Dam wall sample site. The data shows the storage had de-stratified with warmer, oxygenated water reaching below 30 metres toward the bottom of the storage. Data courtesy of WaterNSW.

At the beginning of the month releases from Hume Dam were being managed to deliver system requirements, including meeting minimum flow requirements at Swan Hill. Further rain during mid-April meant that demands downstream of Yarrawonga weir continued to reduce. In response, RMO would have typically looked to further reduce the downstream flow to ensure efficient operations. However, due to possible water access issues at Bullatale Creek, with the forecast low water levels, WaterNSW requested the MDBA to maintain higher flows (accounted as NSW resource) for a few days to ensure customers in that reach of the river would be able to access water.

Following a relatively wet and cool March and early April, the MDBA urged water users and visitors to monitor River Murray flows heading into the mid-April Easter holiday period. With continuing

higher inflows to the River Murray from the Murrumbidgee and Darling rivers, this reduced the water needed from Hume Dam to meet demands in the lower system, including flow to South Australia. Without further rainfall across the upper catchments, inflows from the Murrumbidgee River continued to fall from 8,000 ML/day to 2,500 ML/day by the end of the month. These reducing flows meant lower flows in the Murray between the Murrumbidgee junction and the junction with Darling River, during a period coinciding with Easter and the school holiday period.

During April, updated WaterNSW forecasts indicated the Menindee Lakes system were likely to receive a further 600 - 1,000 GL of inflow (by the end of June) due to additional rainfall across the northern Basin, a significant increase compared to earlier forecasts. As such, WaterNSW adjusted its release plan to increase to 9,000 ML/day at the middle of the month and further increase to 12,000 ML/day by the end of the month. In addition, releases from the Lake Cawndilla outlet continued at 1,800 ML/day for the next nine weeks providing positive environmental outcomes in the Great Darling Anabranch.

As the month progressed, unregulated flows along the lower Darling system and Murrumbidgee system, alongside a reduction in losses and demands, meant flows increased above operational requirements along the mid and lower Murray. As such, unregulated flows became available in the River Murray from Torrumbarry weir downstream to the South Australian border.

During the month, Lake Victoria continued to be drawn down in accordance with the LVOS, with the storage finishing the month at near 53%. Due to the elevated flows across the system and continued drawdown of Lake Victoria, this meant flows to South Australia averaged over 20,000 ML/day for the month.

By the end of April, the BoM reported a climate outlook that predicted May to August rainfall was likely to be above median for most of Australia (**Figure 38**), with the La Niña remaining active in the tropical Pacific but gradually weakening.

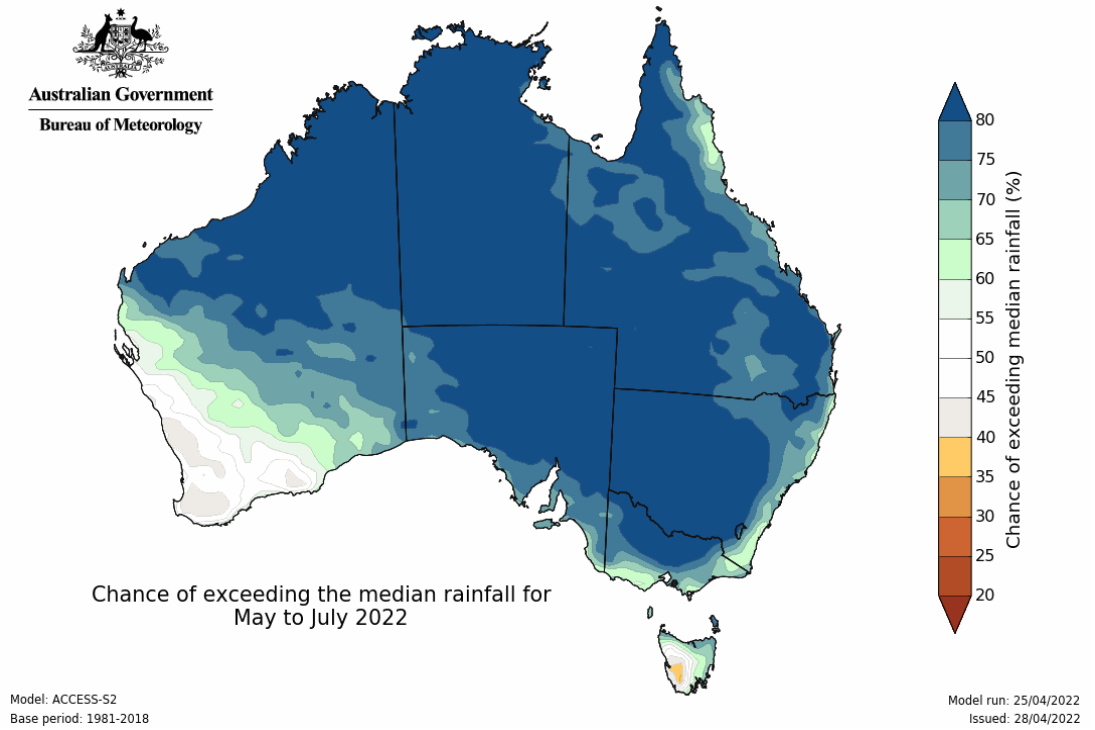
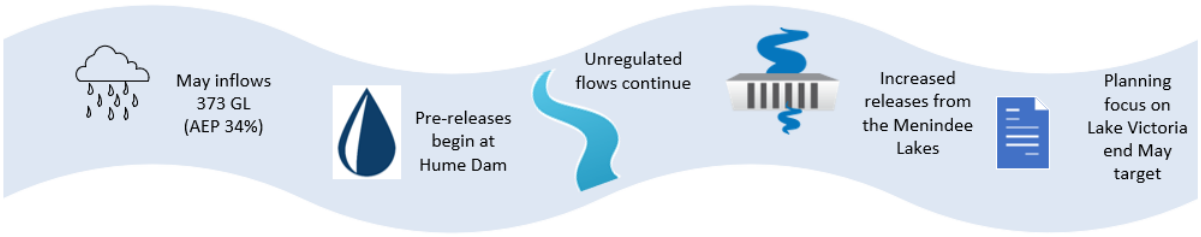


Figure 38: Chance of exceeding the median rainfall for May to July 2022.

May 2022



May area-average rainfall across the Murray–Darling Basin as reported by the BoM was 70.3 mm, 59% above the long-term May average. Rainfall was average to very much above average across much of the Murray–Darling Basin, with nearly all the northern Basin experiencing above or very much above conditions. Whereas much of the River Murray system experienced average conditions with the most southern parts of the Basin receiving below average May rainfall (**Figure 39**). River Murray system inflows for May (excluding Snowy, Darling, IVT and environmental inflows) were around 373 GL, which is well above the month's long-term median of 276 GL.

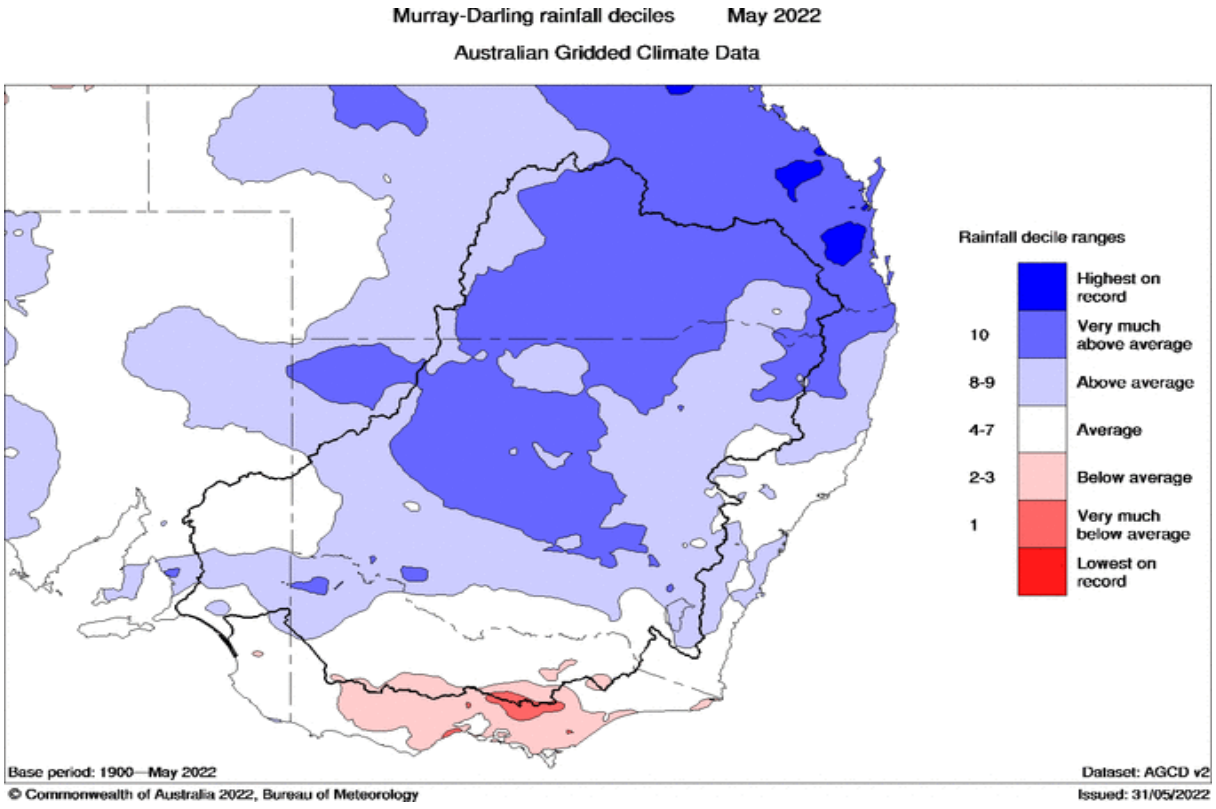


Figure 39: Murray–Darling rainfall deciles for May 2022.

In response to the continuing wet conditions and cooler temperatures, May began with a continued reduction to irrigation demands. In response, releases from Hume Dam were reduced back to the minimum of 600 ML/day by the second week in May.

The low releases from Hume Dam also helped with the management of Lake Mulwala, which, after extensive consultation with the local community, landholders, and businesses, began a winter weir pool drawdown from early May 2022 to facilitate waterweed control. Lowering the lake provides the best means of controlling the highly invasive waterweed *Egeria densa*, whilst also allowing other

maintenance work to be completed around the lake shore. Lowering Lake Mulwala in this way is necessary approximately every 3 to 5 years depending on the growth and extent of Egeria within the lake. To kill the waterweed, the drawdown seeks to expose it to the air and winter frosts which is achieved with a drawdown of about 5 metres below operating level and holding that level for about a month. Furthermore, GMW and other members of the lakeside community can use this opportunity to carry out maintenance works and inspections, including under and around the bridge and bridge pylons, as well as lake retaining wall works and erosion repairs. The lake was planned to be brought back to its regular operating level by early August in preparation for the irrigation season.

By 13 May, Hume Dam releases began to increase above the minimum rate of 600 ML/day as RMO commenced 'pre-releases' to manage airspace and help mitigate flood risks due to possible wet conditions over the approaching winter-spring. The decision to begin airspace management, with the dam around 90%, was commenced in line with the rules set by Basin governments for airspace management (**Box 4**).

The MDBA cannot make releases for the purpose of airspace management without a very high level of confidence the dam can subsequently be filled to 99% capacity before downstream demands exceed inflows later in the season. To ensure high filling confidence, pre-release analysis and decisions must be based on a conservative forecast of demands and an assumed transition to 'serially correlated minimum' inflow conditions that are based on observed historic inflows 'serially correlated' with recently observed inflows to provide a realistic minimum. The transition to dry is assessed and informed by a combination of short-term rain forecasts and medium-term climate outlooks that influence catchment conditions and likely recession rates beyond any immediate rainfall forecast. Assumed inflows also factor in forecast releases from Dartmouth Dam as well as advice on potential releases from the Snowy Mountains Hydro-electric Scheme in coming months.

BOX 4 – Rules set by Basin governments for dam management during floods

The primary purpose of Hume and Dartmouth dams is water conservation with water storage being maximised during wetter periods as insurance against future drier times. During times of flood the MDBA operates both dams based on the following priorities (in priority order):

1. protect the structural integrity and safety of the dam, then
2. maximise water availability (i.e., fill the storage to at least 99% capacity prior to any ensuing drawdown to meet downstream needs), and then
3. limit flood damage to downstream communities and increase benefits to the environment and public amenity.

These priorities have been agreed by the Australian Government and the New South Wales, Victorian and South Australian Governments.

Box 4: Rules set by Basin governments for MDBA dam management during floods.

Release of water from Lake Mulwala alongside pre-releases from Hume Dam, meant flows downstream of Yarrawonga exceeded downstream channel (Barmah Choke) capacity during May. In response, RMO worked with the Barmah–Millewa forest managers to open regulators to allow water into the forests to help manage the higher flows.

At the same time as RMO commenced pre-releases for airspace management at Hume Dam, WaterNSW informed customers and community that airspace releases were increasing from Burrinjuck Dam in the Murrumbidgee River with WaterNSW targeting a storage level of around 80% by end of May. Additionally, WaterNSW continued to make airspace releases at Blowering Dam to target an airspace volume of 80 GL (a volume nominated by Snowy Hydro to respond to the needs of electricity market). In response to the increased storage releases, flows from the Murrumbidgee to the Murray measured at Balranald increased from a low of near 1,800 ML/day at the beginning of the month to back near channel capacity (9,000 ML/day) by the end of the month and MDBA water year.

During May, WaterNSW continued to vary the releases from the Menindee Lakes to manage the surcharged storage in response to a further increase in forecast inflows following additional rainfall in the Northern Basin. As such, releases were increased from the original plan of 12,000 ML/day up to 19,000 ML/day by the end of the month. By late May, WaterNSW advised customers and community that releases from the Menindee Lakes would be increased further to manage the storage volume and ensure water levels across the storage system remained below the maximum permissible induced surcharge levels. Based on updated flow forecasts, WaterNSW was forecasting the lake system would receive a further 1,150 – 1,550 GL additional inflow by the end of July. The revised release plan was adjusted to take releases at Weir-32 from 18,000 to a target of 23,000 ML/day, which was forecast to be maintained for at least 2-3 weeks. By the end of May, releases at Weir 32 had reached 19,500 ML/day with further increases expected in early June.

High inflows from the lower Darling and the Murrumbidgee system, plus rain and subsequent lower demands and conveyance losses, resulted in flows above operational requirements. As such, unregulated flows during May were extended along the whole River Murray, from Hume Reservoir downstream to the South Australian border.

As unregulated flows increased along the system, RMO continued to manage the inflows and outflows from Lake Victoria to operate the storage in accordance with the LVOS. This saw the storage drawdown to a low of 49% in late May before rising to reach the 350 GL end May target (**Figure 40**).

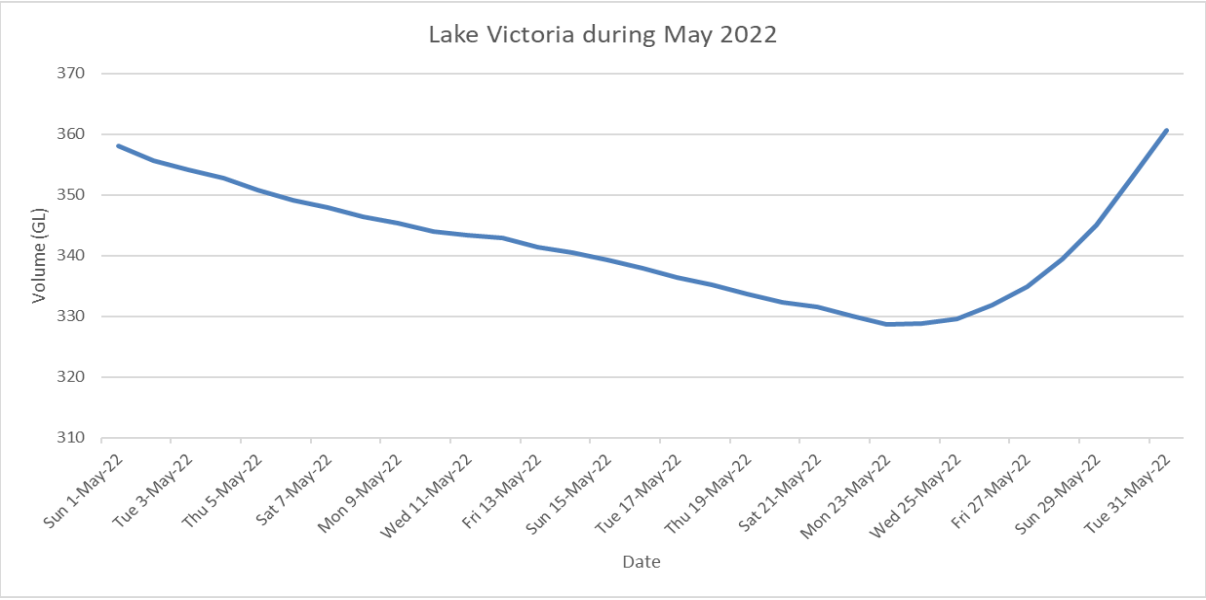


Figure 40: Lake Victoria storage volume during May 2022.

By the end of May, the BoM was indicating a higher likelihood of wetter than median conditions over winter. The factors influencing this outlook included:

- Increased chance of a negative Indian Ocean Dipole (typically, a negative IOD correlates with above average rainfall across much of southern Australia during winter and spring)
- continuing but weakening La Niña (whilst most climate models surveyed by the BoM indicated a return to neutral ENSO during the southern hemisphere winter, two of the seven models maintained La Niña conditions)
- warmer than average waters around northern Australia

On 1 June 2022, MDBA combined active storage was 8,027 GL. This is the highest start of June volume recorded since Dartmouth Dam was completed in 1979 (**Figure 41**). The previous highest volume was 7,572 GL in 2012. Combined active storage in Dartmouth and Hume reservoirs on 1 June 2022 was 6,391 GL, compared with the previous highest volume of 6,100 GL in 1993. There was also 1,467 GL of active storage held in the Menindee Lakes system available to meet Murray system demands, although around 200 GL of this volume is stored above the full supply level (FSL) and according to Menindee Lakes operating rules, any surcharge remaining above FSL on 31 October is to be gradually released to achieve a level at or below FSL by 31 December.

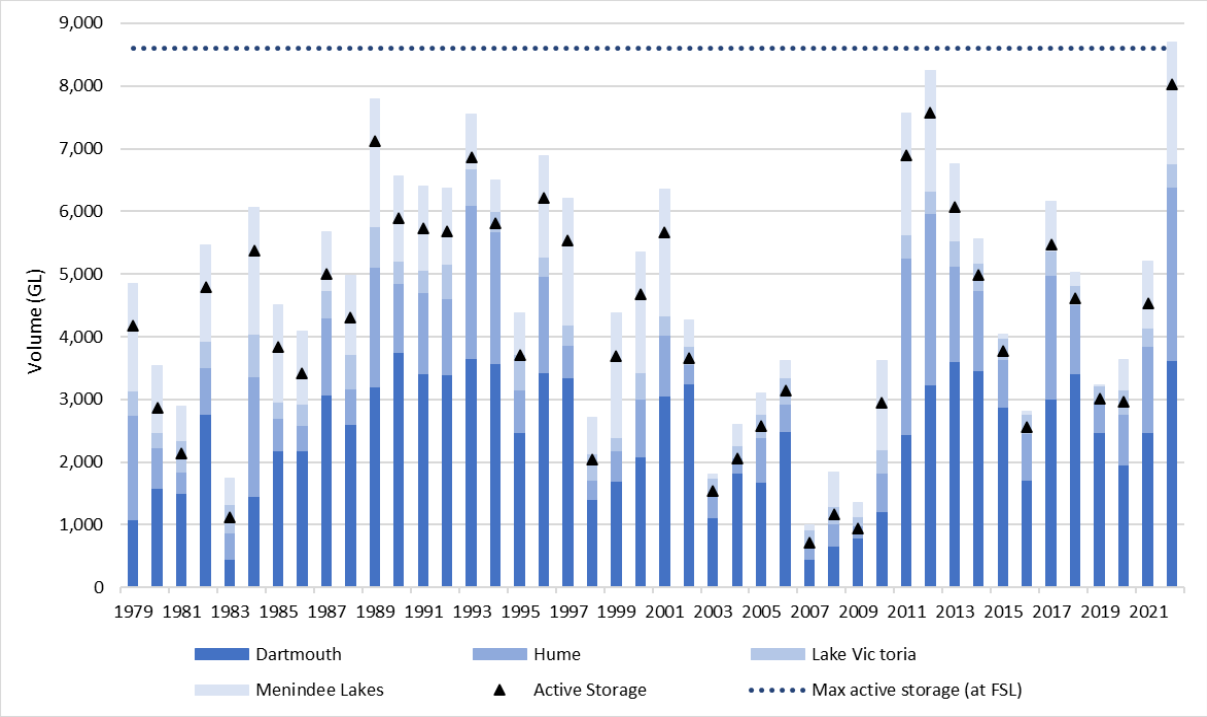


Figure 41: MDBA total water in storage (showing contribution from individual storages) and active storage as at 1 June each year since completion of Dartmouth Dam in 1979.

Additional Dilution Flow (ADF) of 3,000 ML/day above the required flow to South Australia was likely to continue to be triggered during winter and into spring of 2022. The trigger for delivery of ADF is a combined storage in Hume and Dartmouth Reservoirs exceeding 2,000 GL, and Menindee Lakes Storage volumes exceeding 1,650 GL in June and July, 1,500 GL in August and 1,300 GL in September to May.

State resource managers determine allocations and each published their outlooks for water availability in 2022–23. Information is available on the South Australian, Victorian and NSW Murray and lower Darling and NSW Murrumbidgee websites.

The water year in summary:

The beginning of June 2022 marked the end of the 2021–22 'MDBA water year' and the start of the 2022–23 water year for the River Murray system. While this is one month earlier than the states' water year, the MDBA operations water year was designed to facilitate water resource assessments that align with the state's water year, whilst also aligning with the commencement of the winter-spring period when tributary inflows increase, and headwater storages usually replenish. This allows the MDBA to report on system inflows, demands and storage levels across a 12-month period in a way that best matches the systems hydrological and demand cycle. An overview of the rainfall, temperature, inflows, and water in storage for 2021–22 is provided below.

Rainfall summary for 2021–22

For the 2021–22 water year, the Bureau of Meteorology (BoM) has advised that rainfall was above average across most of the Murray–Darling Basin (**Figure 42**). Rainfall across much of New South Wales and south-east Queensland was 'very much above average'. Isolated areas along the Great Dividing Ranges and in the upper catchments of the Murrumbidgee, Lachlan, Macquarie, Condamine, and Border rivers recorded their highest rainfall totals on record for this twelve-month period. Rainfall across much of southern Victoria, the South Australian Riverland and the lower lakes was around average for 2021–22, whilst a small area in southeast South Australia recorded below average rainfall.

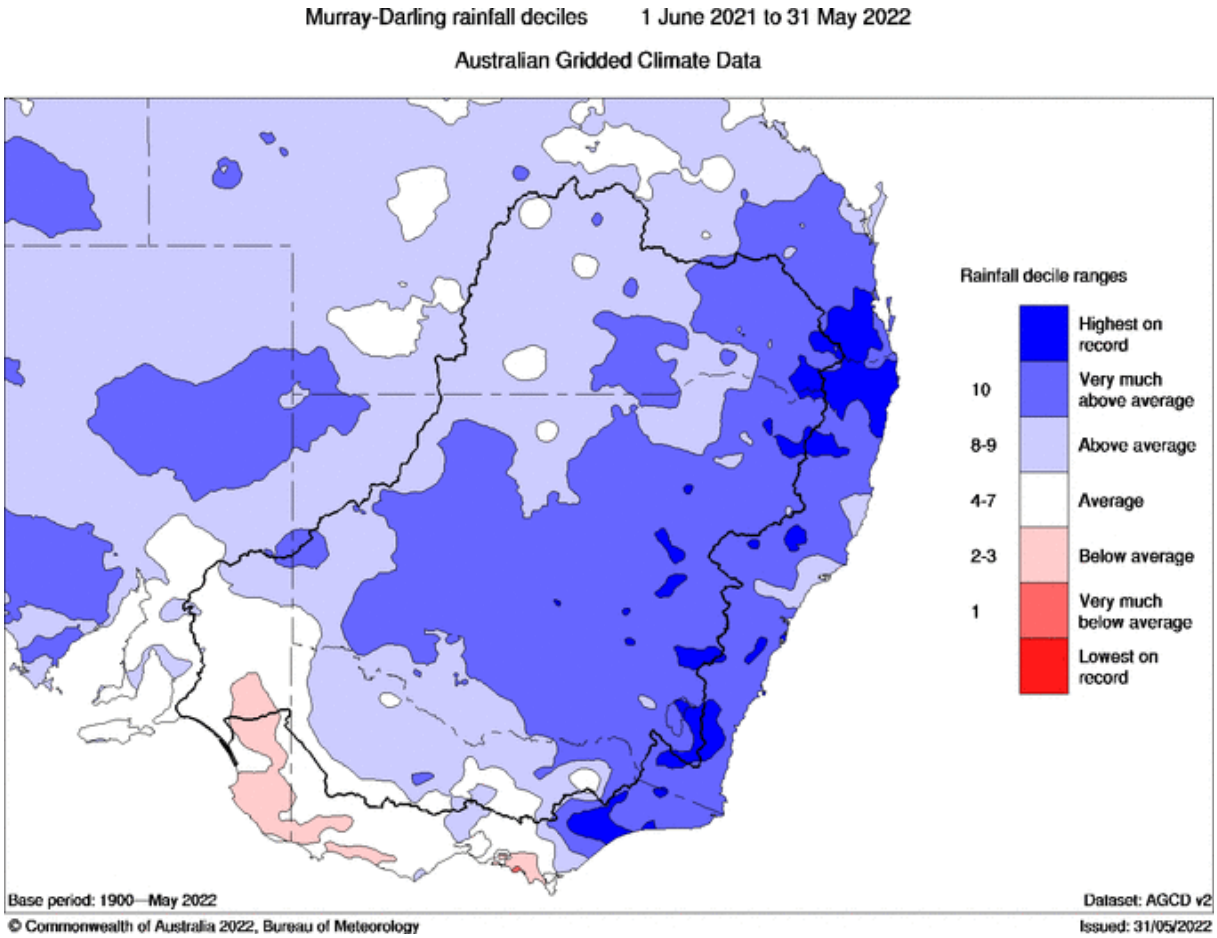


Figure 42: Murray–Darling Basin rainfall deciles from 1 June 2021 – 31 May 2022.

Temperature summary for 2021–22

Mean minimum temperatures for 2021–22 were warmer than average across much of the Basin (**Figure 43 & Figure 44**). Mean maximum temperatures were generally around average, although temperatures along the New South Wales slopes and ranges were cooler than average whilst western Victoria, south-east South Australia and western Queensland were warmer than average.

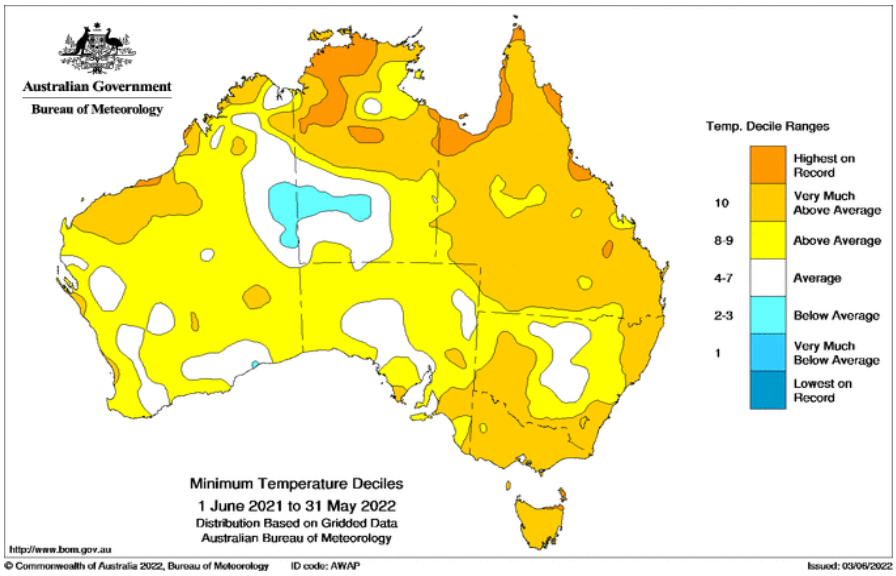


Figure 43: Minimum temperature deciles for Australia for the period 1 June 2021 to 31 May 2022

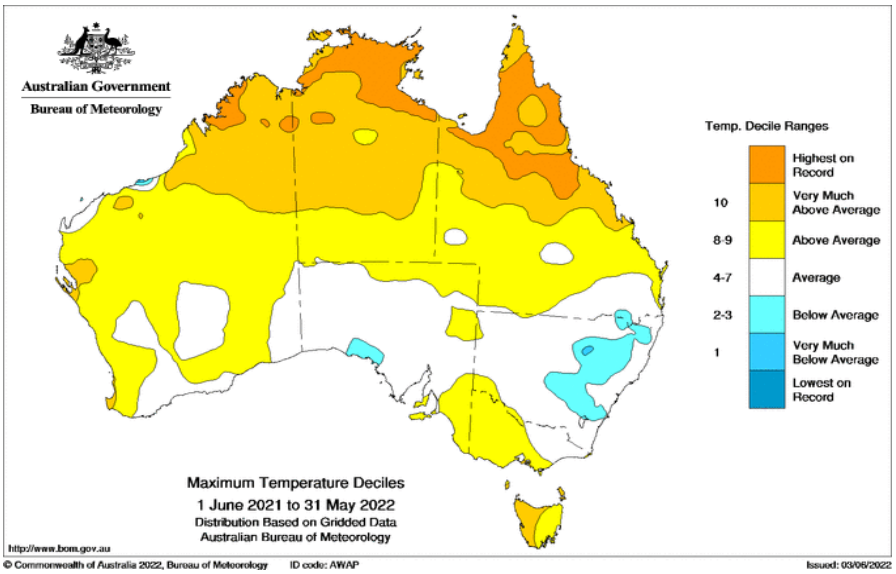


Figure 44: Maximum temperature deciles for Australia for the period 1 June 2021 to 31 May 2022

Inflow summary for 2021–22

River Murray System inflows (not including releases from Snowy Hydro, IVT deliveries, managed environmental deliveries from tributaries and inflows to the Menindee Lakes) during the 2021–22 water year were approximately 10,870 GL (**Figure 45**). In comparison with the historical record since 1896, only about 28% of previous water year inflow totals have been higher than the inflows observed in 2021–22 (i.e., an annual exceedance probability (AEP) of 28%). This inflow volume is around double the volume recorded for the same period in 2020–21 and around 3,550 GL more than the long-term median inflow volume.

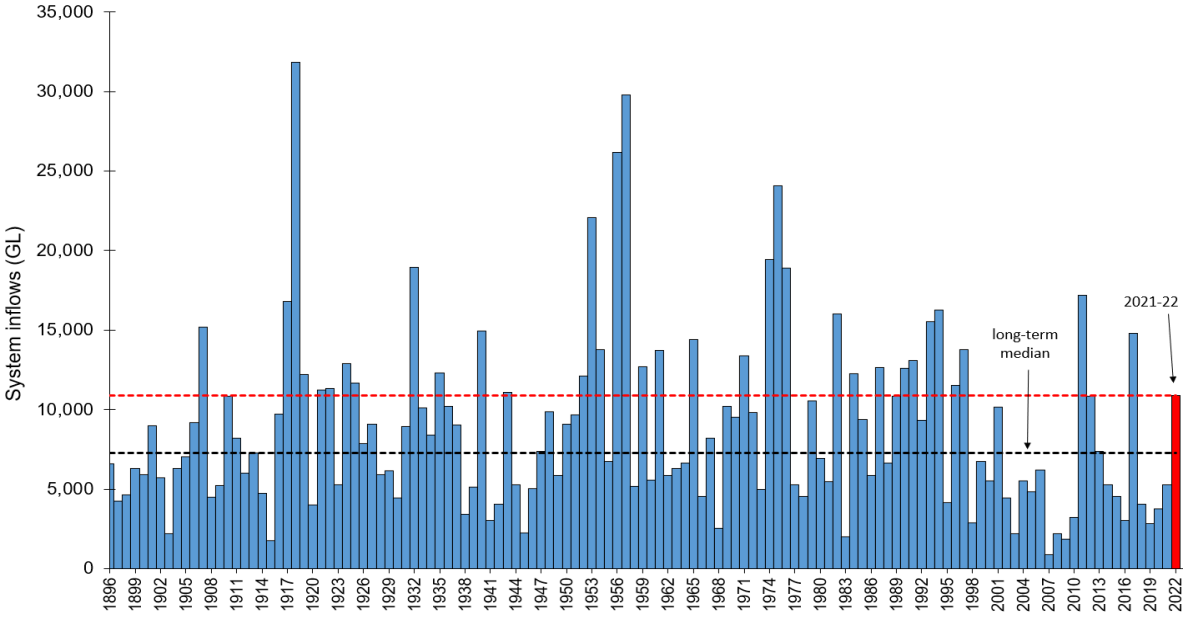


Figure 45: River Murray system inflows—water year totals (to end May) since 1896 (excludes Snowy Hydro inflows, IVT delivery, managed environmental inflows and inflows to Menindee Lakes). Black dashed line shows the long-term median. The red dashed line marks the 2021–22 volume.

Inflows to Dartmouth Reservoir were 1,275 GL (14% AEP). Significant rain events resulted in calculated daily inflows reaching around 30,000 ML/day in September 2021 and 25,000 ML/day in January 2022. Unregulated inflows to Hume were around 3,595 GL (21% AEP). Total calculated inflows to Hume were around 4,830 GL, with a peak daily calculated inflow of around 65,000 ML/day recorded in September.

The River Murray also received significant inflows from the Murrumbidgee River in 2021–22. Inflows from the Murrumbidgee, measured at Balranald, totalled 2,680 GL (6% AEP), with the flow above the end of system target from 2 June until the end of the water year. An additional 410 GL also flowed into the Murray (via the Edward River) from the Murrumbidgee River via the Billabong Creek, measured at Darlot.

Inflows to Menindee Lakes continued throughout 2021–22 with approximately 4,810 GL recorded flowing past the Darling River gauge at Wilcannia upstream of Menindee Lakes. In addition, around 130 GL was recorded at the Talyawalka Creek gauge, by-passing the Wilcannia gauge (when flows upstream of Wilcannia exceed around 26,000 ML/day) and reconnecting with the lower Darling downstream of Menindee Lakes. WaterNSW advises that significant inflows into the Menindee Lakes are expected to continue during winter 2022.

Active storage for 2021–22

MDBA active storage on 1 June 2021 was 4,529 GL, compared with the long-term average for that time of year of 5,089 GL (**Figure 46**). Of this volume, 53% was held in Dartmouth Reservoir, 30% in Hume Reservoir, 4% in Lake Victoria and 13% in the Menindee Lakes system. The active storage increased over winter and spring, reaching around 8,150 GL by the end of November 2021. For the remainder of the water year the volume ranged between around 7,700 GL and 8,200 GL, well above the long-term average. At the end of May 2022, the MDBA active storage was 8,019 GL. Of this volume, 44% was held in Dartmouth Reservoir, 34% in Hume Reservoir, 3% in Lake Victoria and 18% in the Menindee Lakes system.

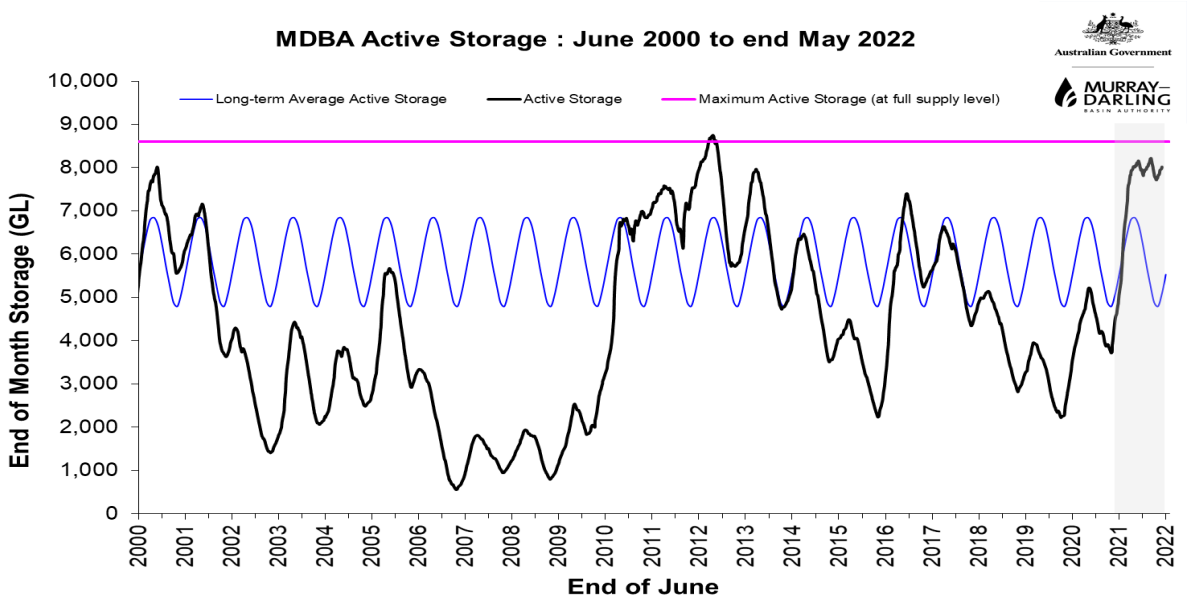


Figure 46: MDBA active storage, June 2000 to end May 2022. This graph shows the sum of active storage in Dartmouth and Hume Reservoirs, Lake Victoria and the Menindee Lakes (when part of the shared resource).

Dartmouth Reservoir gradually increased across the water year reaching 3,614 GL (94%) with an active storage of 3,543 GL by 31 May 2022 (**Figure 47**). Hume Reservoir reached 2,769 GL (92% capacity) by the end of May.

At Lake Victoria, the storage level was managed in accordance with Lake Victoria Operating Strategy (LVOS) reaching a high of 671 GL in mid-November. The storage volume was mostly lowered over summer and autumn falling to a low of 329 GL later in May prior to reaching around 360 GL at the end of May.

At Menindee Lakes the volume in storage increased over winter reaching FSL of 1,750 GL in mid-September 2021. Continuing higher inflows resulted in the storage volume being managed by WaterNSW between 1,580 GL and 1,980 GL for the remainder of the water year. On 31 May, the volume in storage was 1,954 GL. This included 1,474 GL of active storage available to meet demands on the River Murray.

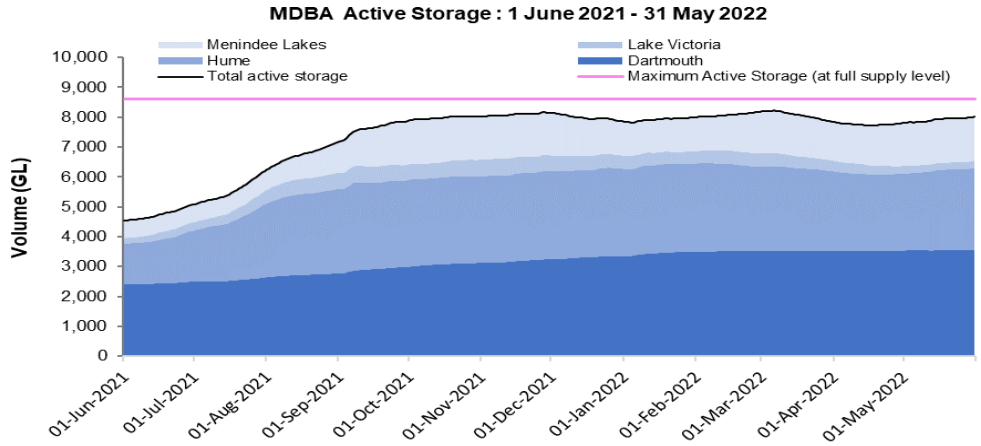


Figure 47: MDBA active storage, 1 June 2021 to 31 May 2022. This graph shows the sum of active storage in Dartmouth and Hume Reservoirs, Lake Victoria and the Menindee Lakes.

For the Murray–Darling Basin as a whole, the volume of water in storage was around 90% of capacity (compared with 58% for the same time last year). More information on water in storages in catchments across the Basin is available in **Figure 48** and from the MDBA website.

Flow to SA for 2021–22

Flow to South Australia in 2021–22 was around 8,210 GL (26% AEP). The flow to South Australia remained unregulated from 15 July 2021 to the end of May 2022 and is continuing unregulated into 2022–23. Flows through the barrages are estimated to have totalled more than 5,500 GL in 2021–22.

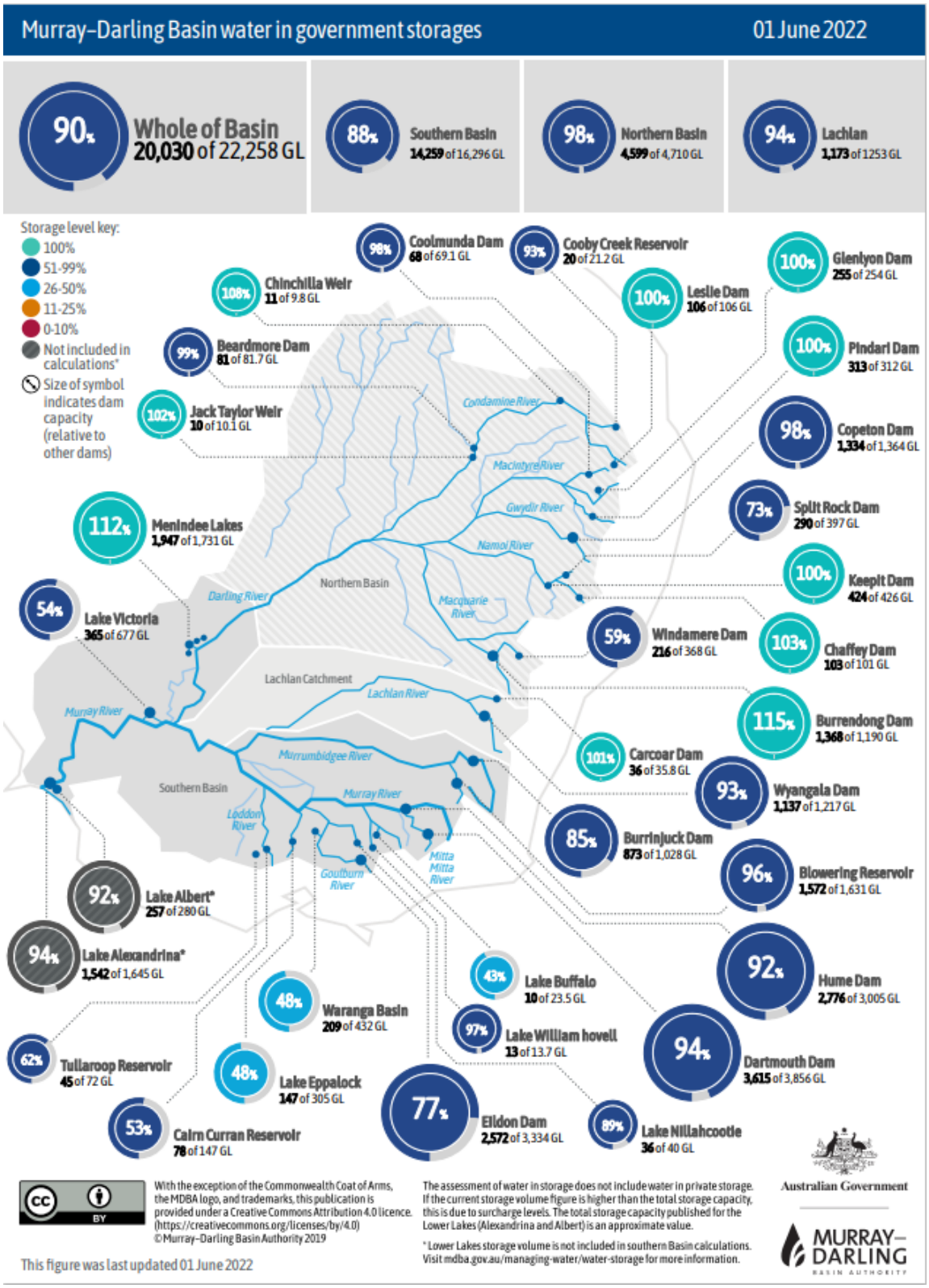


Figure 48: Murray–Darling Basin water in government storages as at 1 June 2022.

Losses and efficiency for 2021–22

Annual and bulk loss measurement

The MDBA tracks and estimates bulk losses through the River Murray System using the River Murray System monthly bulk accounts model. In recent years the volume of losses has been of significant interest. Reported loss volumes are adjusted to account for losses that are debited as water use from environmental water holders. Unregulated flows to South Australia commenced in mid-July 2021 and continued for the remainder of the water year. There were only short periods of time where releases were required to meet consumptive demands. Consequently, losses were significantly influenced by persistent high flow rates through the system driven by extended periods of unregulated flow resulting from airspace releases.

Quarterly losses in 2021–22

Table 8 below summarises losses that occurred for each quarter of the 2021–22 water year and the total annual losses. The losses reported here are calculated using the accounts model, they do not account for evaporation losses from storages, including Hume and Dartmouth Reservoirs, Lake Victoria and Menindee Lakes. Loss percentiles are reported for each quarter for the period since continuous accounting was introduced to the River Murray System (June 1989). The annual values are reported from analysis of the annual losses reported for each of the water years post June 1989.

Table 8: Quarterly losses for the 2021–22 water year. Loss metrics for the period of continuous accounting (post 1989).

	2021–22	Median	75%	99%
Q1	550	308	554	2862
Q2	664	332	685	4444
Q3	368	280	321	1752
Q4	141	110	145	3848
Annual	1723	1031	1706	12905

Losses in each quarter tracked very close to the 75th percentile losses. Total inflows for the year (including Menindee inflows and environmental deliveries) were at the 72nd percentile (or 28% exceedance).

Losses as a proportion of total inflows were 14% in the first two quarters, falling away with reducing inflows in Q3 (9%) and Q4 (6%). The proportion of inflows that resulted in surplus flow to South Australia grew from 12% in Q1 to 64% in Q4.

Transition to improved method for measuring bulk system losses

The accounts method gives a good representation of the magnitude and relative behaviour of system losses across years. The MDBA is currently in the process of updating the accounts model to be based on the Source modelling platform. This will enable the accounts to be better represented and will improve loss estimates. When adoption of the Source accounts model is finalised, more detailed reporting on losses will be possible.

Summary of Performance against General Objectives and Outcomes

Annually, River Murray Operations undertakes a self-assessment of how well river operations complied with the *Objectives and Outcomes for River Operations in the River Murray System* (O&Os). Below is a brief summary that shows all applicable General O&Os were achieved for the 2021–22 water year. Further to this assessment, an independent review is also undertaken with the results provided to the Joint Governments.

Table 9: Self-assessed performance against General Objectives and Outcomes for the 2021–22 water year.

General Objectives and Outcomes with supporting commentary	Performance Rating
(2) Water storage and delivery and accounting	
(i) The conservation of water and minimisation of losses. *The 2021–22 water year was a story of elevated inflows and full storages. During the year flood operations took place across the Upper Murray, Murrumbidgee and Darling catchments. The MDBA maximised available water at the end of the flood operations period to the extent required under clause 102 of the Agreement. Unregulated flows began in July 2021 and continued to the end of the water year, as such Lake Victoria was not required to reach effectively full. At the end of the year the majority of the system's water was stored in Dartmouth Reservoir. IVT and the use of available irrigation infrastructure that bypassed the Choke was used to a minimal extent to assist when required.*	Achieved
(ii) The accurate and timely preparation, delivery, review and, where necessary, amendment of water accounts and water resource assessments, in accordance with this document. *Accounts and water resource assessments were provided at the frequency required with any additional information, clarifications or minor revisions associated with state needs undertaken in a timely manner. Updates were undertaken as required in response to hydrometric corrections, the transition between years and specific state requests for additional information.*	Achieved
(iii) The delivery to the Southern Basin States of their authorised water orders (including water traded under Schedule D of the Agreement) unless physical constraints of the River Murray System prevent this from occurring. *All authorised water orders were delivered during 2021–22.*	Achieved
(3) RMO assets	
(i) The effective management, maintenance, repair, renewal and replacement, and the protection of the security, of River Murray Operations (RMO) assets.	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
No asset issues took place that caused a material impact on river operations. During the ongoing remedial and maintenance works at Hume Dam, RMO continued to provide delivery operational requirements to manage any potential risks to releases and water delivery.	
(ii) The effective management and mitigation of any emergency occurring at RMO assets. *No emergency operations were declared during the water year.*	N/A
(iii) Conduct river operations in ways that protect the structural and operational integrity of RMO assets. *Operation of assets along the River Murray remained within the acceptable operating ranges and did not affect asset works. At all times during the span of the 2021–22 flood events the security of Hume Dam was prioritised. When the storage has been raised close to full supply level there is a general increase to dam safety risks associated with high storage levels that has the potential to threaten the security of the asset. RMO actively managed airspace with regard to rainfall, storm and inflow forecasts to minimise these risks whenever possible. There were no DSEP incidents during 2021–22 flood operations. The MDBA continued to operate the river in a manner that protected the structural integrity of RMO assets.*	Achieved
(iv) The management of floods in order to: • firstly, protect the security of relevant RMO assets; then • secondly, to maximise the available water, calculated in accordance with clause 102 of the Agreement, at the end of the relevant flooding episode; and then • thirdly, subject to the foregoing items, limit flood damage to downstream communities and increase benefits to the environment and public amenity, for example, by prolonging wetland inundation or by supporting recreational activities. *RMO operated in accordance with the priorities above. This was most demonstrated by the operation of Hume dam when heavy rain and/or thunderstorms were forecast or occurring. On these occasions, RMO maintained appropriate additional airspace to minimise risk of storage surcharge or other dam safety risks which is the highest priority objective during flood operations.* *MDBA also achieved the second and third priority outcomes during flood operations including maximising available water. Further details can be found in Outcome 2(i) and 4(ii).*	Achieved
(v) Use existing and new RMO assets to deliver environmental water more effectively and to achieve environmental objectives for water dependent ecosystems. *The MDBA supported the manipulation of weir pools for environmental benefit where it had been planned and authorised. During flood periods and times of high*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
natural inflows, the MDBA worked with forest managers to coordinate the operation of regulators in Barmah–Millewa Forest where necessary. *Additionally, the MDBA worked alongside colleagues from WaterNSW, Meridian Energy (now Peak Renewables), Albury City Council and Northeast Water to utilise the various different outlet configurations from Hume dam to assist with dissolved oxygen and water chemical outcomes.*	
(4) People and communities	
(i) Productive relationships with river managers, users and other stakeholders with an interest in river operations are maintained. *Regular communication was maintained with river operators from state constructing authorities on operational activities. Information on operational activities was provided to the public via numerous regularly published reports such as the River Murray Operations Weekly Report, the publication of the Annual Operating Outlook (AOO), via flow advices and media releases when required, and additional web publications with general operational information. The MDBA, when appropriate and in consultation with state agencies, met with (remotely), spoke to or emailed relevant community groups and individuals to advise on, and support them through, non-routine or significant river operations activities that had the potential to impact their activities or businesses. Additionally, the MDBA provided over 20 Hume dam briefings for downstream community members during period of high storage levels.*	Achieved
(ii) Consistently with sub-paragraph 4(3)(b)(iv), damage to downstream communities is limited, when managing flooding. *The MDBA was able to provide a significant flood mitigation for downstream communities. This was achieved by careful airspace management that ensured a significant proportion of the main inflow peaks could be captured and peak releases were significantly less than peak inflows.*	Achieved
(iii) Events that may adversely affect the quality of water available for urban, irrigation, industrial, environmental, recreational or stock and domestic use are mitigated. *One standout event having potentially adverse impacts on the quality of water occurred in 2021–22, the water quality issues at Hume Dam during quarter three and four. In this case, the event was identified and actions within the control of the MDBA with regards to river operations were taken to mitigate these risks as far as practicable.*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
(iv) Navigational and recreational uses of the River Murray System are properly considered including the requirements of any major public events using parts of the River Murray System. *Navigation was maintained via water level management from Lock 7 through to Euston Weir. Known community recreational events were considered within operations planning and included in the AOO. Additionally, this year the MDBA was able to slightly alter the drawdown of Lake Mulwala to provide a pulse of water to assist with the Southern 80 ski race.*	Achieved
(v) Appropriate regard is given to cultural heritage matters. *Operation of Lake Victoria was undertaken in accordance with the Lake Victoria Operating Strategy, including during the extended period of unregulated flows. The operation of the Lake Victoria inlet and outlet were operated in accordance with SO&O requirements. No erosional impacts were reported during periods of high flow through the Lake Victoria inlet channel. Operating in accordance with the LVOS enabled RMO to delay the filling of Lake Victoria in order to minimise erosional impacts on cultural heritage material on the Lake shore.*	Achieved
(5) Environment	
(i) River operations are managed and operational practices reviewed, and if necessary altered, to ensure that rivers can be managed to achieve multiple objectives including supporting: a. overall environmental attributes, ecosystem functions and ecosystem processes; and b. the environmental watering activities of the Southern Basin States and the Commonwealth by having regard to the environmental watering plans of the Commonwealth, The Living Murray, and Southern Basin States and the current Southern Connected System Environmental Watering Operational scenarios document. *Regarding environmental watering activities, environmental watering plans were considered and incorporated into the development of the RMS Annual Operating Outlook. The MDBA consulted with environmental water holders in the development of watering plans and attended SCBEWC and EWIG (Environmental Watering Improvement Group meetings).* *The MDBA implemented new post Hume flood operating arrangement this year to improve environmental outcomes. This new provision was utilised twice during October/November and December and prevented the otherwise unnatural rapid drop in river level.* *Additionally, the MDBA undertook the first trial of using a 'with and without' environmental water scenario to track a directed release at Lake Victoria. The MDBA met with WLWG members to seek clarification around the specific objective*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
and outcome and the agreed approach was implemented during this year's event and updates to the current SO&O will be made in due course.	
(ii) The knowledge, documentary and practice bases for effective environmental watering are all improved, together with collaboration between relevant stakeholders relating to these matters. *MDBA continued to lead and drive the documentation of environmental water delivery and accounting practices, including the development and implementation of bulk environmental watering accounts in consultation of environmental water holders. Throughout the year, the MDBA provided significant information and helped inform Environmental water holders of opportunities for environmental water use in a year driven largely by flood operations and unregulated flows.*	Achieved
(iii) The Water Liaison Working Group and any other relevant committee receive timely information about any significant actual or predicted change to the River Murray System's water resources, in accordance with sub-clause 15(5). *As elevated tributary inflows continued through June and July 2021, the MDBA assessed the potential for and likely timing of unregulated flows in the Murray. Once updated forecasts indicated that unregulated conditions would occur, the MDBA advised WLWG members and the SCBEWC, via the chair as per standing procedures. The MDBA then requested advice from WLWG on the potential use of these flows including the potential use of RMUF to update forecasts. MDBA continued to provide updated forecasts and information to WLWG and SCBEWC on an on-going basis throughout the unregulated flow period.*	Achieved
(iv) The risk of significant adverse environmental events is reduced and, where such an event is unavoidable, its impact is mitigated. *Refer to 4(b)(iii) for mitigation of adverse environmental event.*	Achieved
(v) The Authority will supply, in a timely manner, the Water Liaison Working Group and the participating government environmental water holders of New South Wales, Victoria, South Australia and the Commonwealth with relevant retail and wholesale level estimates of environmental water use in response to receiving a request for such from the Water Liaison Working Group. *The MDBA provided operational estimates of environmental water usage on a monthly basis for confirmation by Water Liaison Working Group.*	Achieved
(6) Communication and Information Management	
(i) The Ministerial Council, the Committee, the River Murray Operations Committee, the Water Liaison Working Group, other relevant committees, other stakeholders with an interest in the Authority's river operations and the public are each provided with appropriate, timely and accurate information about the Authority's river operations.	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
Committees remained well informed of operational issues and upcoming operational risks with papers and presentations on water resources and current river operations prepared for each meeting. Specific presentations and briefings were provided on the proposed accounting arrangements of directed releases during the transition from air-space management to regulated flow management at Hume Dam.	
(ii) Appropriate and effective means are used to communicate with stakeholders and to refer matters to the Water Liaison Working Group and Committee, in accordance with this document. *The MDBA invested considerable effort in improving the communication of operational information related to the River Murray System by developing regular Hume dam operations briefings and hosting many online webinars.* *Advice and support were sought from WLWG for the specific issues relating to: The proposed accounting arrangements of directed releases during the transition from air-space management to regulated flow management at Hume Dam. WLWG advice was also sought on loss rate to be applied to SA storage right released from Hume in August 2021 and discussion around increasing the minimum flow at Dartmouth Dam.* *A range of mediums were utilised to communicate to stakeholders including fact sheets, infographics, presentations, newsletters and audio clips.*	Achieved
(iii) Any recommendations of the Committee in relation to the establishment, terms of reference, operations or recommendations of the Review Group are implemented. *The MDBA will continue to follow recommendations from the Committee in relation to the IRORG review process when received. The MDBA is publishing the review reports to facilitate transparency.*	Achieved
(iv) Hydrometric stations forming part of RMO assets, as required by clause 45 of the Agreement, are managed according to best practice methods to collect, transfer, store and assure the quality of all data, in accordance with any relevant agreement with a Southern Basin State, and support forecasting of future conditions in the River Murray System. *Within the budget constraints, the MDBA believes the current hydrometric monitoring program is effective and sufficiently accurate to meet its obligations under clause 45 of the Agreement.*	Achieved

Overview of SO&O Performance

Table 10: Summary of self- assessed performance against SO&Os

Specific O&O Site	Overall Rating				
	Q1	Q2	Q3	Q4	Comments
1. Dartmouth Dam					There were some breaches of the rise and fall rules, and minimum planned regulated releases at Colemans. These were immaterial.
2. Hume Dam and Reservoir					There were some breaches of the minimum flow rules downstream of Hume Dam due to technical challenges in accurately rating the Heywoods gauge.
3. Yarrawonga Weir					
4. Barmah–Millewa Forest					
5. Edward-Wakool System					
6. Torrumbarry Weir	Withdrawn from SO&O				
7. Swan Hill					
8. Weir and Lock No. 10 – Wentworth Weir					
9. Lake Victoria					There were some cautions of Lake Victoria inflow and outflow rates.
10. Menindee Lakes					Menindee Lakes remained a part of the shared resource during 2021–22.
11. Lower Lakes Barrages					
12. System Operation					
13. Water Accounts					
14. Water Resource Assessment					
15. Tier 2 & 3 Water Sharing Arrangements					This clause did not apply this water year.

Glossary of Terms and Abbreviations

Abbreviation/term	Definition
BGA	Blue-green algae
BM Forest	Barmah–Millewa Forest
BoM	Bureau of Meteorology
(the) Choke	The Barmah Choke
(the) Committee	Basin Officials Committee
EWH	Environmental Water Holder
FSL	Full Supply Level
GMW	Goulburn-Murray Water
GO&O	General Objective and Outcome
IVT	Inter-Valley Trade
LMW	Lower-Murray Water
LVOS	Lake Victoria Operating Strategy
MDBA	Murray–Darling Basin Authority
O&O	The '*Objectives and Outcomes for River Operations in the River Murray System*' document
RMC	River Murray Channel
RMO	River Murray Operations
River Murray System losses	River Murray System (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific watering actions and evaporative losses from the major RMS storages Dartmouth and Hume Reservoirs, Lake Victoria, and Menindee Lakes System (when part of the shared resource).
RMUF	River Murray Unregulated Flows
SO&O	Specific Objective and Outcome

Office locations – *First Nations Country*
Adelaide – *Kaurna Country*
Canberra – *Ngunnawal Country*
Goondiwindi – *Bigambul Country*
Griffith – *Wiradjuri Country*
Mildura – *Latji Latji Country*
Murray Bridge – *Ngarrindjeri Country*
Toowoomba – *Jarowair and Wakka Wakka Country*
Wodonga – *Dhudhuroa Country*

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