Australian Government

Murray–Darling Basin Authority

River Murray System Summary of River Operations

2022–23 Water Year

August 2023

Published by the Murray–Darling Basin Authority
MDBA publication no: 02/24
ISBN (online): 978-1-922699-46-6

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Cataloguing data
Title: River Murray System Summary of River Operations, Murray–Darling Basin Authority Canberra, 2024. CC BY 4.0

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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, the Northern Basin Aboriginal 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.

Contents

Executive summary

The Murray–Darling Basin Authority (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 2022–23 water year.

The 2022–23 MDBA water year brought above average rainfall across most the of the Murray–Darling Basin. Rainfall across most of Victoria and southern New South Wales was 'very much above average'. Rainfall across much of central New South Wales, the South Australian Riverland and the lower lakes was above average for 2022–23, whilst much of Queensland recorded average or below average rainfall (**Figure 1**).

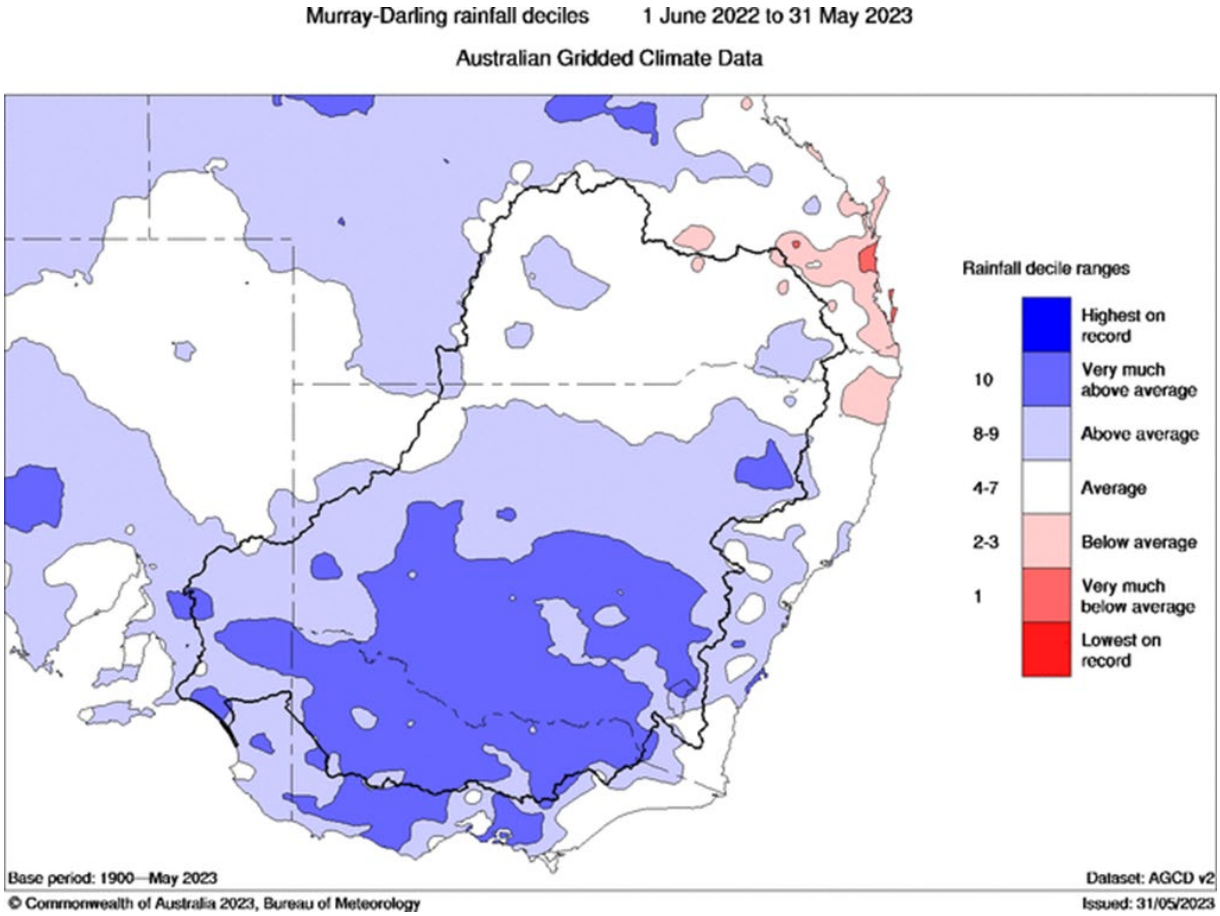


Figure 1: Murray–Darling Rainfall deciles for the period 1 June 2022 to 31 May 2023.

Following a wet 2021–22, the year brought continued elevated inflows, full storages, and flood operations. The MDBA undertook airspace releases and flood operations at Dartmouth and Hume

Dams. WaterNSW also undertook flood operations on the Murrumbidgee and Menindee systems 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 throughout the year.

MDBA active storage on 1 June 2022 was 8,031 gigalitres (GL), compared with the long-term average for that time of year of 5,089 GL (**Figure 2)**. Of this volume, 44% was held in Dartmouth Reservoir, 34% in Hume Reservoir, 3% in Lake Victoria and 19% in the Menindee Lakes system. The active storage increased over winter and spring, reaching around 8,700 GL by the end of December 2022. Until April 2023 the volume continued to fall steadying plateauing out around 7,550 megalitres per day (ML/day), well above the long-term average. At the end of May 2023, the MDBA active storage was around 7,600 GL. Of this volume, 48% was held in Dartmouth Reservoir, 36% in Hume Reservoir, 4% in Lake Victoria and 12% in the Menindee Lakes system.

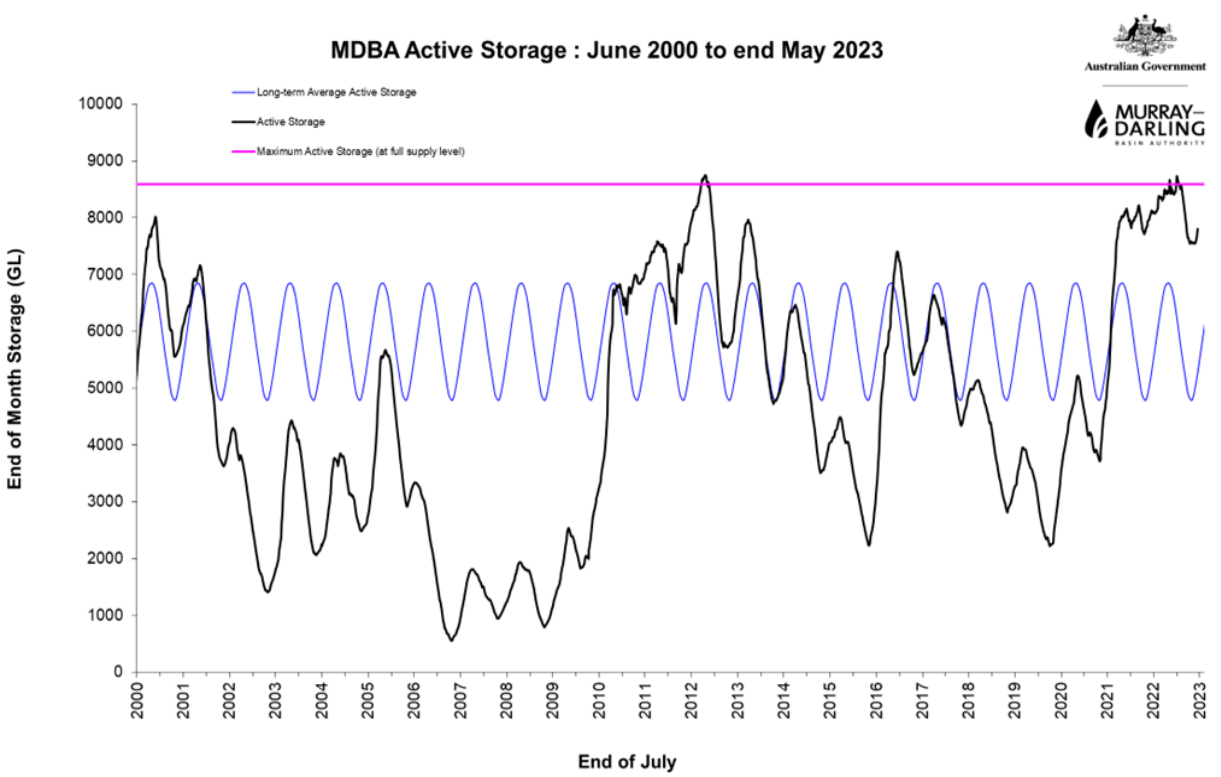


Figure 2: MDBA active storage, June 2000 to end May 2022. This graph shows the sum of active storage in Dartmouth and Hume Reservoirs, Lake Victoria and the Menindee Lakes (when part of the shared resource).

River Murray system inflows (not including releases from Snowy Hydro, inter-valley trade (IVT) deliveries, managed environmental deliveries from tributaries and inflows to the Menindee Lakes) during the 2022–23 water year were approximately 21,900 GL. In comparison with the historical record since 1896, only about 4% of previous water year inflow totals have been higher than those observed in 2022–23 (i.e., an annual exceedance probability (AEP) of 4%). The total of 21,900 GL places 2022–23 as the sixth highest inflow water year in the historic record. The total is around double the volume recorded for the same period in 2021–22 and around 3 times more than the long-term median inflow volume (**Figure 3**).

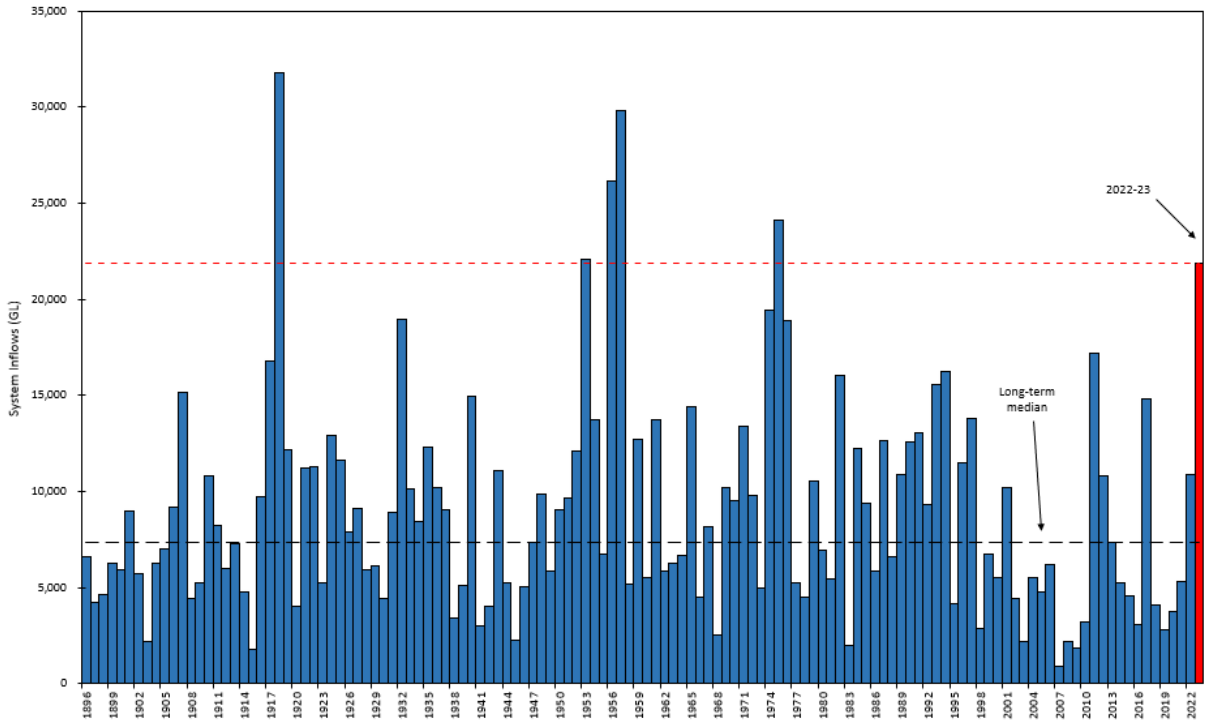


Figure 3: River Murray System inflows for 2022–23 compared with the long-term median.

For the Murray–Darling Basin as a whole, on 31 May 2023, the volume of water in storage was similar to last year at around 90% of capacity. Storage in the northern Basin is currently at 93% of capacity (compared with 98% for the same time last year), while in the southern Basin storage is at 89% capacity (compared with 87% for the same time last year).

Key metrics for 2022–23

The operational metrics in **Table 1** provide a snapshot summary of river operations for the year. 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 2022–23.

Metric		Annual value [i]
Total River Murray system inflows [ii]		21,900 GL (4% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 110 GL ↓ 32 GL ↑ 37 GL ↓ 545 GL
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	1,551 GL 7,941 GL 121 GL 7,890 GL
	IVT Delivery	Murrumbidgee: 0 GL Goulburn: 28 GL
Total consumptive deliveries [iv]		984 GL Victorian Murray

Metric		Annual value [i]
		1,438 GL NSW Murray
River Murray system loss [v]		6,152 GL
Environmental directed releases from Hume Dam [vi]		200.4 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	23,584 GL 696 GL 1,154 GL 106 GL 984 GL (releases and environmental trades to SA) 20,644 GL due to unregulated flows, ADF and forced delivery of deferred SA Entitlement.
Publication of operational information		51 MDBA Weekly Reports 65 Media Releases on 'river operations 16 Alert & Advise Media Releases 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 2022–23 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 2022–23, the SO&Os were found to be achieved (**Figure 4**).

Figure 4: Spatial snapshot of performance against SO&Os during 2022–23.

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**).

Losses and efficiency for 2022–23

Annual and bulk loss measurement

The MDBA tracks and estimates bulk losses through the River Murray using the River Murray system monthly bulk accounts model. In recent years the volume of losses has been of significant interest but has been less of a focus of a focus in 2022/23 year with the unregulated flows to South Australia that commenced in July 2021 and continuing throughout the year. Reported loss volumes have been adjusted to account for losses that are debited as water use from environmental water holders. There were extremely high inflows in spring/summer and losses were dominated by persistent high flow rates through the system driven by extended periods of unregulated flow resulting from airspace releases. As in 2021/22 there were only relatively short periods of time where releases were required to meet consumptive demands.

Quarterly losses in 2022–23

(**Table 2**) below summarises losses that occurred for each quarter of the 2022–23 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 (1989). The annual values are reported from analysis of the annual losses reported for each of the water years post June 1989.

Loss metrics for the period of continuous accounting (post 1989).

Table 2: Self-assessed performance against General Objectives and Outcomes for the 2022–23 water year.

	2022/23 (GL) (% of inflow)	50% (GL)	75% (GL)	99% (GL)
Q1	1431 (33%)	193	674	2170
Q2	2163 (15%)	321	1013	3201
Q3	2900 (82%)	290	340	2574
Q4	-341 (-32%)	125	179	952
Annual	6152 (28%)	1025	2275	5594

The year saw some of the highest Murray inflows and highest losses over the period of interest since 1989 and constant unregulated flow to South Australia. The quantum of losses in the first and second quarter were the second highest observed in the 34 years since 1989. The third quarter losses are particularly notable being ten times the median calculated for that period; however they are likely to be an overstatement of the true value, influenced by the slow flow travel times of the record inflows. This is confirmed by the gains (negative loss) calculated for the fourth quarter which is due to flood flows returning to the river rather than a reflection of extreme conditions over the period. The losses for the year are the highest over the period of interest and are a reflection of the observed flow conditions.

Considering loss as a percentage of inflows demonstrate the variability observed across the quarters, a spread of 114%, likely to be influenced by the travel times of inflows and associated return flows across quarters. The total annual loss is taken to be the best reflection of the year, although the loss volume was the highest observed the 28% loss on inflows was less extreme, with a higher loss rate being seen in 20% of years.

The proportion of inflows (including Menindee inflows) that resulted in surplus flow to South Australia was over 80% for the year. This was around 75% for Q1 and Q2, greater than 90% in Q3, dropping to 56% in Q4, again a reflection of travel times across quarters in the second half of the year.

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. From 2023/24 the Source modelling platform will be used to calculate the

Murray system accounts. 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 2022–23 water year. Further to this assessment, an independent review is also undertaken with the results provided to the Joint Governments.

Table 3: Self-assessed performance against General Objectives and Outcomes for the 2022–23 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 2022–23 water year was a story of continued 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 at the start 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 2022–23.*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
(3) RMO assets	
(i) The effective management, maintenance, repair, renewal and replacement, and the protection of the security, of River Murray Operations (RMO) assets. *Lock 15 at Euston has witnessed damage to a Piezometer Tube, which was caused by debris during the flood event. While this has resulted the Euston upstream pool level to be lower, this has had no impact on flow requirements downstream.* *Lake Victoria Bank repairs after the flooding event were effectively managed and caused no impacts on the operations of Lake Victoria Tar-ru, in line with the LVOS.*	Achieved
(ii) The effective management and mitigation of any emergency occurring at RMO assets. *No emergency operations were declared during the water year. However, the Dam Safety Emergency Plan (DSEP) was triggered at Torrumbarry due to highest record flows for that structure. However, the MDBA emergency action plan was not activated due to the low risk associated.*	Achieved
(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 2022–23 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. 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*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
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).*	
(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 natural inflows, the MDBA worked with forest managers to coordinate the operation of regulators in Barmah–Millewa Forest where necessary.* *Additionally, the MDBA continued to work 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.*	Achieved
(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.*	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 less than peak inflows.*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
(iii) Events that may adversely affect the quality of water available for urban, irrigation, industrial, environmental, recreational or stock and domestic use are mitigated. *The ongoing water quality issues at Hume Dam during 2021–22 continued during this water year. Actions within the control of the MDBA with regards to river operations were taken to mitigate these risks as far as practicable.*	Achieved
(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 timing of a Goulburn IVT pulse 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).*	Achieved

General Objectives and Outcomes with supporting commentary	Performance Rating
The MDBA utalised the Hume flood operating arrangement this year to improve environmental outcomes notably prevented the otherwise unnatural rapid drop in river level.	
(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 improvement 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). *Unregulated flow this water year continued through the entire water year. The WLWG and SCBEWC (via the Chair) received timely notice of the potential for, and actual, unregulated flow period, in accordance with 5(b)(iii). RMO followed routine unregulated flow procedures and followed the draft Operations Reference Manual section for the determination of unregulated flow conditions in the River Murray system developed in 2022–23.*	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.	
(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 continued to invest considerable effort in improving the communication of operational information related to the River Murray system by undertaking regular Hume and Dartmouth dam operations briefings.* *Advice and support were sought from WLWG for the specific issues relating to: Update to the accounting arrangements of directed releases during the transition from air-space management to regulated flow management at Hume Dam. WLWG was advised of the SA storage forced spill.* *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 4: 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 exceedances of Lake Victoria inflow and outflow rates.
10. Menindee Lakes					Menindee Lakes remained a part of the shared resource during 2022–23.
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
(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
MISL	Maximum Induced Surcharge Level
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
The Bureau/Bureau	Bureau of Meteorology

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 a number of 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 requirement for **quarter one** of the 2022–23 water year and also 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 for quarter one, including key achievements, key drivers, key metrics and month-by-month summary
    b. Summary of self-assessed quarterly performance for River Murray operations against the GO&Os
2. Technical appendices
    a. Quarter one threshold Report

The performance reporting uses criteria shown in **Table 5** whilst noting that operational decisions are made on the best available information and in the context of the particular operational drivers affecting the system at the time.

Table 5: 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 GO&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 GO&O for this quarter with a substantial number of minor breaches or a major breach of small consequence.	The SO&O did not apply to this quarter.	Did not meet the requirements of the GO&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.*

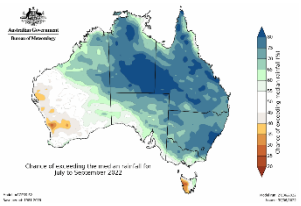
Quarter 1

River Murray Operations (RMO) activities for quarter 1 (Q1) primarily focused on the planning and preparation of the River Murray (RM) System for the new water year (June 2022 to May 2023). Q1 saw Bureau of Meteorology (the Bureau) outlooks consistently suggesting a higher probability of wetter than median conditions during winter into spring, with a La Niña WATCH activated in June.

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. However, River Murray storages began Q1 at relatively high levels following good inflows during the 2021–22 water year. This meant that significant focus was given to the management of storage inflows and airspace, with airspace management 'pre-releases' that started in late autumn to manage airspace at Hume Dam continuing into Q1. In addition, this same requirement at Dartmouth Dam was expected during winter-spring even under relatively dry planning scenarios. Careful focus was also given to the management of an on-going and extended unregulated flow period driven by elevated Murrumbidgee River inflows, subsequent high inflows from other tributaries and airspace management releases from Hume Dam.

Between managing variable rain and inflow events and forecasting uncertainties, RMO also maintained a strong focus on planning for and delivering water for the environment. This was undertaken whilst simultaneously managing a partial drawdown of Lake Mulwala where the level was successfully maintained around 5 metres below FSL from June until mid-July to manage the invasive weed *Egeria densa*. From mid-July the lake was gradually re-filled in preparation for the coming irrigation season. Annual operations 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 across the year based on 6 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 with operations adjusted in line with the Lake Victoria Operating Strategy (LVOS) whilst RMO provided regular, clear information regarding the duration and extent of unregulated flows to support state supplementary water

Management of Hume and Dartmouth Dam airspace given a 'wet' Bureau climate outlook and above average rain across catchments during June changing to drier conditions during July. Airspace management releases from Hume Dam dominated Q1 and started

licence access and management of RMUF.	at Dartmouth Dam during August as rain increased.

Key external drivers influencing operations in Q1

Whilst winter and spring are statistically the higher inflow periods for the River Murray system, adaptability of operational activities and responses to observed inflows during the 'filling season' is critical. In this respect, River Murray Operations recognised 5 **Key Drivers** that shaped Q1.

- **Key Driver 1 – 'Average winter rainfall'.** The quarter began with the Bureau continuing to indicate that winter rainfall was very likely to be above average for the Murray–Darling Basin. In addition, all system storages, except Lake Victoria, started the new water year at a higher level than June 2021, with Dartmouth at 94% capacity (compared with 64% one year prior) and Hume at 92% capacity (46% one year prior). The Menindee Lakes storage volume had continued above the threshold of 640 GL (the trigger level at which Menindee Lakes water resource is shared with the Murray) from May 2021 and reached 112% at the beginning of June 2022 (61% one year prior). For Lake Victoria, the storage volume was 54% capacity (43% one year prior). Despite the Bureau outlook for above-median rainfall during winter, rain during June and July was average to below average before conditions turned relatively wet during August. The combination of high storage levels and decent tributary inflows meant flows arriving at Lake Victoria and the South Australian border steadily increased across the winter months. This maintained the unregulated flows to South Australia, that had commenced back in mid-July 2021, into a second winter.

- **Key Driver 2 – 'Management of Hume and Dartmouth Dam and downstream effects'.** With both Dartmouth and Hume Dams at relatively high levels leading into Q1, storage airspace was an operational focus, with airspace management releases already underway at Hume Dam from mid-May 2022. These releases continued throughout June and into July at rates below channel capacity at Doctors Point (downstream of the Kiewa River junction). However, with dry conditions and more modest inflows to Hume Dam during July, releases were switched over to deliver environmental water demands (ordered by environmental water holders to meet downstream targets) at rates that exceeded the release needed to manage airspace. Renewed forecasts and observed rain and responses during August led to airspace management releases re-commencing from Hume Dam on 3 August, around 2 weeks later, as wetter conditions emerged. This rain was also sufficient to ensure storage filling at Dartmouth Dam and triggered airspace management releases from Dartmouth from 5 August. Airspace management releases then continued for the remainder of Q1 at both dams. With the Bureau outlook for wet conditions strengthening as spring approached, it was likely that airspace management releases would continue, and the potential for flood operations would persist during the months ahead.

- **Key Driver 3 – 'Wet conditions in the Murrumbidgee'.** Q1 saw wet conditions re-develop in the Murrumbidgee catchment following wet conditions during autumn. With both Burrinjuck and Blowering dams already at high levels, airspace management releases were required by WaterNSW at both dams. These releases helped boost the average flow at Balranald during winter to around 11,400 ML/day, well above the normal end-of-system target. The resultant high inflows from the Murrumbidgee continued to influence broader River Murray system operations including the continued unregulated flows on the Murray and the operation of Lake Victoria.

- **Key Driver 4 – 'Wet conditions in the Darling & Menindee Lakes above surcharge.** The quarter began with the continuation of high releases from the Menindee Lakes to manage airspace as high inflows persisted following considerable autumn rain across much of the northern Basin. Further rain events during winter 2022 generated additional inflow from several Barwon-Darling tributaries and maintained high inflows to the Menindee Lakes and continuing storage spill into the lower Darling River and Great Darling Anabranch throughout Q1.

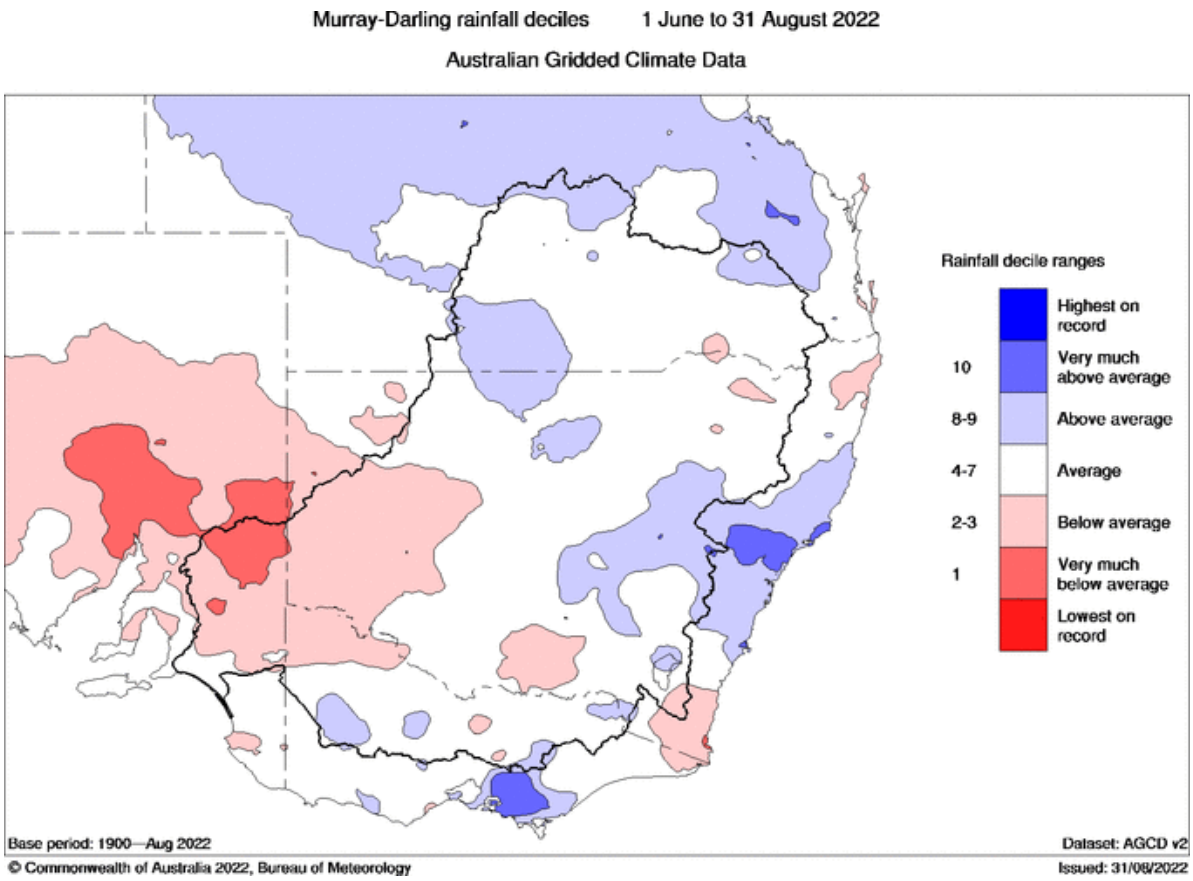


Figure 5: Murray–Darling Rainfall deciles for Q1 shows above average conditions for some upper Murray catchments and parts of central, eastern and northern New South Wales; with average to below average conditions elsewhere (Source Bureau).

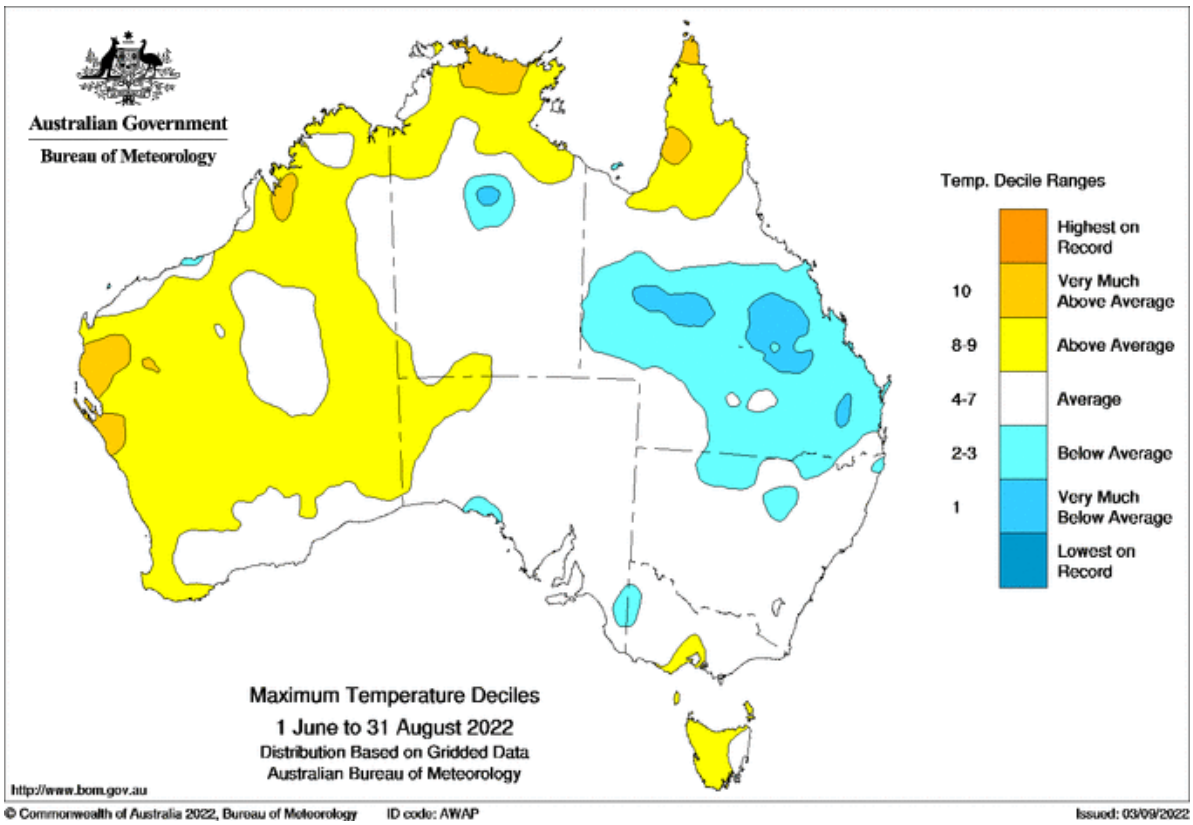


Figure 6: Maximum temperature deciles for Q1 show below average conditions in parts of the northern Basin, with more average conditions elsewhere (Source Bureau).

Key metrics for Q1

The operational metrics in **Table 6 provide a snapshot summary of river operations for Q1.** All figures should be considered within the context of the key drivers outlined above.

Table 6: Key metrics for River Murray system operations during Q1.

Metric		Quarter One [i]
Total River Murray system inflows [ii]		4,113 GL (35% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 208 GL due to capture of inflows ↑ 120 GL due to capture of inflows along with airspace management and environmental releases ↑ 41 GL due to capture of unregulated tributary inflows and directed release provisions ↓ 39 due to airspace management releases to accommodate further inflow
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	226 GL with AGL entitlement, airspace management and minimum releases 1772 GL with releases for airspace management and water for the environment 0 GL 1,951 GL into the lower Darling River and 175 GL released to the Great Darling Anabranch for airspace management

Metric		Quarter One [i]
	IVT Delivery	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		95 GL Victorian Murray 142 GL NSW Murray
River Murray system loss [v]		1431 GL
Environmental directed releases from Hume [vi]		85 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	4002 GL 174 GL 149 GL 0 GL 262 GL 3,418 GL due to unregulated flows, ADF (276 GL) and forced delivery of deferred SA Entitlement
Publication of operational information		14 MDBA Weekly Reports 28 Media Releases on 'river operations' AOO Publication

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 as a result 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 New South Wales 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.

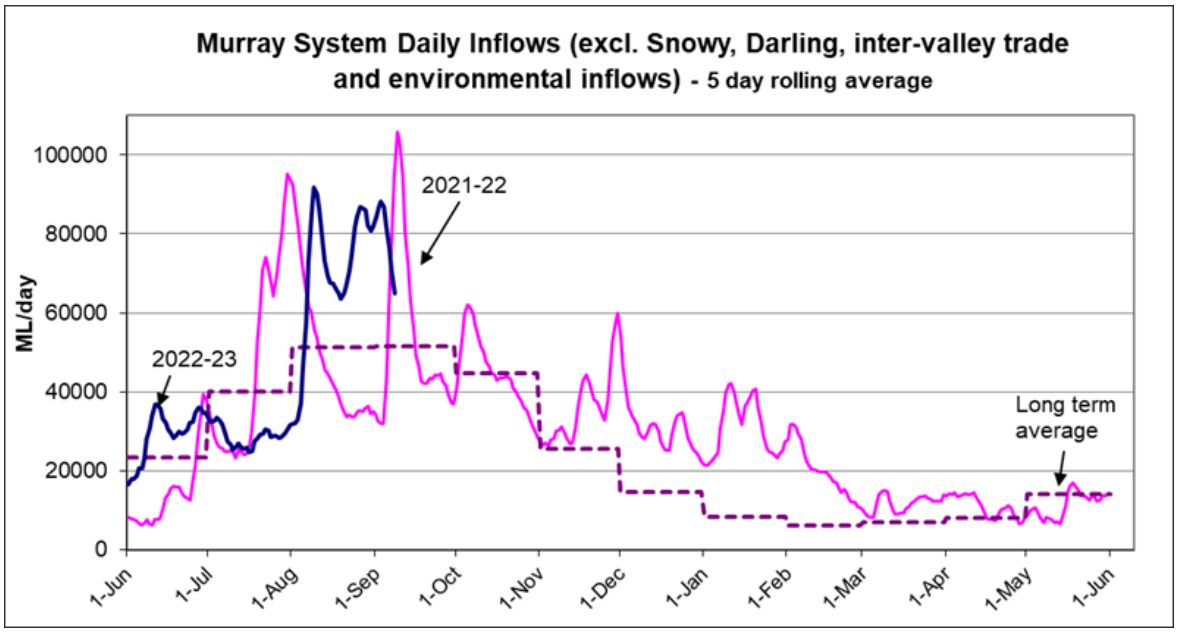


Figure 7: Murray System daily inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) for Quarter 1, 2022–23 compared with 2021–22 and long-term average inflows.

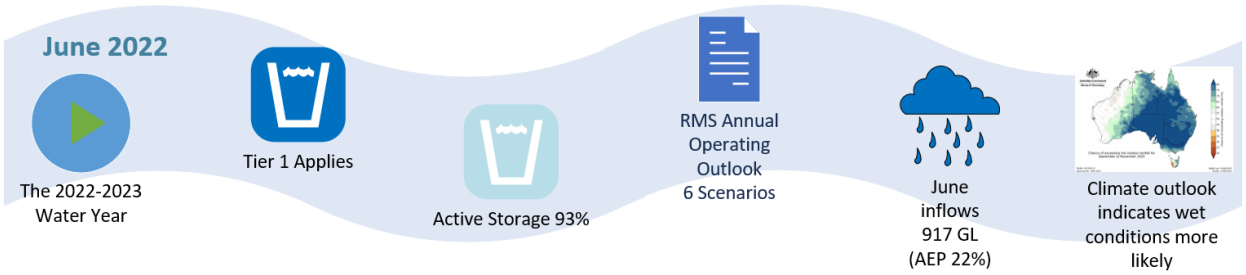
BOX 1: Status of Water Sharing and State Shares in Storage

As per the Murray–Darling Basin Agreement and Basin Plan, the River Murray system started the year in 'Tier 1'. This meant 'normal' water sharing arrangements applied and as stated in the AOO, this classification was expected to continue for the remainder of the 2022–23 water year and likely into next water year (2023–24), given the Bureau's wet outlook for spring at the end of Q1. 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 New South Wales 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 2022



River Murray system inflows for June (excluding Snowy, Darling, IVT and environmental inflows) were almost 917 GL, which is above the month's long-term average of 705 GL. In comparison with the historic record 22% of previous monthly totals for June have been higher than the inflows observed

in June 2022. At the beginning of the water year (1 June 2022) the active storage in the MDBA's reservoirs was 8,029 GL or 93 % capacity, up from 4,529 or 53% at the same time in 2021. By the end of August, total active storage had increased to 8,315 GL or 97%, well above the long-term average and at its highest level since early 2012 (**Figure 8**).

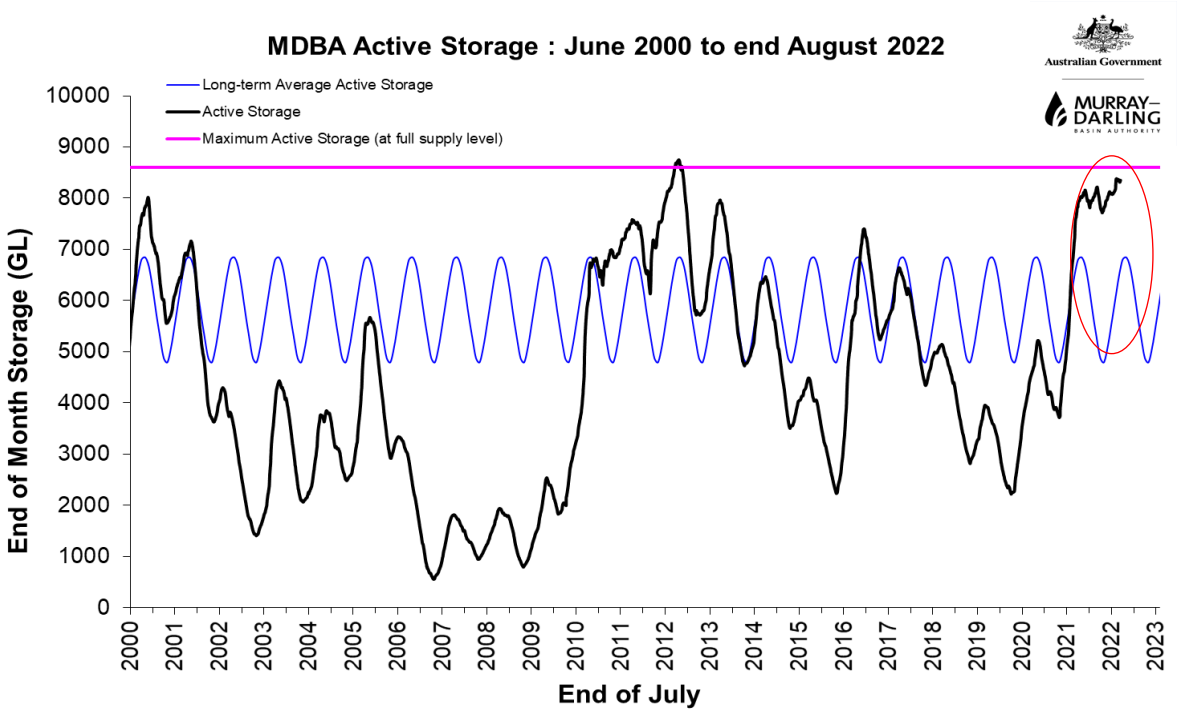


Figure 8: The River Murray system total active storage increased above the long-term average by the end of Q1.

The Bureau reports that for June 2022 rainfall was below average across much of the Murray–Darling Basin (Map 1) with an area-average rainfall totalling 20.8 mm. This is 31% below the long-term June average for the Basin. However, for the upper Murray catchments, rainfall was average to above average, and in addition to rain during autumn, this helped maintain above average inflows to both Hume and Dartmouth Dams for the month of June.

System inflows to 30 June: 917 GL

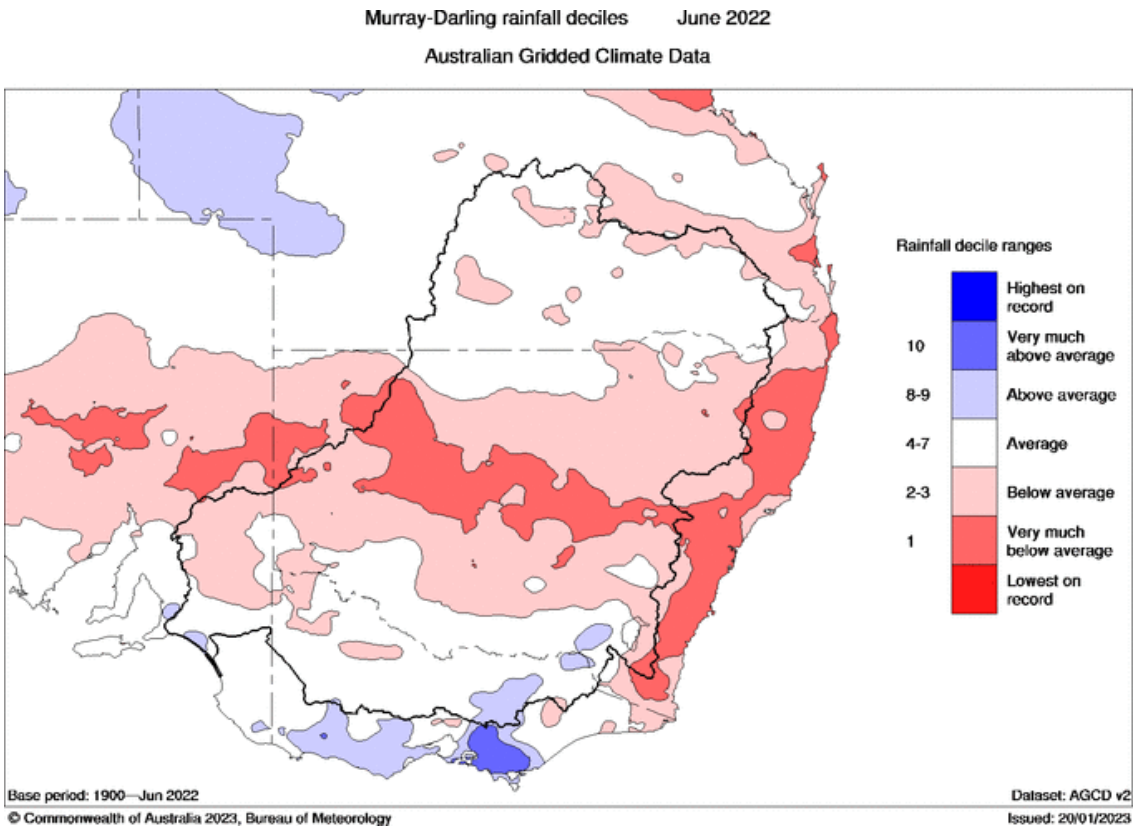


Figure 9: Rainfall deciles June 2022 (Source: Bureau).

The Annual Operating Outlook (AOO) for the 2022–23 water year was published in July 2022. The AOO is a key component of the operations planning process and uses 6 inflow and water demand scenarios to help outline the range of potential operational activities and flow trends expected for 2022–23 under different climatic conditions. In developing the AOO for the 2022–23 water year, more focus was placed on wetter scenarios than in most other years, with RMO noting the Bureau outlook and the prospect for wetter than usual winter-spring conditions, wet catchments, and relatively high storage levels. The inflows assumed for each of the 6 scenarios are shown in **Figure 10**

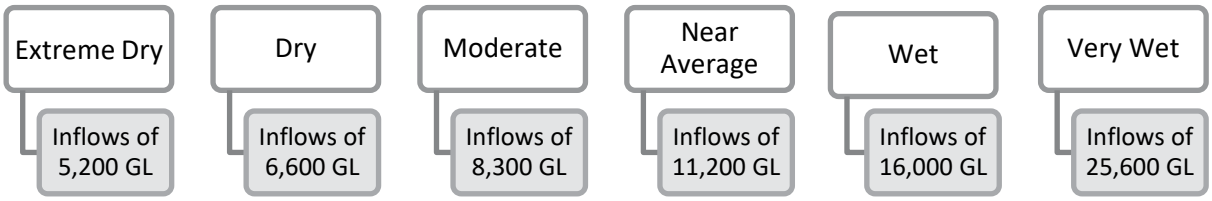


Figure 10: The 6 River Murray system Annual Operating Outlook (AOO) scenarios showing the volume of annual system inflow assumed in each case (Section 5.2, 2022–23 AOO).

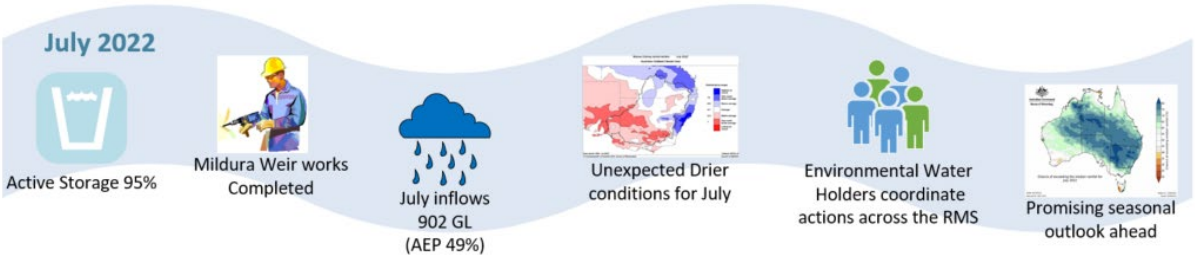
In early June, rainfall totals of 25-50 mm fell across the upper Murray catchments, with isolated totals of 100-150 mm. This resulted in streamflow increases in the upper Murray and an inflow peak into Hume Dam of around 20,000 ML/day that reduced Hume Dam airspace to 135 GL (95.5% capacity). These inflows required a step up in Hume releases to increase airspace whilst continuing to meet filling requirements going forward.

As such, Hume releases were increased to 19,000 ML/day during mid-June and were then maintained at rates around 15,000 ML/day well into July with airspace increased to around 200 GL. In addition to Hume Dam releases, increased tributary inflows from the Kiewa and Ovens rivers during this period resulted in flows downstream of Yarrawonga rising to a peak of 28,000 ML/day in late June before

receding to 15,000 ML/day as drier conditions set in and inflows reduced. Forest regulators in the Barmah and Millewa forests were opened to manage river levels as per standard arrangements. Forest managers co-ordinated the opening of a number of 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 the end of June, Bureau climate outlooks for the first half of July were neutral for early July but trended to a wetter outlook for the second half of July and into August.

July 2022



System inflows for July: 902 GL

During July, drier conditions emerged, with low rainfall across the southern Basin, including the upper Murray catchments. As a result, River Murray system inflows reduced to 902 GL, below the long-term average of 1,199 GL. However, with low winter demands, MDBA total active storage continued to increase and reached 8,178 GL (95% capacity) by the end of the month.

The dry conditions were in clear contrast to previous Bureau outlooks for July that indicated a higher chance of wetter conditions for the month (**Figure 11**, **Figure 12**). This contrast between forecast and observed conditions highlighted the continuing challenge of airspace management and the importance of the analysis needed to balance storage filling requirements with potential flood mitigation within the context of rainfall forecasting uncertainties.

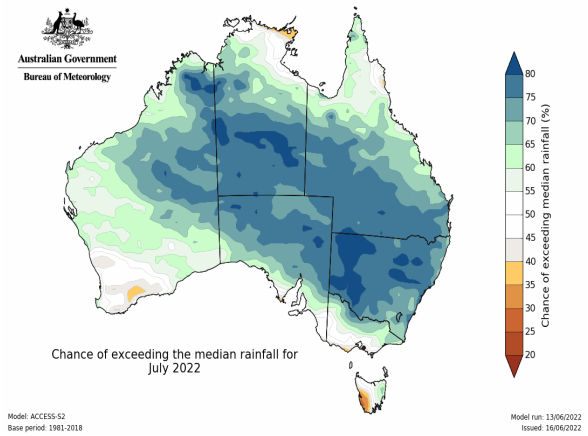


Figure 11: Chance of exceeding median rainfall for July 2022 as of mid-June 2022 (Source: Bureau).

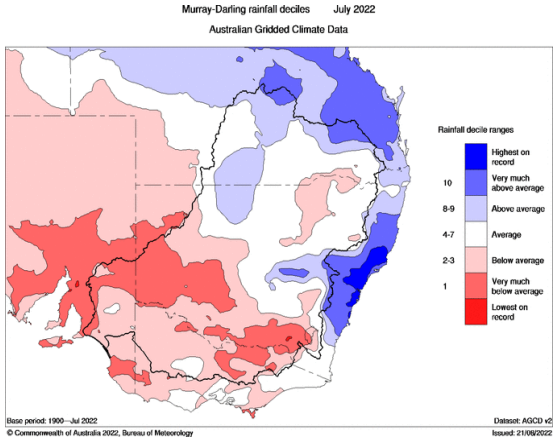


Figure 12: Murray–Darling Basin rainfall deciles for July 2022 (Source: Bureau).

Works planned for the Mildura weir in 2021 that were not completed due to the COVID-19 pandemic, were completed in July 2022. This included the interchange of 3 trestles and the commissioning of a new winch assembly.

During July, Dartmouth Dam storage increased by 21 GL to 95.5%, however Hume Dam decreased by 52 GL to 92.2% with releases of water for the environment during the second half of the month to target 15,000 ML/day at Yarrawonga further increasing airspace. 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. In particular, forecasting the commencement of releases of water for the environment added to the challenges of managing airspace and the process of filling the storage towards the end of the airspace management period.

To manage this increased uncertainty, the MDBA, working with state partners, proposed further enhancements to the provisions of SO&O 2.4 to establish an updated approach to making directed releases of water for the environment during airspace management. This would improve environmental outcomes whilst simultaneously improving the management of flood risks related to high storage levels. Support for this change was attained from the Water Liaison Working Group (WLWG) and the change was adopted by the Basin Officials Committee (BOC). The change allowed for a proportion of the releases made towards the end of a period of airspace management to be accounted as water for the environment when orders to deliver this water were in place. The approach was used for the first-time during 2021 and carried forward into the 2022–23 water year with new enhancements in place.

With careful planning and communication, the releases of water for the environment were managed to target ecological benefits and build resilience in Murray System ecosystems. The releases, which took place from mid-July to early August provided a low-level 'over-bank' watering of the Barmah-Millewa Forest (with accounting in accordance with the General and Specific O&Os), whilst simultaneously helping to increase airspace in Hume Dam.

In accordance with environmental water holder water orders, Barmah-Millewa Forest Environmental Water Allocation (BMFEWA) was used as part of the environmental delivery, which targeted a flow of 15,000 ML/day downstream of Yarrawonga weir. Releases to target 15,000 ML/day at Yarrawonga weir commenced after flows through Yarrawonga Weir peaked at 28,000 ML/day in late June before receding into July. The environmental water releases continued until renewed rainfall and higher inflows necessitated higher releases from Hume Dam to manage airspace in early August.

85 GL of environmental water released from Hume Dam.

From 18 July, the water for the environment delivery was managed in conjunction with the re-filling of Lake Mulwala following its partial winter draw-down during May which was maintained during June to control the evasive water weed *Egeria densa*. Lowering the lake by up to 5 metres below full supply level (FSL), enabled the weed to be exposed to frost events during winter.

Inflows from the Upper Murray combined with elevated Murrumbidgee inflows (averaging 12,700 ML/day at Balranald) and continued high inflows from the lower Darling system, averaging 15,900 ML/day at Burtundy, continued across July. These elevated flows helped to maintain unregulated flows in the lower reaches of the Murray system and into South Australia, despite the relatively low rainfall across the southern Basin during July.

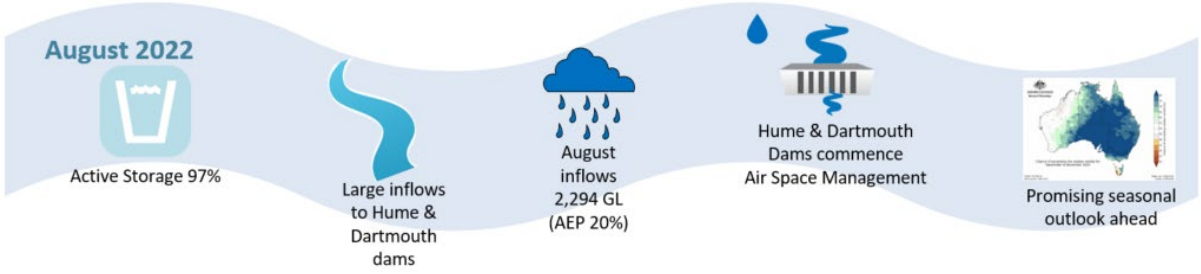
On Thursday 28 July, a directed release from Lake Victoria commenced with the anticipation of boosting a peak flow height to South Australia by using up to 100 GL of environmental entitlements. The subsequent filling of Lake Victoria would be managed within the requirements of the Lake

Victoria Operating Strategy (LVOS) and the need to bring the storage to effective full supply at the conclusion of the unregulated flow period, less the 100 GL directed release order volume.

Despite conditions drying through July, relatively high storage levels and further indications from the Bureau that wet conditions could re-develop into spring meant that airspace requirements at both Dartmouth and Hume Dams continued to be a focus. Target airspace calculations were monitored, and release plans regularly revised to steer towards these targets in response to observed and forecast inflows and demands. These airspace management releases helped to balance downstream flood risks (associated with high storage levels) against the requirement to store water up to the specified filling target (99% capacity under a 'without environmental water' scenario) under a realistic range of possible future inflows by the time downstream demands emerge.

At Dartmouth Dam, the drier conditions observed in July meant the storage could not yet be filled under the 'very high probability of filling' risk profile adopted by the Basin Officials Committee (BOC). However, airspace calculations indicated airspace management releases were highly likely to be triggered as soon as further significant rain and inflow occurred. 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 at Dartmouth Dam was imminent.

August 2022



Conditions in August 2022 shifted wet, with well above average rainfall across much of the Murray–Darling Basin (**Figure 13**). Some areas of central New South Wales recorded totals that were highest on record for the month. The Bureau reported that area averaged rainfall across the Murray–Darling Basin was 58.6 mm in August 2022. This was 49% above the long-term August average for the Basin and the highest August figure since 1985.

System inflows for August: 2,294 GL

River Murray system inflows for August (excluding Snowy, Darling, IVT and environmental inflows) increased substantially compared with July and reached almost 2,294 GL. This was within the highest 22% of system inflows on record for August. However, unregulated inflows to Hume and Dartmouth Dams were even more significant. Inflows to these 2 storages were within the wettest 9% and 6% (respectively) of August inflows and the fourth highest inflows for any month since 2000.

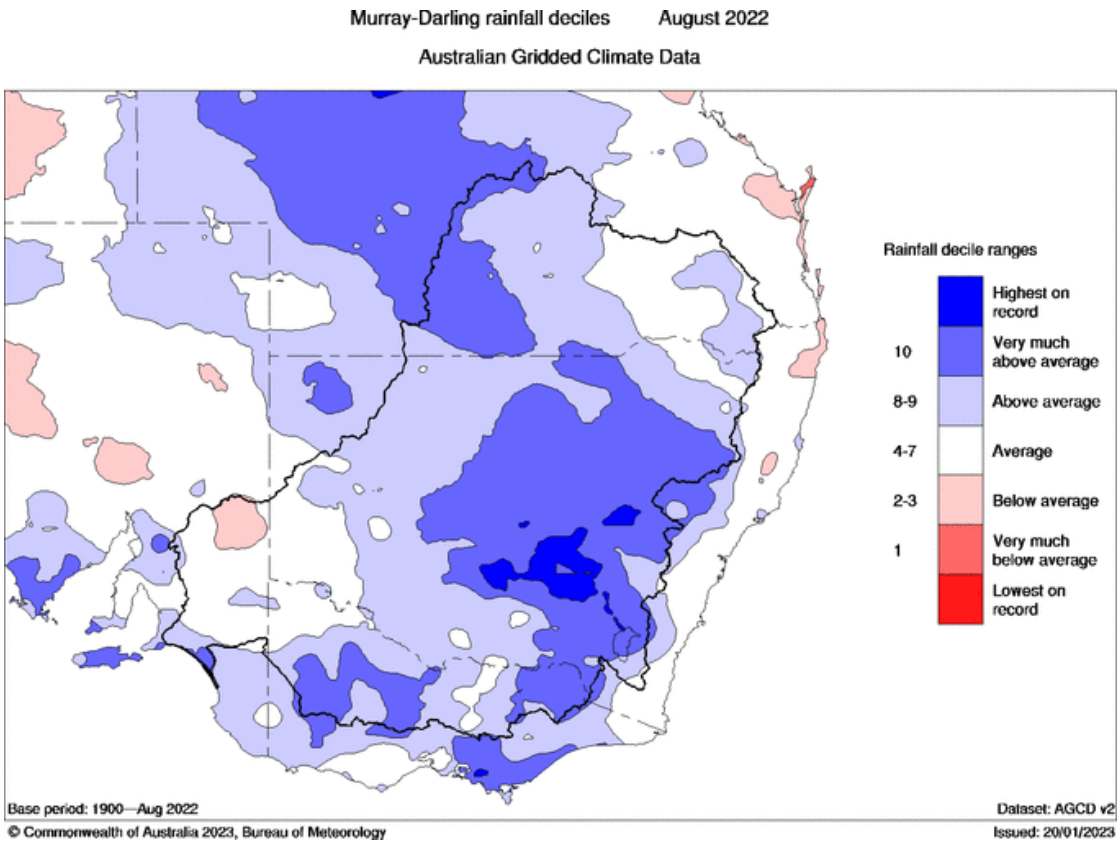


Figure 13: Murray–Darling Basin rainfall deciles for August 2022. (Source: Bureau).

The high inflows for August were kick-started early in the month following significant rain over several days across the south-eastern Basin with falls in excess of 100 mm across parts of the Kiewa, Mitta Mitta, upper Murray, and Murrumbidgee catchments (**Figure 14**).

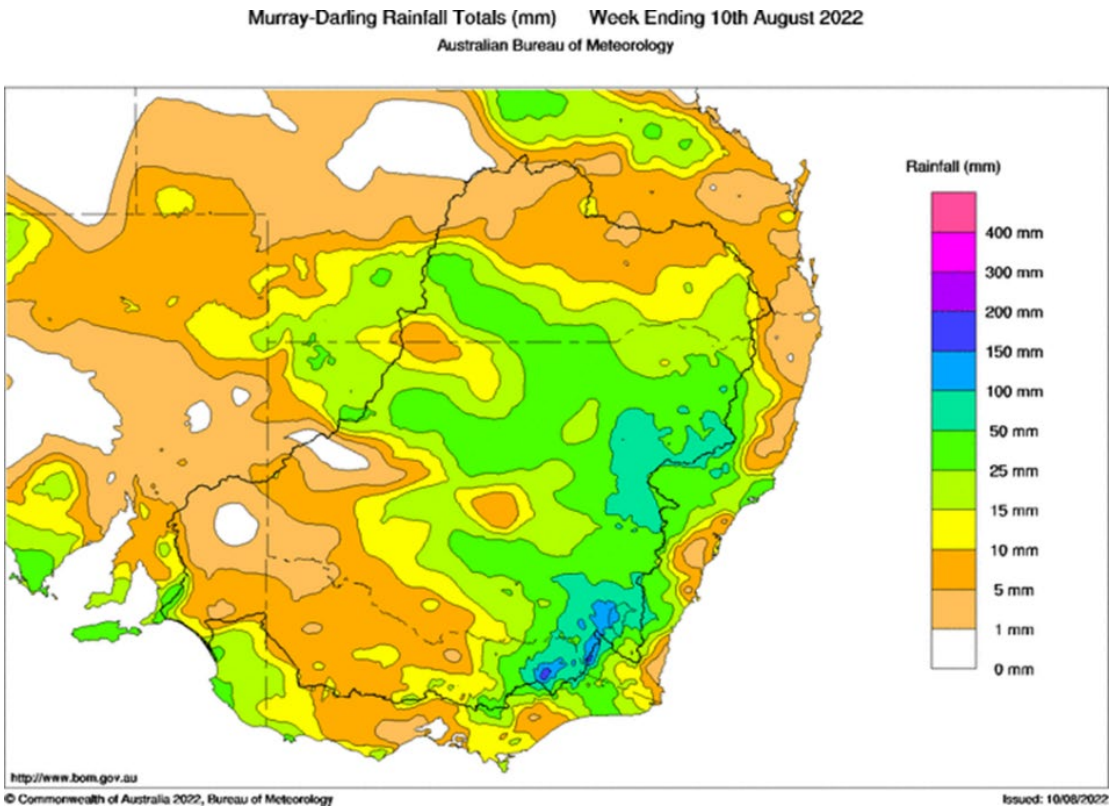


Figure 14: Murray–Darling Basin rainfall totals for the week ending 10 August 2022 (Source Bureau).

At the beginning of August, updated scenario testing with the addition of potential inflows from forecast rain indicated Dartmouth Dam pre-releases could begin within days (**Figure 15**).

On August 5, with actual rain and inflows on the higher end of the range of forecasts, airspace management releases were commenced. Releases were stepped up further over the following days and adjusted to target rates around channel capacity at Tallandoon by 9 August as the storage level increased to 80 GL below FSL with higher inflows persisting.

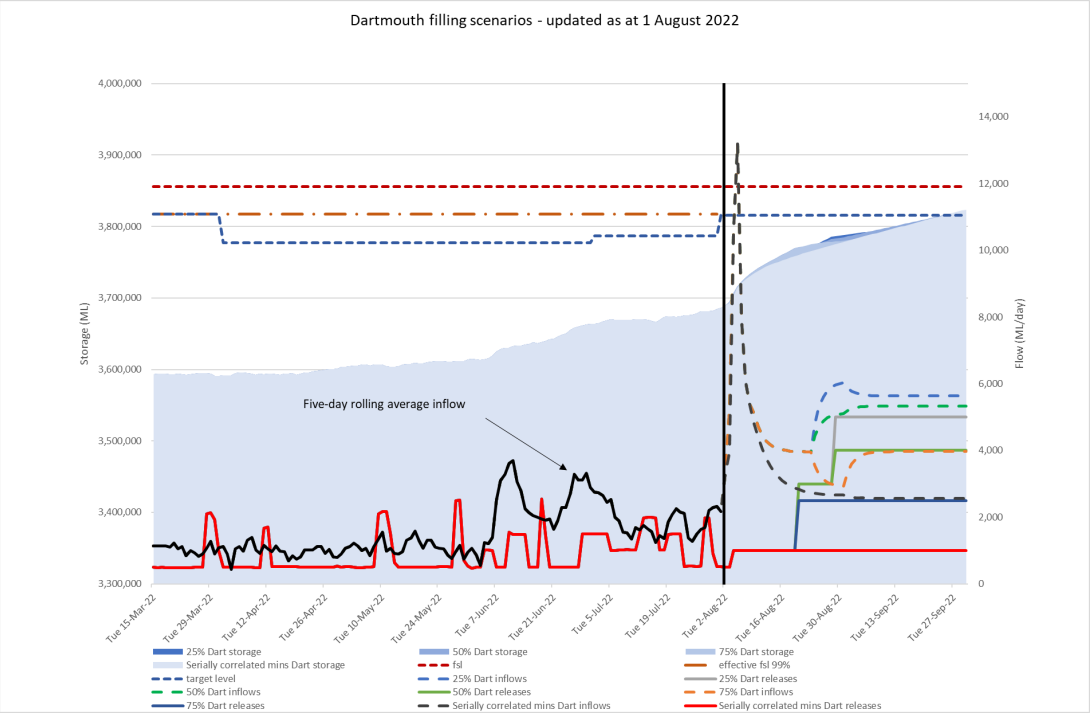


Figure 15: Dartmouth Dam airspace planning scenarios as of 1 August. Additional inflows in the near-term based on forecast rain indicated airspace releases would be necessary under all but the 'Serially Correlated Minimum' inflow scenario. Subsequent (observed) inflows from the rain event were on the higher end of the forecast range with airspace management releases beginning on 5 August.

With the step up to Dartmouth Dam releases to manage airspace, the Dartmouth storage level remained fairly steady for much of August. However, rainfall events towards the end of the month saw the level rise further and reached 99% capacity on 31 August. At this level, the Dam exceeded the 'target level' set in Part 3 of Schedule D to the *Dartmouth Power Station Agreement* and was also considered 'effectively full' (from a water storage perspective) under the O&O.

> *"Over any period during which the level of water in the water storage remains above the target level specified below. The release of water for electricity generation may be any volume required by the southern hydro".*

The rainfall at the beginning of August also resulted in large streamflow responses in other Murray tributaries. Upstream of Hume Dam, flows at Jingellic peaked around 52,000 ML/day, while on the Kiewa River at the Bandiana gauge, flows peaked around 5,800 ML/day on 12 August. On the Ovens River at Wangaratta, flows peaked on 8 August at almost 21,000 ML/day.

As a result of this event and the increase to forecast inflows, updated pre-release analysis confirmed that release requirements for airspace management at Hume Dam exceeded the rates needed to meet environmental orders on 3 August. As inflows increased towards a peak of around 65,000 ML/day on 6 August, further release increases were needed as high inflows persisted and

RMO transitioned from ‘pre-releases’ into flood operations on 5 August as flows at Doctors Point exceeded regulated channel capacity (25,000 ML/day).

There were further rainfall events throughout August, most notably on 23 and 30 August (**Figure 16**, **Figure 17**), that further boosted flows along Murray tributaries. On the Ovens River at Wangaratta, flows peaked on 25 August at around 24,000 ML/day; whilst on the Kiewa River at the Bandiana gauge, flows reached an instantaneous peak just under 10,000 ML/day on 30 August.

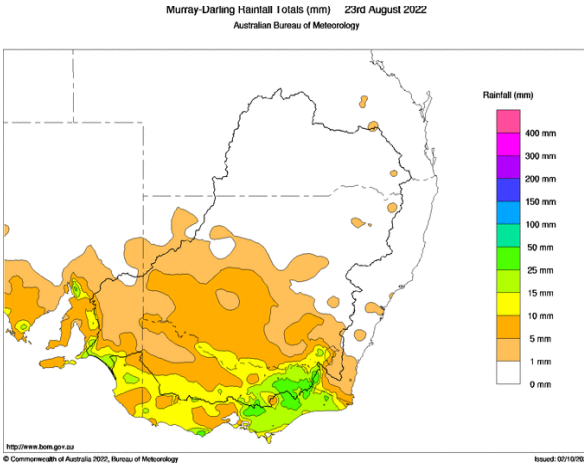


Figure 16: Murray–Darling Basin rainfall totals for 23 August 2022 (Source Bureau).

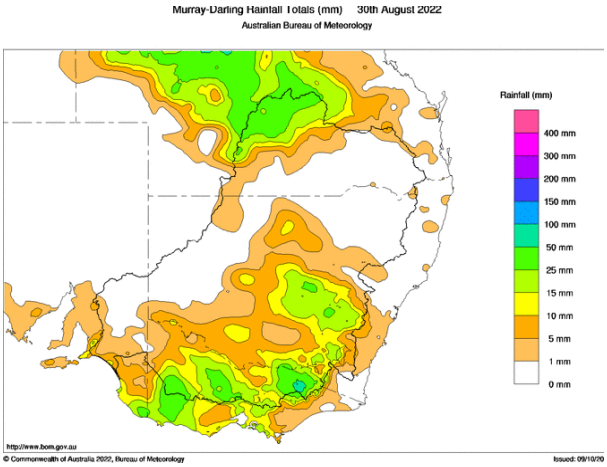


Figure 17: Murray–Darling Basin rainfall totals for 30 August 2022 (Source Bureau).

Releases at Hume Dam were stepped up to rates above 30,000 ML/day by 7 August and then maintained in the range 30,000 to 36,000 ML/day across the remainder of month to maintain airspace as further rain and elevated inflows continued and resulted in more than 1,000 GL entering the storage from 1-31 August. Releases were also adjusted in response to changing Kiewa River inflows to help manage river levels and reduce community impacts downstream. Although flows at Doctors Point remained above channel capacity, the river remained below 41,000 ML/day at this gauge and below the minor flood level at Albury throughout August.

With airspace management transitioning quickly to flood operations following heavy rainfall at the beginning of the month, releases from Yarrawonga Weir increased on 7 August from a targeted rate of 15,000 ML/day (delivering an order from Environmental Water Holders) to significantly higher rates driven by flood operations releases from Hume Dam combined with elevated tributary inflows from the Kiewa and Ovens Rivers. As the wetter conditions persisted across the month, these inflow-driven conditions and the connection with and passing of flows from catchment areas upstream of Hume and Dartmouth Dams maintained high flow rates downstream of Yarrawonga Weir that were well above environmental delivery target rates for the rest of August and into spring.

Within these high flow conditions, Lake Mulwala was re-filled from the partial drawdown over winter to the normal operating level from around 124.6 to 124.9 m AHD on the planned date of 15 August, by which time downstream releases had reached 40,000 ML/day. By the end of August, flows had exceeded 60,000 ML/day and RMO were targeting pool levels in the lower end of the normal operating range to provide an airspace buffer whilst flows were high as per the standard flood operations approach for Yarrawonga Weir.

During August, WaterNSW continued to make significant airspace releases from Blowering and Burrinjuck Dams as heavy rain and high inflows also impacted the upper Murrumbidgee catchments. This resulted in flows in the Murrumbidgee at Balranald persisting at around 12,000 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, with flows through the inlet reduced. The LVOS aims to stabilise the lake foreshore and protect cultural heritage sites by encouraging the growth of native vegetation. To help achieve this, river 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, according to LVOS storage targets, to provide a lake shore drying cycle.

Meanwhile, on the Darling River, inflows to Menindee Lakes receded to 20,000 ML/day at the end of August, with the lakes reaching a peak level of 2,000 GL (115%) around the middle of the month. However, inflows were expected to increase again off the back of further heavy rain across parts of the northern Basin during July and August. This would see WaterNSW maintain high releases from the Menindee Lakes into spring and cause flows from the lower Darling River into the River Murray to steadily rise as flood waters from the northern Basin continued to move along the Barwon-Darling River system and into the Menindee Lakes.

With Hume and Dartmouth Dams also close to full, the trigger for Additional Dilution Flow (ADF) continued to be met. When triggered, ADF provides an additional 3,000 ML/day to South Australian Entitlement. However, with unregulated flows into South Australia continuing, no additional releases from storage were needed for ADF delivery.

By the end of August, MDBA major storages remained high, with Hume Dam (96% capacity), Dartmouth Dam (99% capacity), Lake Victoria (59% capacity) and Menindee Lakes (111% capacity), all undertaking airspace management and effectively spilling. These storage levels were also sufficient for Tier 1 water sharing arrangements to remain in place as expected.

Heading into spring, the Bureau's climate outlook for September to December (released in late August) indicated that spring rainfall was likely to be above median for the Murray–Darling Basin. As well as the potential for a La Niña event, a weak negative Indian Ocean Dipole was forecast to continue. Over the coming months, it was therefore likely that early season water availability for Murray entitlement holders would be high, whilst operationally, RMO remained alert to the high likelihood that flood operations would persist into spring at key Murray system storages and high inflows from flooding along tributaries were also more likely to occur.

Given the situation, the MDBA continued to work closely with Bureau flood forecasters in sharing advice on likely streamflow responses from forecast rain events and possible release requirements from storages that could influence flood levels along the river. This close cooperation between agencies was also extended into the provision of targeted external engagement and communication with key stakeholder and community groups such as downstream landholders along the river. In particular, the MDBA, with Bureau support, increased the provision of on-line Hume Dam public briefings during August (that had re-commenced in 2022 during May) to a weekly timetable in order to help support and inform the community of the operational situation and the evolving catchment, inflow and climate conditions that were influencing overall flood risk.

Quarter 2

Historically during quarter 2 (Q2), the focus of river operations is to capitalise on healthy tributary inflows that can boost storage in Lake Victoria and help set up the system for summer. The coordinated release of water for the environment can also be a priority to help build on the benefits of natural tributary inflows where possible. During wetter years, headwater storages may require airspace management releases to occur, further elevating flows through the system. During these years, airspace management and potential flood operations become the primary focus for operations until high inflows recede and demands emerge.

In 2022, Q2 began with above average rainfall continuing and a strong focus on flood operations at Dartmouth Dam, Hume Dam and Yarrawonga Weir. Wet conditions then persisted through Q2 across the Murray–Darling Basin, with very high rainfall totals over Murray system catchments and along the river itself. In response, storages across the River Murray system continued to spill, with flood operations occurring for all of Q2. Operational planning during Q2 was strongly focused on managing unregulated flows to South Australia and airspace at Lake Victoria guided by the Lake Victoria Operating Strategy (LVOS).

During October, a very significant rainfall event affected much of the southern Basin with the heaviest rain over the Kiewa, Ovens, Goulburn, Campaspe, Loddon and Murrumbidgee river systems. The event produced rainfall totals at some locations that were well above the top end of most Bureau of Meteorology model guidance in the lead up to the event. Major flooding occurred along many tributaries as a result of this event with flood peak and rainfall records broken at a number of locations. Flood waters then moved progressively into the Murray with flows peaking at Torrumbarry Weir around late October and large volumes of water moving into the Edward-Wakool system in southern New South Wales.

Follow up rain events at the beginning and mid-way through November were more focussed over upper Murray catchments and resulted in a considerable step up in flood operations at both Dartmouth and Hume Dams. This led to more significant flood peaks upstream and downstream of Hume Dam, further flooding along tributaries, major flooding downstream of Yarrawonga Weir, and an extension of flooding along the mid to lower Murray as flows connected with and then built upon the earlier flood peaks and on-going high inflows from the Murrumbidgee and Darling/Baaka Rivers.

As heavy rain continued and high inflows continued across the Basin, the MDBA used a range of modelling expertise to assist states and response agencies in the complex process of tracking and forecasting the movement of flood waters from tributaries and storage releases into the River Murray, through the Edward-Wakool system and on towards the lower Murray in South Australia.

Key achievements for Q2

Successful flood management at Dartmouth and Hume Dams and Yarrawonga Weir, with RMO able to safely pass events downstream whilst mitigating multiple high flow events during a period of record rain and inflow for the October-November period.

Management of unregulated flows and operation of Lake Victoria in accordance with the Lake Victorian Operating Strategy in response to evolving inflow conditions and significant flooding across multiple Murray–Darling Basin river systems.

The successful use of the *Source* Murray Model to develop scenarios and provide advice on forecast flood peaks in the mid to lower Murray. This provided valuable input to state constructing authorities, operators, and emergency response organisations on peak flows and timing of flood impacts to help plan and manage one of the most significant River Murray flood events in the historic record.

Key external drivers influencing operations in Q2

Spring is historically the period of seasonally high inflows. The inflows of spring 2022 were the highest ever recorded. As such, many of the key drivers of Q1 remained applicable or strengthened in relevance across Q2. In this respect, River Murray Operations recognised 4 **Key Drivers** that shaped Q2.

- **Key Driver 1 - 'Persistent very wet conditions' –** The quarter began with the Bureau outlook for above average rainfall across much of the Murray–Darling Basin coming to fruition as the re-commencement of *La Niña* was confirmed by the Bureau on 13 September. Above average rain in September transitioned to highest-on-record rainfall during the October-November period for much of the southern Basin. In response, much of the focus for river operations was on flood operations and the management of storages in response to very high inflow.

- **Key Driver 2 – 'Wet Murrumbidgee catchment' –** Q2 saw wet conditions in the Murrumbidgee catchment 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 inflow to the River Murray system remaining well above the end-of-system target and building steadily towards a major flood peak by the end of November. These substantial inflows continued to significantly influence broader River Murray system operations,

including the extent and volume of unregulated flows and the operations undertaken at Lake Victoria.

- **Key Driver 3 – 'Operation of Menindee Lakes' –** Continuing high flows in the Barwon-Darling system resulted in almost 2,600 GL flowing past Wilcannia and into the Menindee Lakes during Q2. With the storage at 110% (1,905 GL) on 1 September, flood operations and high releases were required by WaterNSW throughout the Q2 period. Inflow rates to the Menindee Lakes were continuing to rise at the end of Q2 with one of the highest flood peaks in the historic record anticipated to arrive at the storage by late December (during Q3). By the end of Q2, WaterNSW had advised that significant releases would be necessary to manage this peak, with the storage likely to remain in surcharge well into summer. These high releases from the Menindee Lakes would influence broader system operations by joining with flood waters in transit from the upper Murray, Murrumbidgee system and the Victorian tributaries and into South Australia.

- **Key Driver 4 – 'Continued flood operations at Dartmouth and Hume Dams'-** Q2 brought multiple significant rainfall events for the upper Murray catchments resulting in extended flood operations. Airspace management at Dartmouth Dam helped delay spillway flows until late September and maintain flows in the lower Mitta Mitta River to within channel capacity until mid-October. Larger inflow events during November were mitigated through the storage due to the attenuation effect of spillway flow. During Q2, RMO was able to successfully manage storage airspace at Hume Dam through multiple inflow events and provide mitigation of several flood peaks for downstream communities. 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, both storages were continuing to spill whilst inflows were generally receding from peak rates.

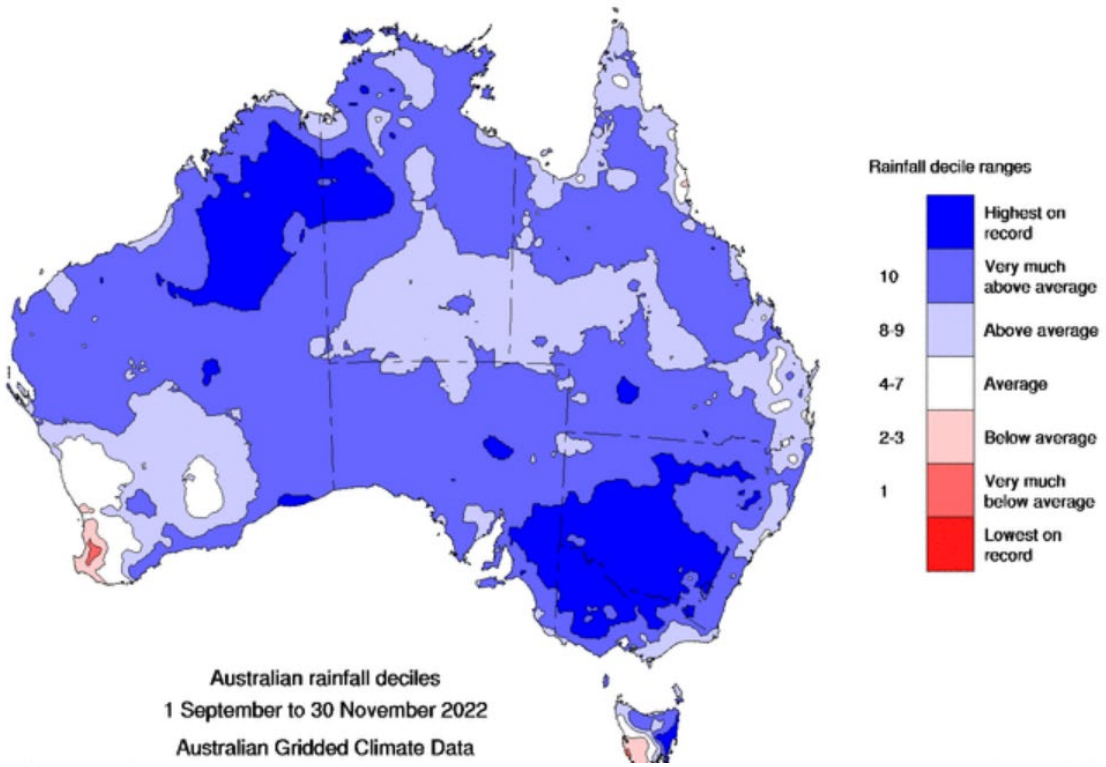


Figure 18: Murray–Darling Rainfall deciles for Q2 indicate highest on record rainfall across much of the southern and central parts of the basin, with the nothern basin experiencing mostly very much above average conditions (Source: Bureau).

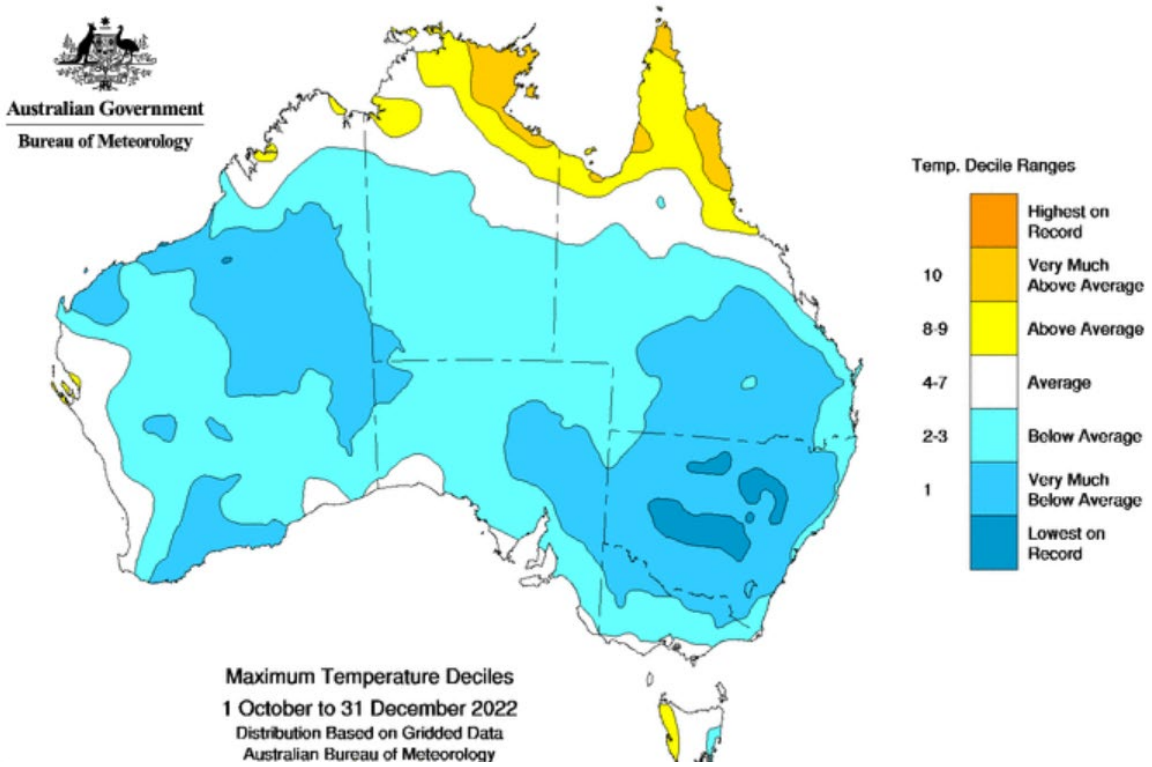


Figure 19: Maximum temperature deciles for Q2 show very much below average conditions through the basin with isolated areas of lowest on record through central New South Wales (Source: Bureau).

Key metrics for Q2

The operational metrics in **Table 7** provide a snapshot summary of river operations for Q2**.** All figures should be considered within the context of the key drivers outlined above.

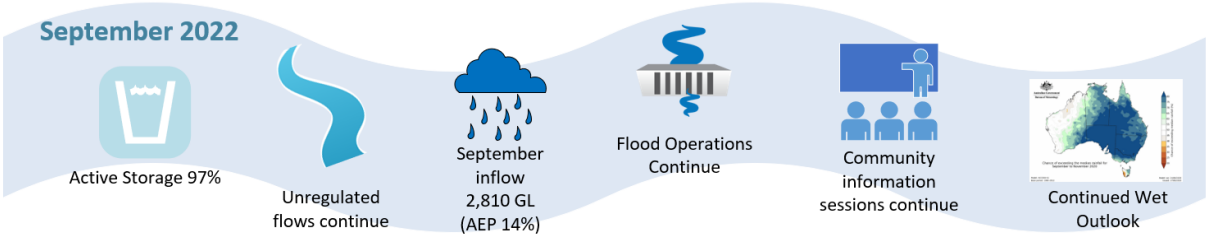
Table 7: Key metrics for River Murray system operations during Q2.

Metric		Quarter 2 [i]
Total River Murray system inflows [ii]		13,233 GL (1% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↑ 79 GL due to capture of inflows and airspace management (spill) ↑ 6 GL due to capture of inflows and airspace management (spill) ↑156 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS) ↓ 161 GL due to airspace management releases occurring (spill) as anticipated high inflow arrive in Q3
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	866 GL comprising of airspace management releases (spill) 4,299 GL comprising releases for airspace management (spill) 3 GL due to the management of storage filling (spill) and the LVOS during unregulated flows 2,239 GL releases to the lower Darling River and 166 GL released to the Great Darling Anabranch for airspace management (spill)
	IVT	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		70 GL Victorian Murray 228 GL NSW Murray
River Murray system loss [v]		2,163 GL (15%)
Environmental directed releases from Hume [vi]		0 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	7,013 GL 174 GL 312 GL 28 GL 98 GL 6,401 GL due to unregulated flows and additional dilution flows (ADF).

Metric	Quarter 2 [i]
Publication of operational information	13 MDBA Weekly Reports 21 Media Releases on 'river operations' 14 Alert & advice articles on the ongoing flooding

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 as a result 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 2022



At the start of spring 2022, the active storage in the MDBA's reservoirs was at 97% capacity (8,315 GL), higher than the 84% capacity observed the previous year (i.e., on 1 September 2021) (**Figure 20**). Rainfall for the Murray–Darling Basin in September 2022 was reported by the Bureau as the fourth highest on record (since 1900) with rainfall within the highest decile range for large areas of New South Wales, northern Victoria, and southern Queensland. Rainfall across the upper Murray and Victorian tributary catchments was broadly above average (**Figure 21**). As a result of the wet conditions, River Murray system inflows for September (excluding Snowy, Darling, IVT and environmental inflows) increased to around 2,810 GL and were within the highest 14% of inflows on record for September.

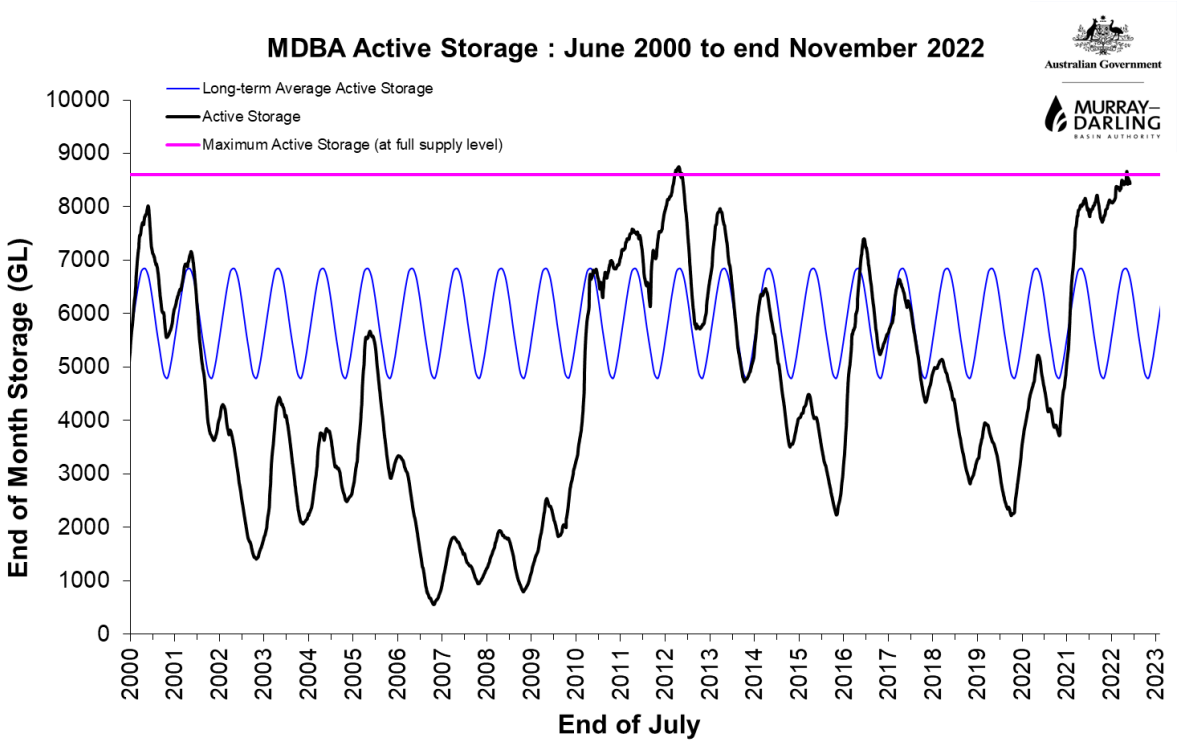


Figure 20: The River Murray system total active storage exceeded the maximum level by the end of Q2 with Dartmouth Dam, Hume Dam and Lake Victoria close to 100% and the Menindee Lakes surcharged above 100%.

Operations at Dartmouth Dam continued to focus on airspace management during September as high inflows during August continued into spring. By late September, almost 300 GL had been released from Dartmouth Dam for airspace management (at flow rates targeting a level at or below the downstream channel capacity of 10,000 ML/day at the Tallandoon gauge) to help delay storage filling, and minimise the chance of spillway flows occurring, to the extent possible. However, with the persistent wet

conditions and above average inflows, the storage level reached the full supply level (FSL) on 22 September and spillway flows commenced for the first time since 1996.

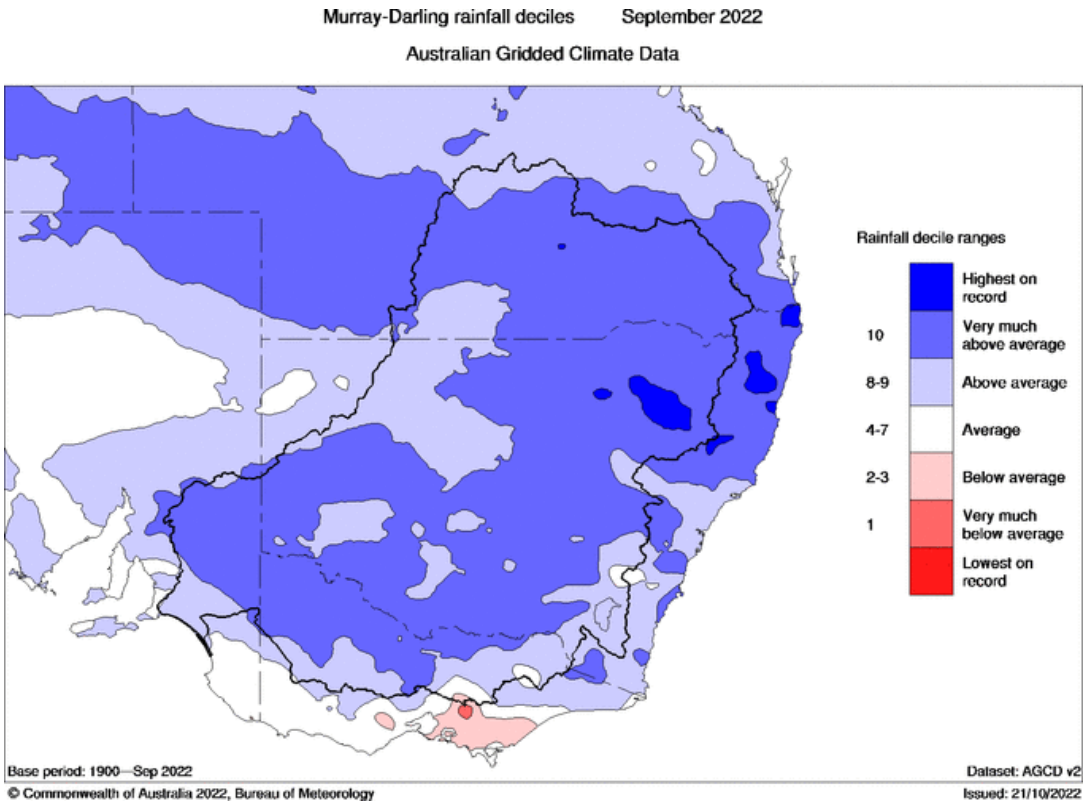


Figure 21: September 2022 Murray–Darling Basin rainfall deciles showing mostly above average to very much above average conditions (Source: Bureau).

As per standard operating arrangements, operation of the Dartmouth Power Station was ceased by the power station operator (AGL Hydro) as the 'physical spill' over the spillway began. Storage releases would then be driven by the flow rate over the spillway (initially low rates well below channel capacity) that in turn was dependent on the amount of inflow and the resultant storage height above FSL during the weeks ahead. Allowing all releases to pass over the spillway would also ensure that the full attenuation effect of the spillway design would be used to mitigate downstream flows compared to inflows to the dam.

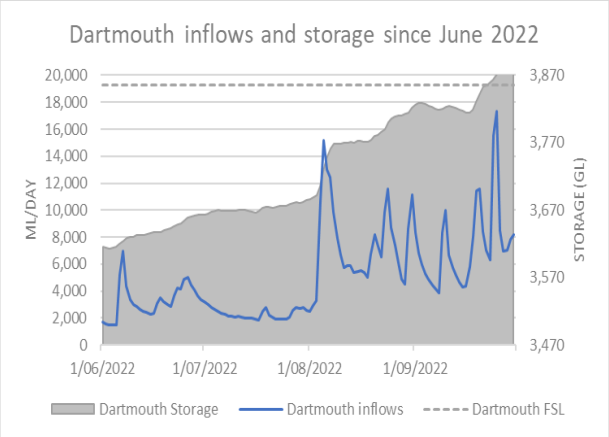


Figure 22: Dartmouth Dam storage level and inflows from June-September 2022. Airspace releases during August and September delayed the storage reaching FSL as high inflows continued. Spillway flows eventually started on 22 September.

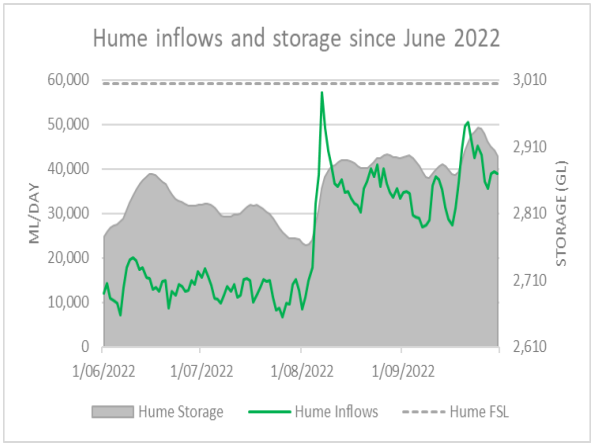


Figure 23: Hume Dam storage level and inflows from June-September 2022. Airspace was managed with additional releases below channel capacity until early August when rainfall and inflows increased. Airspace management releases were stepped up to maintain airspace whilst a number of inflow peaks were mitigated downstream.

At Hume Dam, high inflows and flood operations persisted during September (**Figure 23**), with repeat rain events requiring releases to continue for airspace management.

In the second week of September, a cold front delivered rain across south-eastern Australia with totals over 50 mm recorded at some locations across the upper Murray, Ovens, Kiewa and Goulburn River catchments (**Figure 24**). A second rainfall event in mid-September saw rainfall totals of up to 50 mm each day over a 5-day period, largely concentrated over north-east Victoria and the New South Wales Snowy Mountains. Totals across this period exceeded 100 mm at some locations (**Figure 25**).

Releases were maintained within a range of about 30,000 – 35,000 ML/day to manage these inflows until 21 September. It was then necessary to increase releases progressively to 48,000 ML/day by 26 September, as inflows reached a peak above 55,000 ML/day. This increase ensured flood peak mitigation was achieved as airspace decreased below 70 GL, but also took account of updated forecasts and receding inflows towards the end of the month to regain airspace to mitigate further rain events going forward. By the end of the month, airspace was back above 100 GL and continuing to increase and releases had been eased to 45,000 ML/day. With wet conditions forecast through to December in updated Bureau outlooks (**Figure 26**), a revised assessment of target airspace and filling risks supported the need to continue increasing airspace into October to further improve potential flood peak mitigation for further events.

The river level at Albury reached Minor flood level on 23 September and remained above this level for the remainder of September, with inflows from the Kiewa River that exceeded 12,000 ML/day contributing significantly to the combined flow. Flows at Doctors Point remained above channel capacity (25,000 ML/day) for all of September, whilst further downstream at Corowa, the river reached Moderate flood level on 27 September as higher flows arrived from upstream.

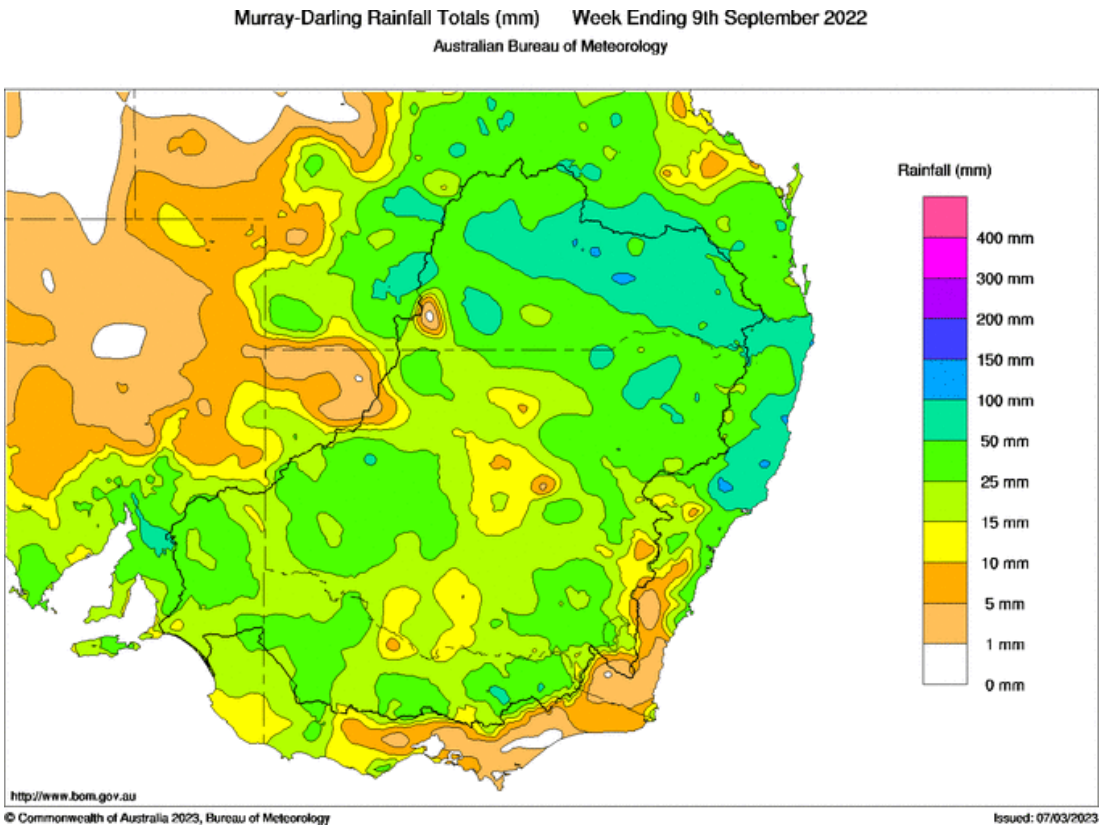


Figure 24: Murray–Darling Basin rainfall for week ending 9 September 2022 (Source: Bureau).

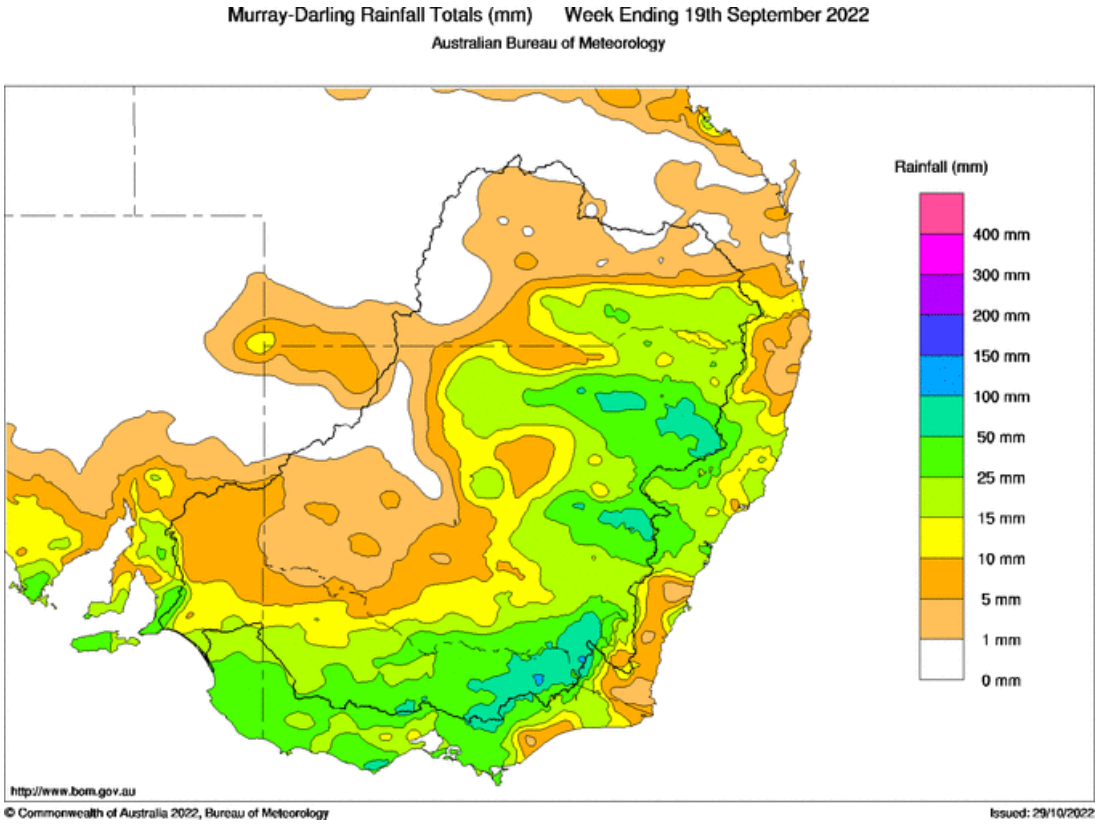


Figure 25: Murray–Darling Basin rainfall for week ending 19 September 2022 (Source: Bureau).

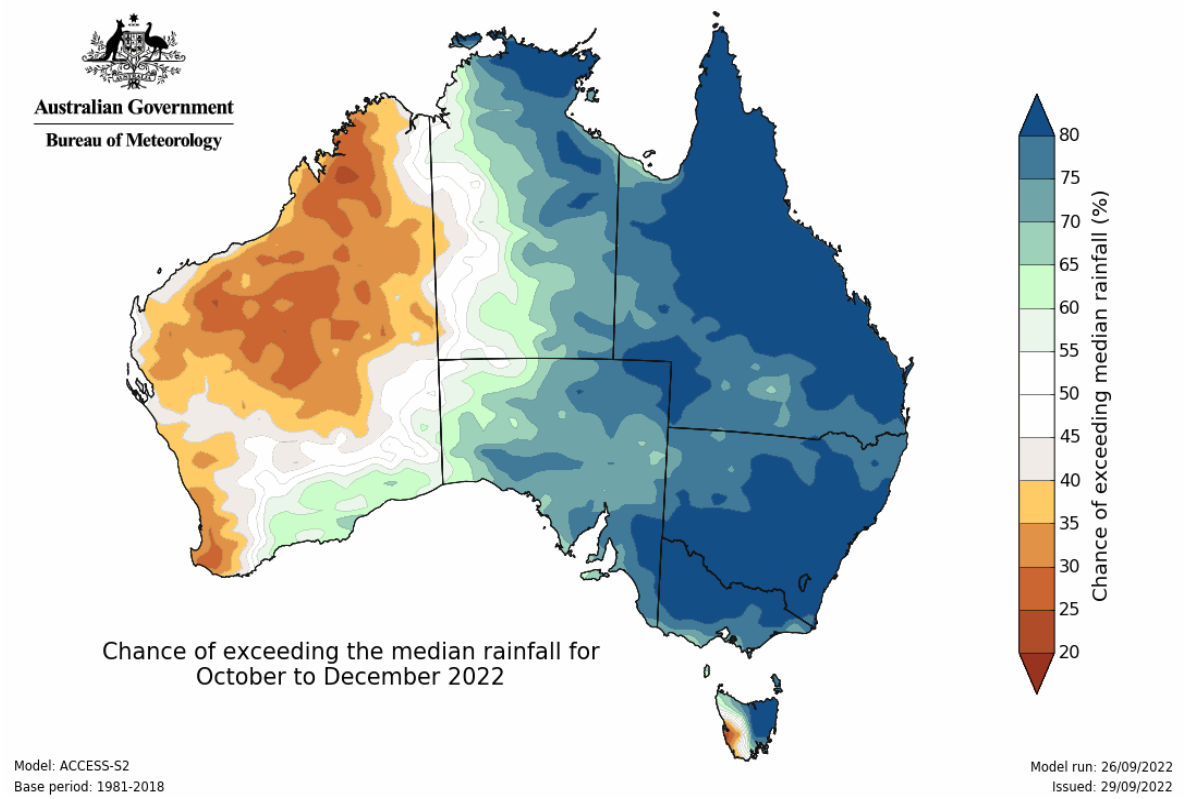


Figure 26: Chance of exceeding median rainfall for October – December 2022 as of late September 2022 (Source: Bureau).

As Hume Dam releases were increased to some of the highest rates required for some years, the potential arose for inconsistencies between the measured release from the dam and the gauged flow at the Heywoods site (immediately downstream of the dam). These differences result from changes to the channel profile that can occur during the large period of time between high flow events. In response to an observation that the flow rating at Heywoods was at times higher than the targeted release (based on outlet settings), the MDBA worked with WaterNSW to arrange flow gauging's at Heywoods as well at other gauges such as Doctors Point and Corowa on the Murray, and Bandiana on the Kiewa River to determine and cross-check the extent of these measurement differences and if rating tables needed to be revised.

This action resulted in an updated rating table for Heywoods, which upon implementation provided more consistency with outlet-setting 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.

With flood operations at Hume Dam extending right across September, the MDBA also continued its focus on informing communities on the operational situation at Hume Dam in collaboration with stakeholder agencies such as the Bureau and the State Emergency Service (SES). In particular, online Hume Dam operations briefings to downstream community stakeholders were continued during September, delivered on a weekly basis or as conditions required. These briefings covered catchment conditions, storage releases, forecast rainfall, inflows, and the storage operational plans for the coming week.

Positive feedback was received from the community on the format and content, which aimed to improve understanding of flood risks and the need to be prepared for possible flooding both upstream and downstream of Hume Dam.

In addition to the high inflows across the upper Murray tributaries, elevated inflows continued to reach the Murray from major tributaries further downstream. In response to continued rainfall and elevated inflows from the Murrumbidgee catchment, WaterNSW continued to actively manage airspace at Blowering and Burrinjuck Dams. The resultant releases from these dams along with tributary inflows meant inflows from the Murrumbidgee to the Murray grew steadily across the month. At the Balranald gauge (just upstream of the Murray junction), flows during September averaged near 16,000 ML/day, well above the end of system target flow for September of 1,330 ML/day with the daily flow rate exceeding 23,000 ML/day by the end of September.

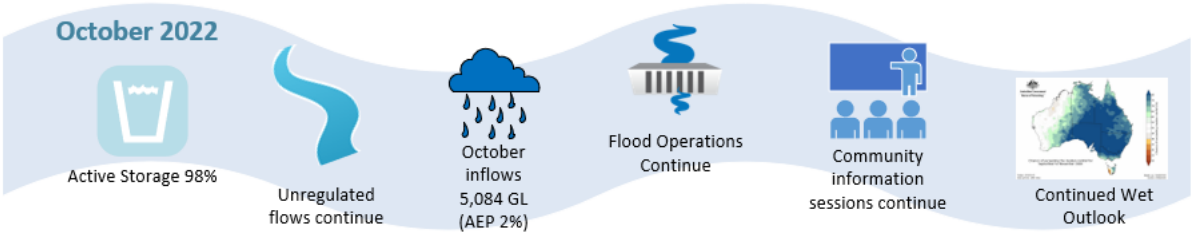
Similarly, WaterNSW had been closely monitoring the Barwon-Darling flows and assessing the capacity to store all inflows in the Menindee Lakes. As further rain fell in the northern Basin, revised forecasts indicated that increasing flows in transit along the Barwon-Darling/Baaka River were likely to raise the storage towards the Maximum Induced Surcharge Level (MISL) unless releases above 20,000 ML/day were continued. By 30 September, revised forecasts indicated further release increases would be needed during October. Releases into the Great Darling Anabranch also continued during September, averaging 1,900 ML/day. As well as helping to maintain airspace for flood mitigation, these releases targeted environmental benefits along the Anabranch.

As a result of high flows throughout the River Murray system and increased releases for airspace management at Dartmouth and Hume Dams, unregulated flows extended along the entire river downstream from Hume Dam, including in the Edward-Wakool System. On 5 September the gauged height at Picnic Point reached 2.6 m, even with all forest regulators being opened. As per SO&O 4.2 and 5.4., RMO contacted Picnic Point community members to advise that levels above 2.6 m were expected to occur if wet conditions persisted and flows through the Barmah-Millewa Forest continued to build.

Downstream at Torrumbarry Weir, increasing flows were arriving from both the Murray and the Goulburn River and were forecast to rise further. In response, the structure's radial gates were lifted clear of the water on 12 September. This is an operational requirement for Torrumbarry Weir that maintains dam safety requirements and allows for clear passage of flows through the structure during high flow periods.

Flows into South Australia continued to rise across September and averaged nearly 50,000 ML/day. As flows increased, interest grew in predictions of the timing and ultimate peak flow rate to South Australia if wet conditions persisted. To assist South Australia in understanding potential flow rates and plan flood response and community safety management and communication requirements for stakeholders, RMO held regular discussions with the South Australian Department for Environment and Water. Discussions were also held with Environmental Water Holders, who were considering using water for the environment to boost flows into South Australia up to a maximum rate of around 80,000 ML/day. This action would be ceased if on-going wet conditions upstream pushed flows above this rate. The 80,000 ML/day target was seen as an opportunity to provide multiple benefits to flood plain areas throughout the lower Murray system in the event that conditions dried off and flows peaked below this rate. However, ultimately a much higher flow peak occurred, and the action was ceased accordingly.

October 2022



Conditions during October became even wetter than September, with record October rainfall (for historical observations since 1900) across a large portion of the central, southern, and western Murray–Darling Basin (**Figure 27**) and as an area average for the Basin as a whole.

Examples of very high monthly rainfall totals recorded during October include 490 mm at Mt Buller (Goulburn River catchment), 412 mm at Falls Creek (Kiewa River catchment), 322 mm at Hunters Hill, 242 mm at Khancoban, 198 mm at Albury, and 143 mm at Jingellic (upper Murray River catchment) (**Figure 28**).

The River Murray system inflow for October (excluding Snowy, Darling, IVT and environmental inflows) of almost 5,084 GL was amongst the highest 2% of October inflows on record. And whilst active storage in the MDBA's reservoirs stood at 98% capacity (8,448 GL) in October, the system was effectively sitting at maximum storage with airspace management continuing at all 4 storages meaning there was sufficient forecast inflows to reach effective full supply once conditions dried off.

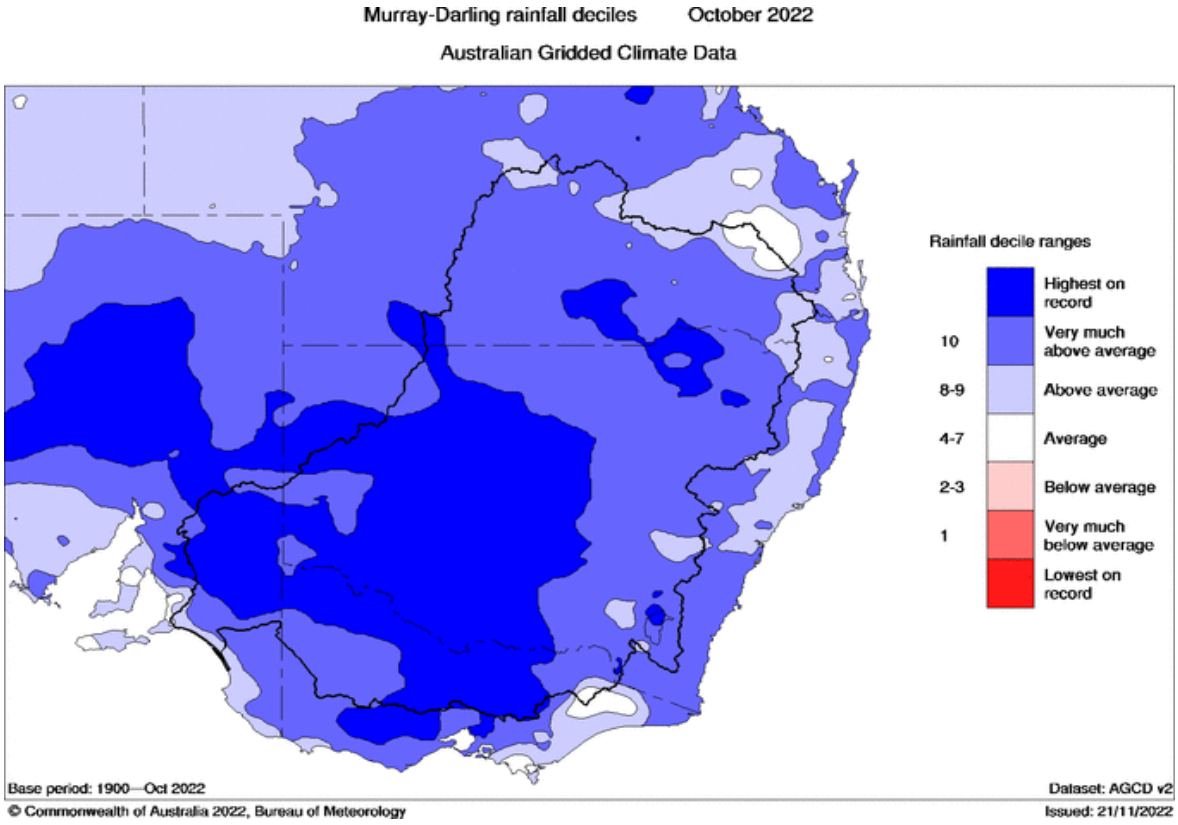


Figure 27: October 2022 Murray–Darling Basin rainfall deciles showing very much above average to highest on record rainfall deciles across much of the Basin (Source: Bureau).

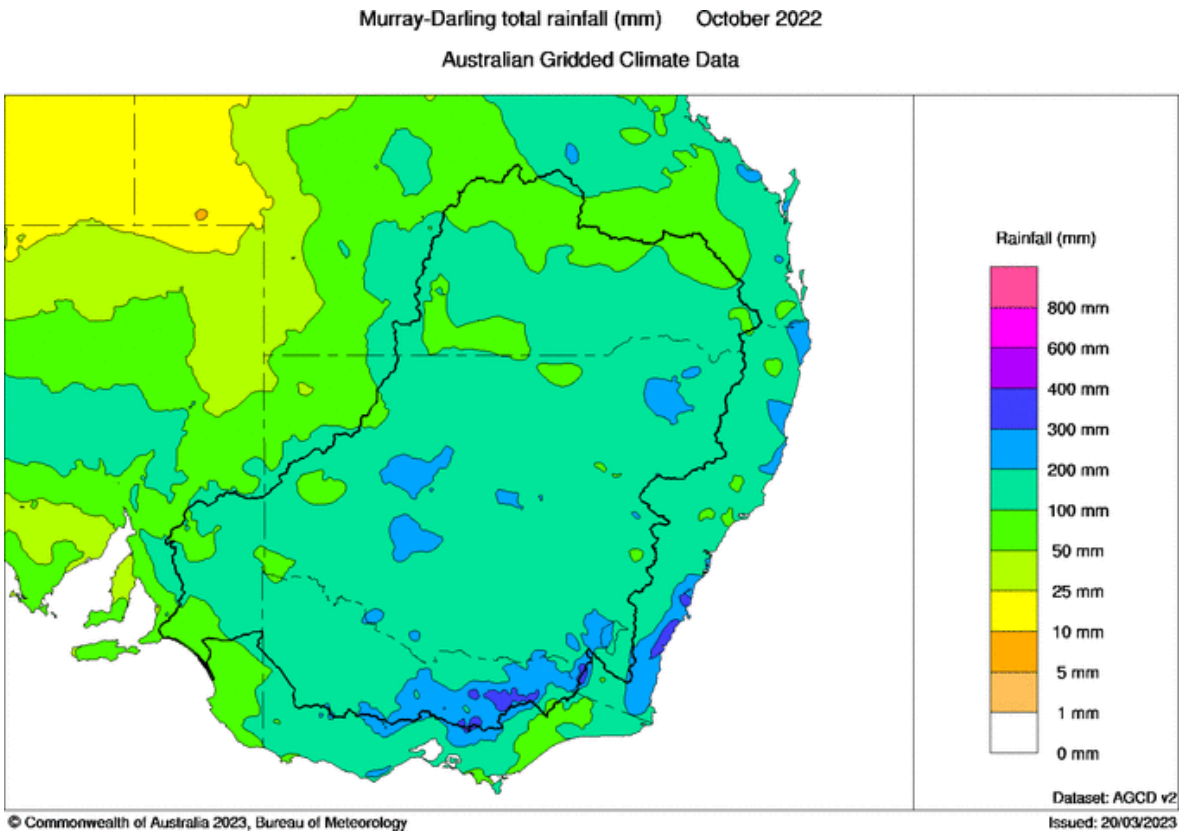


Figure 28: Murray–Darling Basin rainfall for October 2022 showing high rainfall totals across the Basin and very high totals over the key River Murray tributary catchments in the south and south-east (Source: Bureau).

At the start of October, flood operations continued at Dartmouth Dam with storage reaching 101.4% and inflows peaking near 13,500 ML/day. Spillway flow rates continued, initially, to stay low enough to maintain flows below channel capacity in the lower Mitta Mitta River (3.4 m at the Tallandoon Gauge or approximately 10,000 ML/day). However, by 14 October, increasing flows over the spillway, combined with inflows from the Snowy Creek increased the Tallandoon level to just above 3.4 m. Despite spillway flows continuing throughout October, the river remained below the Tallandoon Minor flood level.

The high October rainfall was delivered primarily through 4 significant rainfall events. These events delivered rain across south-eastern Australia with widespread totals over 50 mm recorded across parts of the upper Murray, Ovens, Kiewa and other catchments during each event (**Figure 29 – Figure 32**), with each event affecting different catchments to varying degrees.

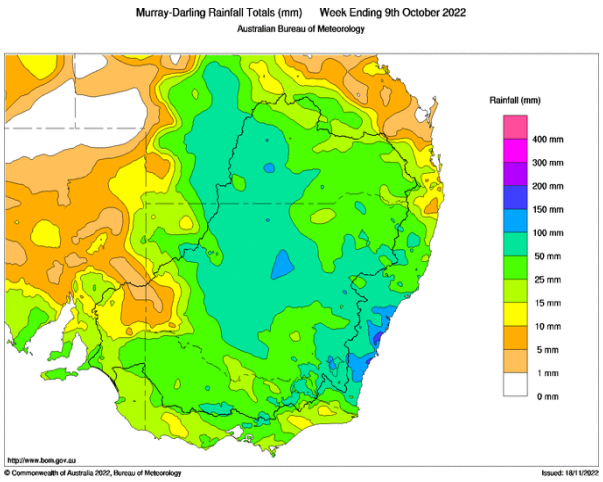


Figure 29: Murray–Darling Basin for the week ending 9 October 2022 (Source: Bureau).

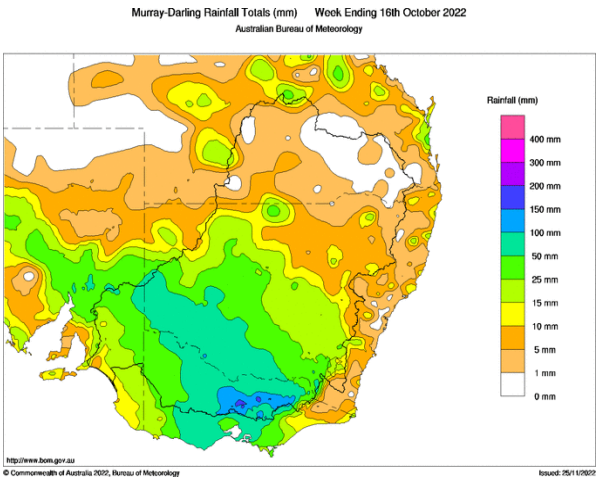


Figure 30: Murray–Darling Basin for the week ending 16 October 2022 (Source: Bureau).

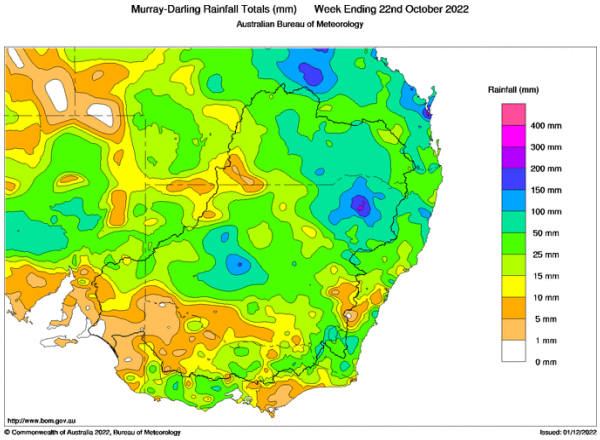


Figure 31: Murray–Darling Basin for the week ending 22 October 2022 (Source: Bureau).

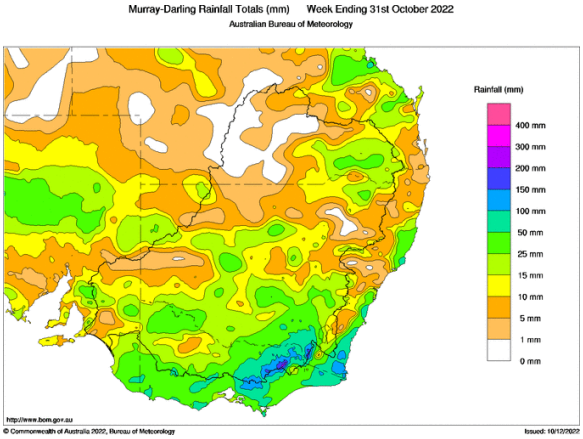


Figure 32: Murray–Darling Basin for the week ending 31 October 2022 (Source: Bureau).

At Hume Dam, a slow recession in inflows prior to the first rain event enabled additional airspace to be regained with around 200 GL of airspace by 7 October. This action increased peak flood mitigation during the subsequent inflow events – particularly mid-month, when Hume releases were reduced to below 30,000 ML/day during a high inflow peak above 60,000 ML/day and inflows peaking at 22,000 ML/day from the Kiewa River; and towards the end of the month when inflows again increased to over 50,000 ML/day. The target airspace was also supported by revised airspace and filling analysis and by the continuing La Niña event and strong signal from Bureau outlooks that wet conditions and resultant high inflows were likely to persist into December. (**Figure 33**).

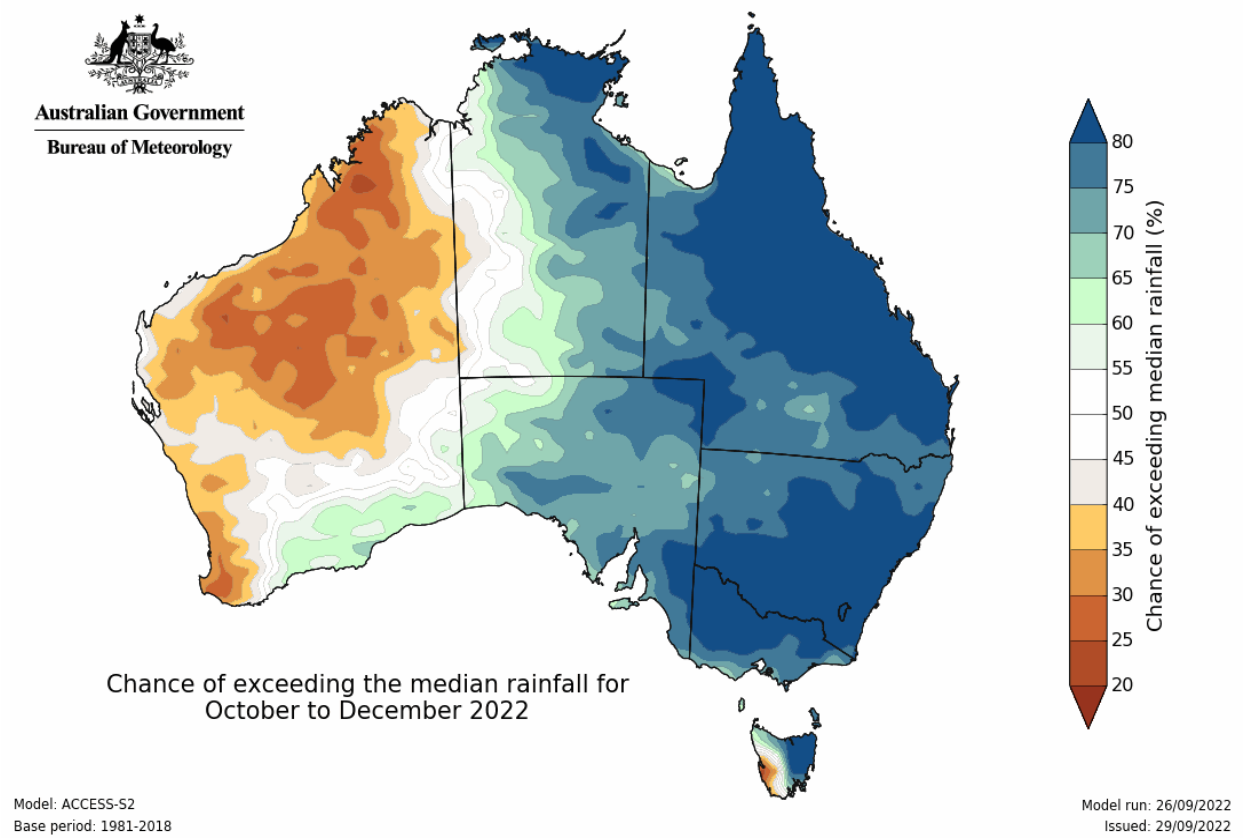


Figure 33: Chance of exceeding median rainfall for October – December 2022 (Source: Bureau).

River levels at Albury remained above the Minor flood level for much of October but reached a height of 4.72 m on 31 October with Moderate flooding as Hume releases were stepped up from around 40,000 to 50,000 ML/day in response to increasing inflows and forecasts for additional rain into November. Albury levels were boosted by elevated Kiewa River inflows that exceeded 12,000 ML/day at the Bandiana gauge before increasing further during early November.

Throughout the month of October, flows at Doctors Point remained above channel capacity (25,000 ML/day), whilst downstream at Corowa, the river remained above the Moderate flood level and reached a flow of 49,000 ML/day by the end of the month. With heavy rain falling during much of the final week of October (**Figure 32**) and into early November, flow rates were expected to continue rising and there was the potential for a further step up in Hume Dam release rates as Major flooding developed upstream of Hume Dam.

Downstream at Yarrawonga Weir, RMO continued flood operations across October with a focus on safely passing upstream flood water downstream of the weir as it arrived. This approach accords with the Objectives and Outcomes for river operations in the River Murray system, prioritises the safety of the weir and aims to pass peak flows downstream with little or no mitigation.

For the first half of October, releases downstream of Yarrawonga varied mostly between 55,000 and 65,000 ML/day, driven by a combination of Hume Dam releases and inflow contributions from both the Kiewa and Ovens Rivers that varied generally between 5,000 and 15,000 ML/day each.

This situation intensified following the month's second rain event that impacted most heavily on the Campaspe, Goulburn-Broken, King and Ovens River catchments over 13 and 14 October (**Figure 34** and **Figure 35**). On the Ovens and King Rivers, the response to this rain was rapid and significant, with the Ovens at Peechelba reaching a peak that approached 90,000 ML/day on 15 October with Major flooding. These inflows arrived at Lake Mulwala on 16 and 17 October and combined with Murray inflows to increase the release downstream of Yarrawonga Weir to a peak above 132,000 ML/day on 17 October with Moderate flooding downstream. This flow resulted in extensive inundation of the Barmah-Millewa Forest floodplain and wetland complex at levels not observed since 2016.

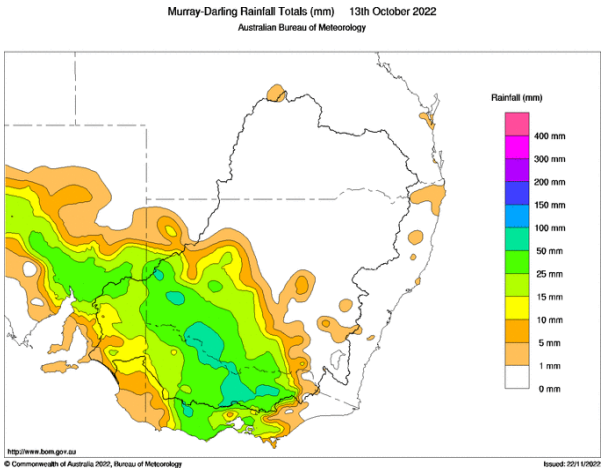


Figure 34: Total rainfall Murray–Darling Basin 13 October 2022 (Source: Bureau).

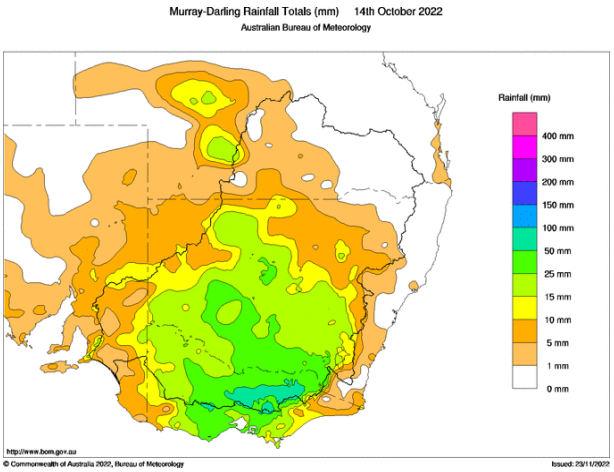


Figure 35: Total rainfall Murray–Darling Basin 14 October 2022 (Source Bureau).

A major focus of the mid-October rain event was over the Goulburn, Loddon and Campaspe River catchments where widespread heavy rain fell onto already wet ground. Observed rainfall totals were well in excess of most Bureau model guidance and resulted in large stream flow responses and one of the most significant flood events to impact central and northern Victoria in the historic record. In addition to a storage spill from Lake Eildon, where releases peaked at around 39,000 ML/day, inflows from tributaries along lower the Goulburn-Broken system increased quickly with many gauges exceeding the Major flood level.

Several towns were impacted by this flood, including Shepparton, where the Goulburn River peaked at around 133,000 ML/day with Major flooding. At McCoy's Bridge, just upstream of where the Goulburn enters the River Murray, the flow reached around 83,000 ML/day on 20 October with a large additional volume observed by-passing the gauge along flood ways and channels through the lower flood plain. A large volume entered the River Murray from this event with flows at McCoys Bridge remaining above the Major flood level for around 5 days and above 50,000 ML/day for around ten days, whilst Major flood peaks along the Campaspe and Loddon Rivers added to the overall inflow as water spread out across northern Victorian flood plains. The combination of these flows drove a substantial flood peak into the River Murray and into the Edward-Wakool system, with flows being large enough to temporarily reverse the direction of Murray flow along reaches near Barmah, until increasing Murray flows arriving from Yarrawonga Weir pushed this water back downstream. This boosted the scale and extended the duration of the flood downstream including around Echuca and Moama where Major flooding caused considerable community impacts.

On the River Murray at Torrumbarry, these flood waters combined to push the river level above the Major flood level of 7.8 m for 47 days from mid-October to early December with a peak flow of over 55,000 ML/day. At these levels, most of the flow upstream of Torrumbarry leaves the river and flows north through the Koondrook-Perricoota Forest wetland complex and into the Wakool River. This meant that flows in excess of 100,000 ML/day were likely to occur along the lower Wakool River during November.

Although the level at Torrumbarry was the highest observed at Torrumbarry Weir since 1993, it exceeded all levels observed since the commissioning of the upgraded weir in the mid-1990s. This meant both the Flood Incident Management Plan (FIMP) and Dam Safety Emergency Plan (DSEP) for Torrumbarry Weir were triggered by Goulburn-Murray Water on 15 October based on forecast river rises. Although no dam safety concerns arose during the event, the activation of the FIMP and DSEP processes ensures GMW establishes an increased level of structural performance monitoring and stakeholder communication appropriate to the dam safety risks inherent in large floods.

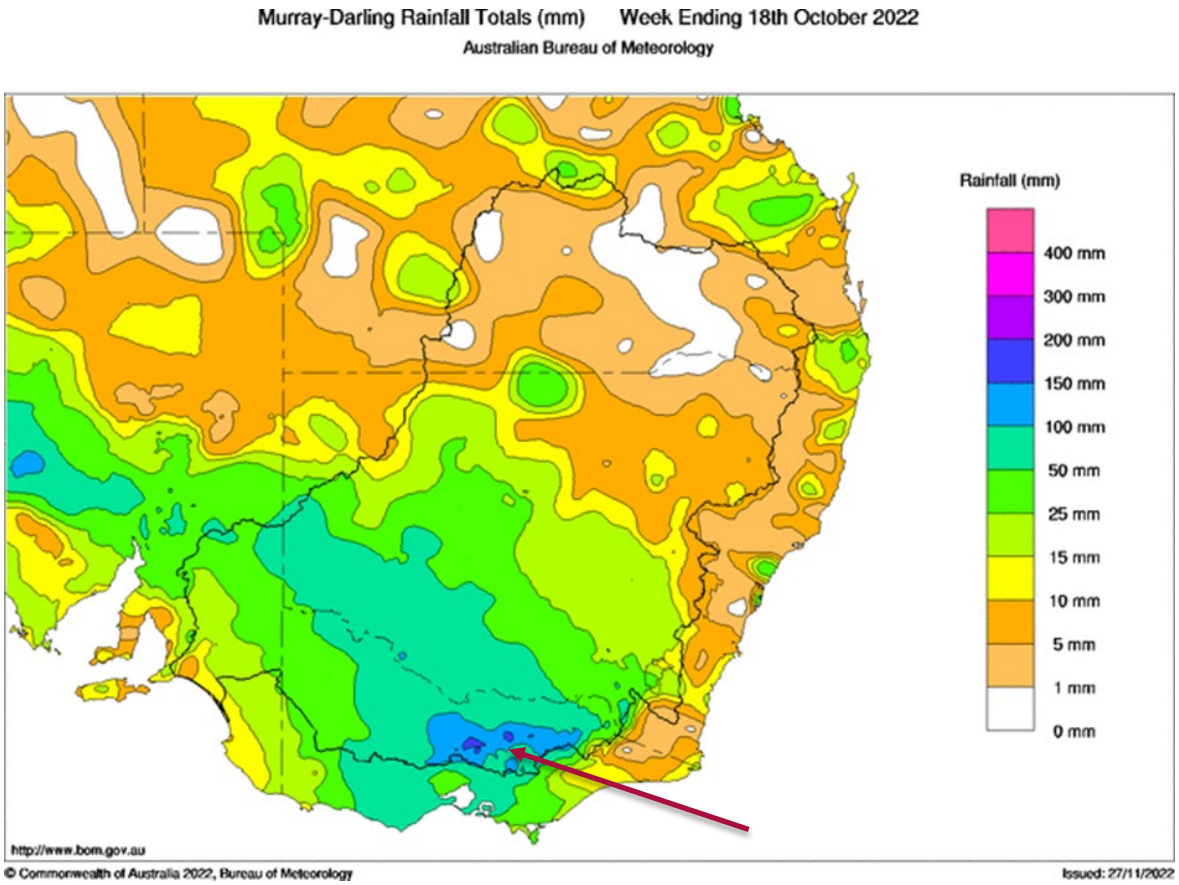


Figure 36: Total Murray–Darling Basin rainfall for the week ending 18 October 2022 (Source: Bureau). The arrow indicates the area around central Victoria where intense rain resulted in areas of Major flooding and inundation of infrastructure along parts of the Campaspe, Goulburn-Broken and Ovens and King River systems, before flowing into the River Murray.

During October, wet conditions also continued to affect the Murrumbidgee catchment. This resulted in Murrumbidgee inflows to the Murray averaging about 26,100 ML/day, well above the end of October system target of 1,030 ML/day.

As well as the southern Basin, conditions in the northern Basin were also very wet, with patches of record monthly rain over some catchments. These wet conditions resulted in Major flooding along several

northern Basin rivers and continued to drive up Barwon-Darling flows with the flow at Walgett rising rapidly towards a peak that was expected to exceed 200,000 ML/day during early November. Further downstream, the flow at Bourke reached 100,000 ML/day by the end of the month, whilst at the Menindee Lakes, inflows averaged near 28,700 ML/day.

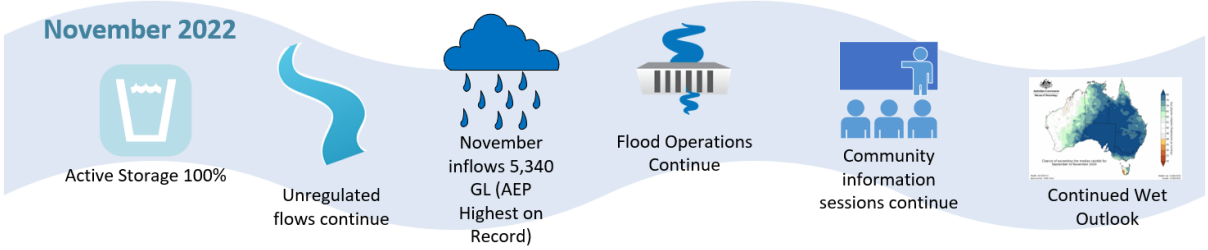
In response, WaterNSW continued to manage the lakes above the surcharge range with high releases into the lower Darling expected to push Weir 32 flows towards 30,000 ML/day in November. The flow downstream at Burtundy averaged near 16,700 ML/day during October and releases from Lake Cawndilla, down the Great Darling Anabranch, were maintained at 1,900 ML/day.

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. Operating rules for the use of Menindee Lakes surcharge require releases to target a storage level at 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 rain and flood inflows that can take place in the northern Basin during summer and early autumn in association with the summer monsoon period. However, with very high flows expected to reach the lakes during November and December, WaterNSW continued to actively manage airspace with the aim of mitigating the expected flood peak as it arrived whilst balancing downstream impacts and prioritising dam safety.

In South Australia, flows continued to rise through October and climbed to near 85,500 ML/day at the end of the month. The high river and increasing flows had necessitated the removal of all navigable pass structures and the Lock 11 weir at Mildura which meant there were free-flowing conditions along the length of the river system from Yarrawonga Weir to the Lower Lakes. With a historically significant flood event moving downstream from the upper Murray, Goulburn, Murrumbidgee, and Darling/Baaka River systems, RMO made use of the additional flow routing capability of the Source Murray Operational Model, to gain a greater understanding of the potential peak height, timing, duration and volume of the expected event through the system to South Australia. Forecast outputs from this model were shared and discussed with colleagues at the Bureau and South Australia to support emergency response and infrastructure management, community safety and flood warnings, and stakeholder communication for communities along the lower Murray.

At the end of October, the updated Bureau climate outlook indicated the chance of above average rainfall conditions remained likely for the rest of the year. With most storages already full and spilling, it was likely that wet conditions would drive operations for the remainder of Q2.

November 2022



Very wet conditions continued into November 2022, with very much above average rainfall across almost all the southern Murray–Darling Basin. The Bureau reported that rainfall in November 2022 was the thirteenth highest on record for the Basin, and in the highest 10% of historical observations (since 1900), over most of the southern Basin. For Victoria, it was the wettest November since 1954 with parts of the upper Murray catchments receiving highest November rain on record (**Figure 37**).

The wet conditions in November extended upon the very wet weather observed since late winter and resulted in rain for the September to November period reaching record levels across most of the southern Basin **(Figure 38**).

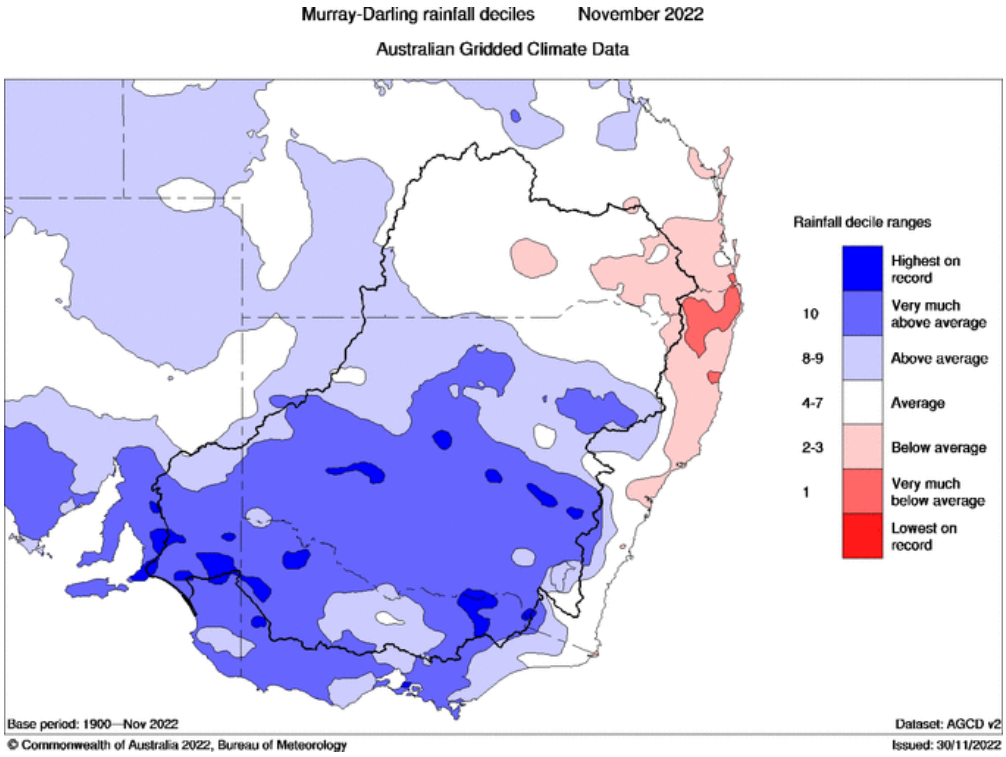


Figure 37: Murray–Darling Basin rainfall deciles for November 2022 (Source: Bureau).

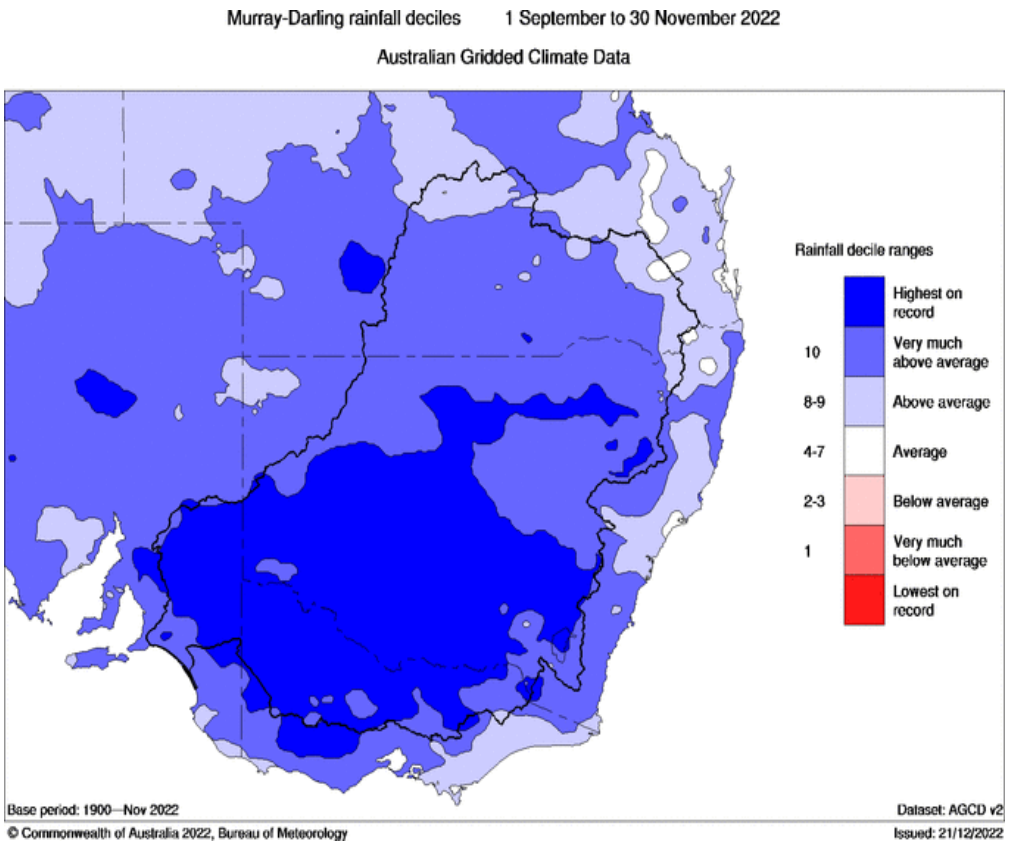


Figure 38: Murray–Darling Basin rainfall deciles for the 3-months September to November 2022 (Source: Bureau).

With this rain coinciding with what is typically the wettest period of the year across much of the southern Basin, inflows along all major tributaries continued to climb to some of the highest ever observed. As a result, the active storage in the MDBA's reservoirs was at 100% capacity (8,579 GL) and system inflows (excluding Snowy Hydro, environmental water deliveries and Darling inflows) increased to a record November total of around 5,340 GL (**Figure 39**). This is almost twice the previous November inflow record since records have been kept (1892) which was observed in 1917. When including inflows from the northern Basin into the Menindee Lakes, the inflow volume for November was around 6,450 GL, which was also around double the previous November record observed in 1956.

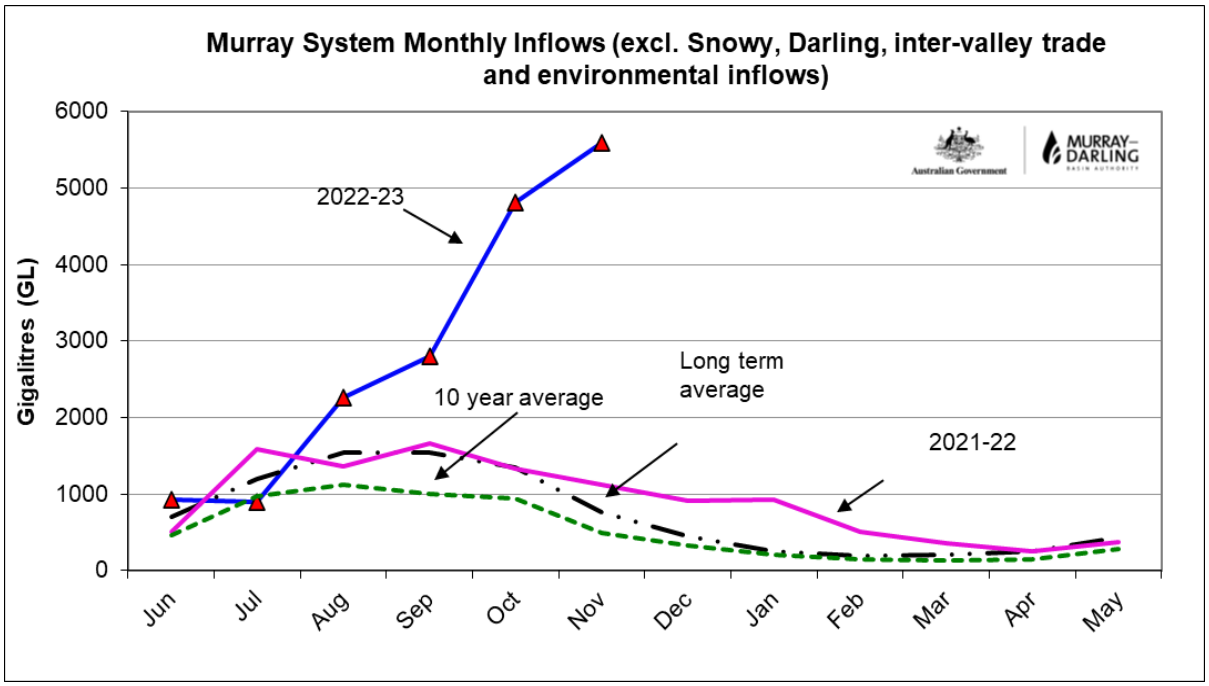


Figure 39: Murray System monthly inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) until the end of Quarter 2, 2022–23. Inflows for November and the October-November 2-month period were the highest on record.

For the combined months of October-November, inflows (excluding Snowy Hydro, environmental water deliveries and Darling inflows) were at record levels, whilst for the 3 months of Q2, total system inflows grew to a total of 14,845 GL (1% AEP), which was the second highest total on record after 1917.

The Bureau reported that for Australia as a whole in November 2022 the mean temperature was 1.17 °C cooler than the average (1961-1990) with much of the month affected by cloudy and rainy weather. Across the Murray–Darling Basin, minimum temperatures were mostly below average to very much below average, whilst maximum temperatures were mostly below average to very much below average (**Figure 40** and **Figure 41**).

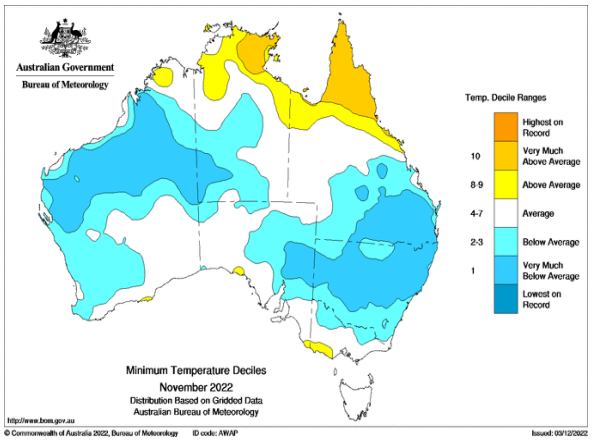


Figure 40: Murray–Darling Basin minimum temperature deciles November 2022 (Source: Bureau).

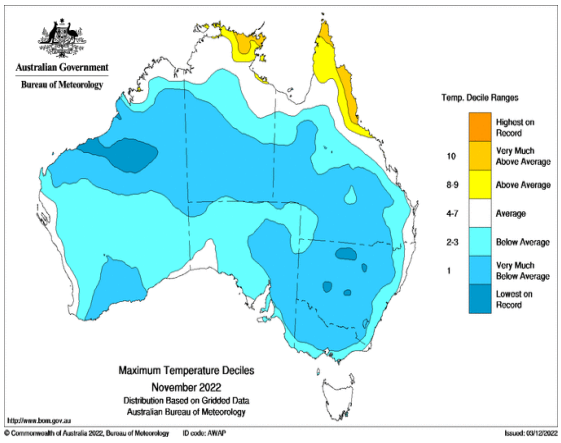


Figure 41: Murray–Darling Basin maximum temperature deciles November 2022 (Source: Bureau).

At Dartmouth Dam, flood operations continued across the month of November. The storage level and spillway flow rates increased due to 3 heavy rain and inflow events in late October to early November (**Figure 44**), during the middle of November (**Figure 45**) and around 19-23 November (**Figure 46**). The peak storage volume of 3,936 GL (102.1%, 16 November) resulted in a peak spill rate at Colemans of just over 22,000 ML/day. Whilst this led to a peak river level of 5.26 m at the Tallandoon gauge (Moderate flooding) on 15 November, it represented significant mitigation of the peak inflow rate (35,000 ML/day) due to the attenuation effect of the spillway.

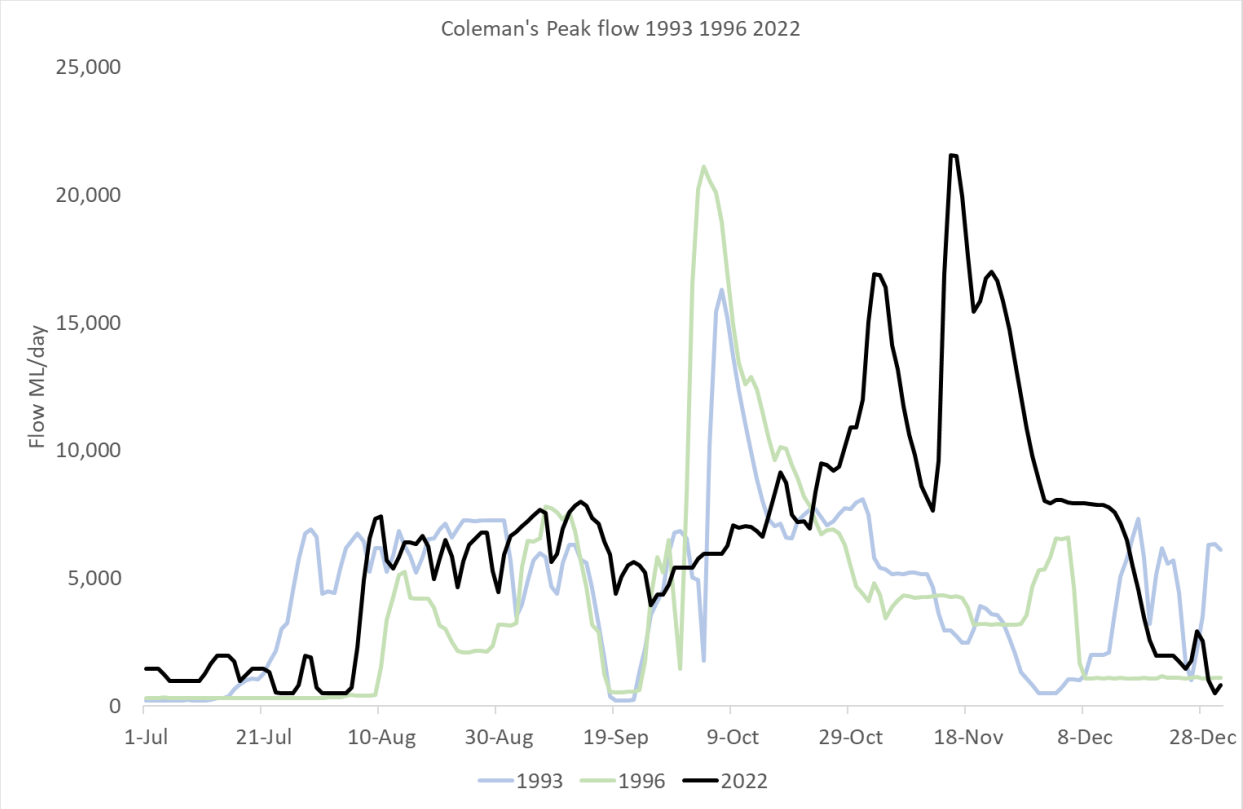


Figure 42: Comparison of Dartmouth releases (measured as Coleman daily flow) during the 3 years with the highest spillway flow rate in Dartmouth's history – 1993, 1996 and 2022. The peak rate in 2022 slightly exceeded the peak of 1996 to become the highest on record, whilst the 2022 spill duration and volume were also greater than any previous spillway flow event.

The peak spill rate and peak height at Tallandoon were also significant in a historic context. Since the commissioning of Dartmouth Dam in 1979, the 2022 peaks were the highest observed, slightly exceeding previous records from October 1996 (**Figure 42** and **Figure 43**). The continuation of spillway flows from September and October into November and multiple inflow peaks across the month also resulted in the spill duration exceeding that of both 1993 and 1996.

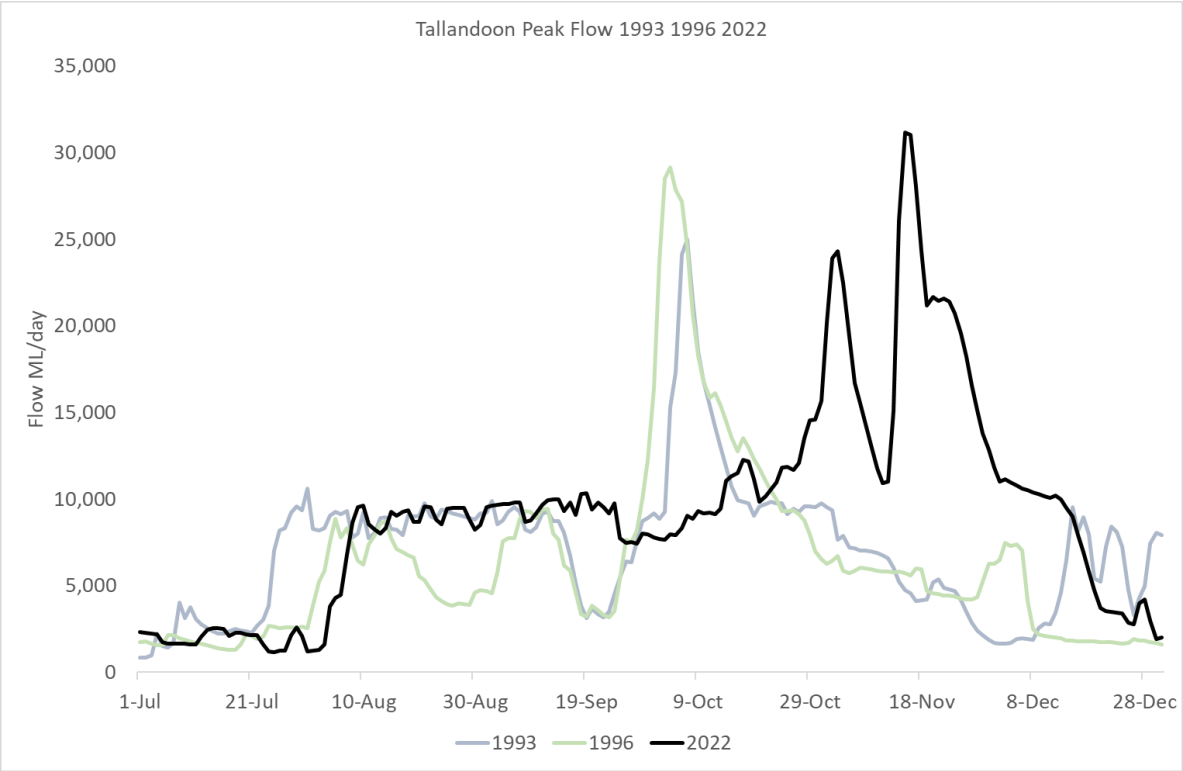


Figure 43: Comparison of daily flow at the Tallandoon gauge during the3 years with the highest spillway flow rate in Dartmouth's history – 1993, 1996 and 2022. Flows at Tallandoon (which are also driven by additional inflow downstream of Dartmouth Dam) peaked at a slightly higher rate during 2022, whilst 3 inflow peaks in November resulted in a longer duration of flows above 10,000 ML/day compared with 1993 and 1996.

With the addition of elevated inflows from Snowy Creek downstream of the dam, flows at Tallandoon remained above channel capacity (3.4 m or 10,000 ML/day) until 2 December 2022 as spillway flows receded. This marked a period of almost 50 days with flow above channel capacity at the Tallandoon Gauge. With relatively high inflows receding by the end of the month as rainfall eased, spillway flows were expected to continue well into December 2022 as the storage level steadily reduced towards FSL.

With heavy rain focussed over the upper Murray catchments in late October continuing into early November, flood operations and storage releases at Hume Dam were stepped up considerably during the final month of Q2. Record November rainfall in and around Hume Dam and over parts of the upper catchment fell in association with intense storm activity that brought a high level of uncertainty to potential inflows and a heightened chance that more severe flooding could occur.

Airspace management and responsive decision making was critical in this period to ensure high inflow peaks were safely managed through the dam and to provide flood peak mitigation downstream of the dam where possible. Target airspace and release plans were informed with regular advice from Bureau flood hydrologists and meteorologists during a month that saw periods of intense rainfall and widespread Major flooding impacting large parts of the Murray–Darling Basin.

Hume Dam inflows reached a peak of around 140,000 ML/day early in November following rain in the range 100 – 150 mm falling across most of the upper Murray in the 10 days to 2 November and totals in the range 150-250 mm observed in some areas (**Figure 44**). In response, RMO stepped up releases from 50,000 to 75,000 ML/day early on 1 November as inflows increased and the storage level climbed.

Although some additional rain fell during the following week, a further step up in releases was not required as storage airspace was used to achieve very considerable peak flood mitigation during a 5-day period during which inflows remained above 80,000 ML/day. The storage level peaked with an airspace of 11 GL (99.6% capacity), with releases then maintained at around 75,000 ML/day to regain airspace as inflows receded ahead of a strengthening forecast for another round of heavy rainfall towards the middle of the month. The degree of mitigation achieved was also possible due to a consistent dry forecast that gave confidence that airspace could be used to store a large component of peak inflow. The significant flood mitigation achieved provided additional value to communities during this event due to the impact of heavy rain in and around Albury and the lower Kiewa valley downstream of the dam. For example, rain totalling 81 mm in Albury over the 3 days to 2 November brought considerable additional inflow to the Murray from local creeks and drains that further raised river levels along this part of the Murray with the river exceeding the Moderate flood level at Albury.

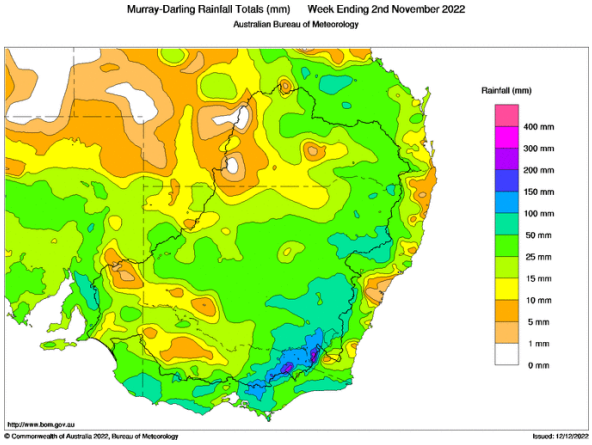


Figure 44: Murray–Darling Basin for the week ending 2 November 2022 (Source: Bureau).

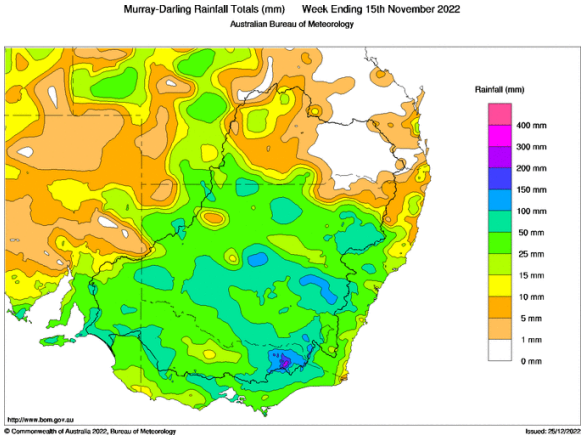


Figure 45: Murray–Darling Basin for the week ending 15 November 2022 (Source: Bureau).

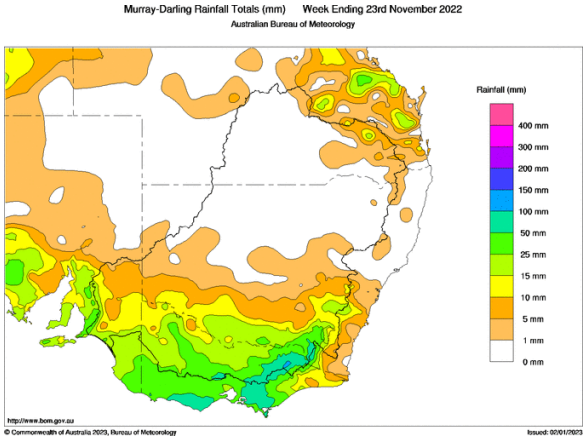


Figure 46: Murray–Darling Basin for the week ending 23 November 2022 (Source: Bureau).

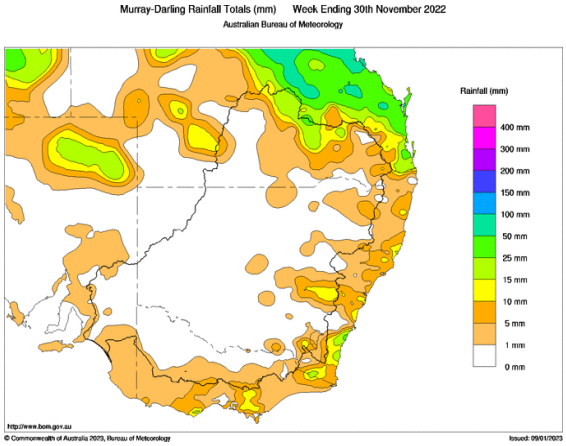


Figure 47: Murray–Darling Basin for the week ending 30 November 2022 (Source: Bureau).

By the second week of November, the Bureau advised that forecast models were again indicating the potential for heavy rain linked to tropical moisture and a potential for storms and very high rainfall rates to occur. Bureau modelling indicated an elevated chance of even higher inflow rates and volumes into

Hume Dam from this event than occurred during the early November event. RMO responded by managing releases to more rapidly increase airspace to help reduce the risk of the river exceeding the Albury Major flood level, or potentially threatening the Albury levee, should rain and inflows occur in line with the higher end of the Bureau forecast model guidance. This decision was discussed with and endorsed by the MDBA River Management Executive Director as per the MDBA's approach to flood operations decisions during larger flood events and noting the decision trade-offs and balance of risk between different forecast rainfall scenarios being taken into consideration.

Hume releases were increased to 85,000 ML/day on 10 November and then to 95,000 ML/day on 11 November with heavy rain forecast to begin on 12 November. Following the initial period of rain, the release was stepped back to 80,000 ML/day late on 13 November with airspace approaching 250 GL considered to be sufficient to provide an appropriate buffer to mitigate the range of high inflow scenarios being forecast. The reduced release rate also helped increase the level of mitigation achieved as intense rainfall around the dam increased inflows to an initial peak around 120,000 ML/day.

The release reduction also helped decrease the impact of rising river levels around Albury and further downstream. This increase was driven by another round of heavy rain and localised run-off and inflow from creeks and drains downstream of the dam as intense storms moved across the region. River levels at Albury briefly exceeded the Major flood level for around 6 hours before this additional inflow moved further downstream. A further Hume Dam release reduction to 65,000 ML/day was made overnight in the early hours of 14 November as further flow responses were observed. This helped to improve peak mitigation and further reduce the river level ahead of rapidly rising flows being generated along the Kiewa River. Kiewa River inflows peaked at almost 35,000 ML/day at Bandiana late on 14 November as storage inflows again increased above 100,000 ML/day.

With inflows averaging around 75,000 ML/day between 15 and 20 November, releases were managed at an average rate around 65,000 ML/day which continued to provide a degree of flood mitigation downstream whilst maintaining sufficient airspace to manage the risk of further potential rain events taking place in the near term. With Kiewa River flows receding, river levels at Albury and downstream continued to decrease.

Further downstream from Hume Dam, the flow at Corowa increased to its highest rate for the year as Hume Dam releases, Kiewa inflows and significant local rain and run-off boosted the flow to a peak above 135,000 ML/day on 14 November. The river at Corowa remained above the Moderate flood level across November and the flow remained above 50,000 ML/day at Corowa until 27 November.

Downstream at Yarrawonga Weir, flood operations were on-going throughout November. There were 2 inflow peaks driven by the rain events at the beginning and middle of the month. The first peak was driven by increased releases from Hume in conjunction with higher flows from the Kiewa River and the Ovens River where the flow at Peechelba peaked at 46,000 ML/day. Storage inflows reached 129,000 ML/day with a peak release downstream of Yarrawonga Weir of 126,000 ML/day on 5 November. Inflows and releases then reduced until 12 November when the release had decreased to 99,000 ML/day. Rapid increases to Kiewa and Ovens River inflows combined with heavy rain along the river and higher releases from Hume Dam resulted in a second inflow peak at Yarrawonga Weir of 185,000 ML/day on 16 November. To manage this peak, a lower pool level around 124.5 m AHD was targeted as the peak approached. This action combined with round the clock flood operations helped keep the downstream

release to a maximum of 178,000 ML/day. This release was just below the Major flood level and was the highest downstream release from Yarrawonga Weir since 2016, when releases peaked at a slightly higher rate around 180,000 ML/day (**Figure 48**).

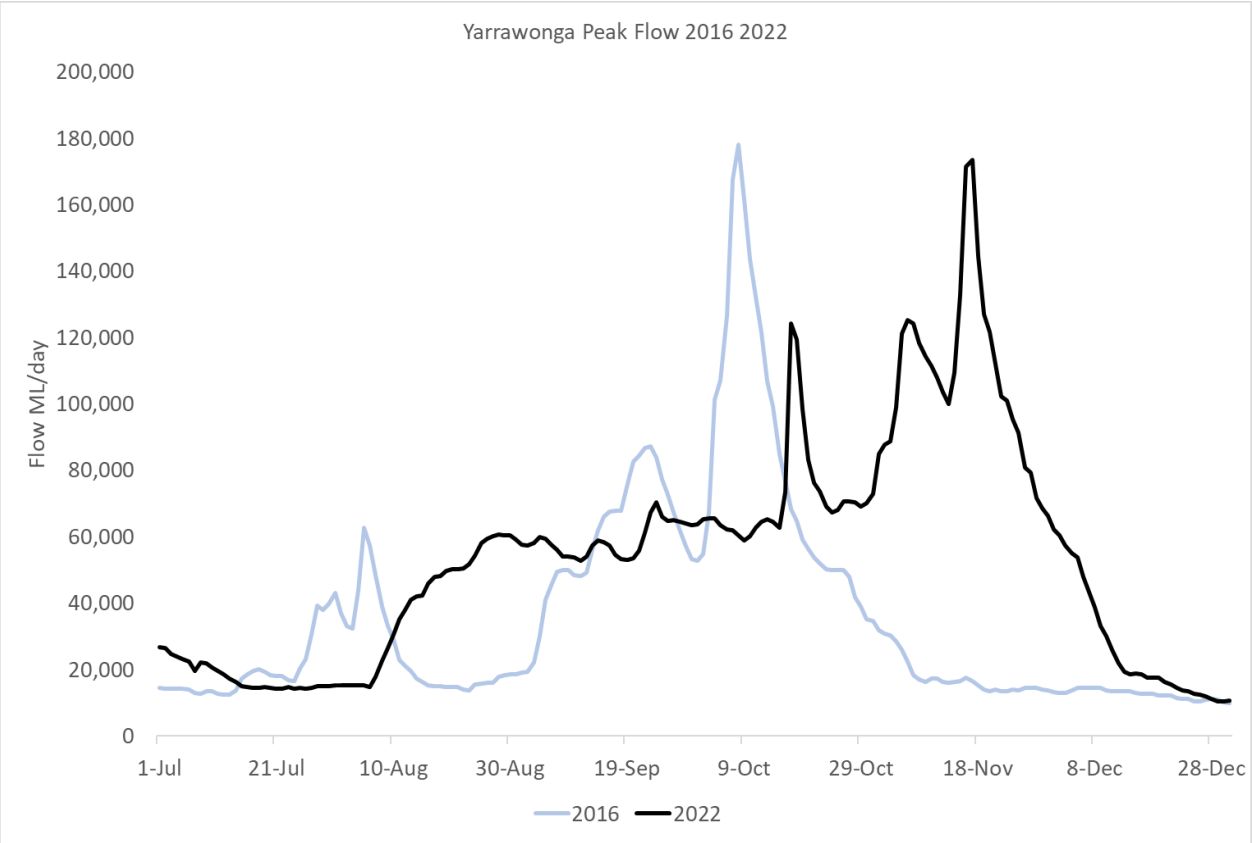


Figure 48: Release from Yarrawonga Weir, May – December 2016 compared with 2022. The peak release on 16 November 2022 was just below the peak observed in 2016, however, 2022 saw a longer duration of high flows and experienced 2 additional peaks in excess of 120,000 ML/day.

On the Goulburn, Loddon and Campaspe rivers, major flooding continued in early November, however, flows generally receded slowly across the remainder of the month with lesser rainfall impacting the Goulburn catchment during November compared to the upper Murray. Downstream on the Murray at Torrumbarry Weir, the flow remained around 55,000 ML/day in early November before receding slowly towards the end of the month, with all gates remaining clear of the water.

As high flows continued along the Murray and multiple tributaries, a substantial flood peak moved along the River Murray and Edward-Wakool system, as multiple flood peaks combined and spread across the mid-river flood plains. This resulted in the flow at Stoney Crossing exceeding 125,000 ML/day with similar flow rates persisting into early December. On the Edward River at Moulamein, the river level remained above the Major flood level from 20 November until 12 December.

During November, continued wet conditions in the Murrumbidgee catchment resulted in flows to the Murray averaging near 38,000 ML/day, well above the November end of system target flow of 568 ML/day. By the end of November, the flow at Balranald had increased to 53,000 ML/day and was approaching a Major flood peak expected in early December. The broad nature of the flood hydrograph

on the Murrumbidgee and the resultant large volume entering the Murray continued to be a major driver of flood conditions and on-going unregulated flows along the lower River Murray. Forecasting Murrumbidgee inflow also continued to be a key driver of uncertainty for forecasting peak flow rates and the timing of the flood event along the lower River Murray. This was due to a number of factors including determining the volumes and timing of water entering the Murray across the lower Murrumbidgee flood plain and the inherently reduced accuracy of rating tables at such high river levels.

Although rain reduced across much of the northern Basin during November, some New South Wales catchments continued to receive well above average rainfall that helped extend high flows along a number of tributaries of the Barwon-Darling/Baaka River. In addition, flood waters generated by rain in September and October continued to move through the system towards the Menindee Lakes. At Bourke, the flow peaked near 210,000 ML/day on 24 November with Major flooding, whilst at the Menindee Lakes, November inflows averaged 31,400 ML/day and were continuing to increase. By the end of November, WaterNSW advised that an estimated 1,800 – 2,200 GL of additional inflow was expected at Wilcannia by the end of January 2023.

In response to November and forecast December inflows, WaterNSW continued to undertake flood operations at the Menindee Lakes and manage releases to reduce the storage from surcharge towards FSL, whilst targeting a level of 9.6 m AHD at the Menindee town gauge. Flows along the lower Darling/Baaka River at Burtundy continued to rise slowly across the month and averaged near 17,300 ML/day. Additional releases from Lake Cawndilla into the Great Darling Anabranch were also continued to help increase the overall release volume whilst benefitting the anabranch environment.

At the South Australian border, flow rates continued to climb quickly as flood waters arrived from upstream. The flow reached 152,000 ML/day by the end of November and was continuing to rise. Forecasting the peak of the event continued to be a focus, with RMO running the Source Murray Operational Model to regularly update forecasts and key stakeholders with advice and provide support for their needs.

During this period, forecasting confidence and skill was reduced by a range of factors including levee and other bank breaches that moved significant additional water onto the flood plain and altered the flow in the river, and by uncertainties in gauge height readings and rating tables at many locations. With the river reaching levels at many locations not seen since the 1970s or earlier, a reduced level of accuracy in flow ratings was expected. Field hydrographers were deployed to gauge flows at a range of river levels to help improve flow rating information and update rating tables using modern gauging equipment and techniques. A key outcome from this work was an indication the flow rates at these higher flood levels were generally less than indicated by the pre-existing rating table. Importantly, this meant that peak river levels observed as the flood moved downstream were higher than expected from earlier forecasts, based off the pre-existing rating tables.

With an historically significant flood event moving through the system, unregulated flows continued along the length of the River Murray system and, under the rules of the Lake Victoria Operating Strategy (LVOS) this allowed for a further delay to the filling of Lake Victoria. As such, RMO looked to lower the Lake Victoria storage level in accordance with the 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 maximise water availability by the end of the unregulated flow event.

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

By the end of Q2, the Bureau advised that La Niña conditions would continue in the tropical Pacific with indications it would remain active until at least late January. Along with Australia's other climate drivers, the outlook indicated that rainfall was likely to be above average for parts of eastern Australia (**Figure 49**).

Additionally, December to February maximum temperatures were likely to be above median for most of Australia, but below median daytime temperatures likely for eastern New South Wales (**Figure 50**).

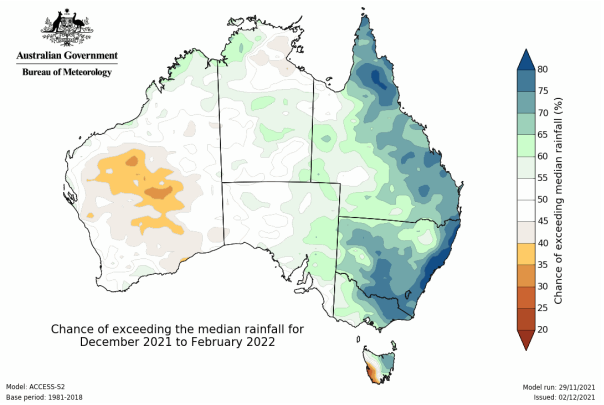


Figure 49: Chance of exceeding the median rainfall for December 2022 – February 2023 (Source: Bureau).

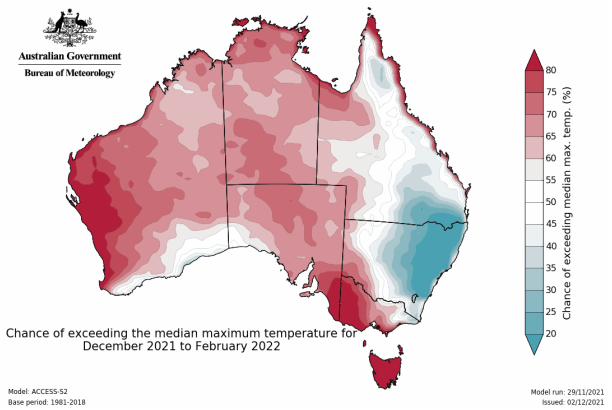


Figure 50: Chance of exceeding the median maximum temperature deciles for December 2022 – February 2023 (Source: Bureau).

The **end October update** to the *River Murray System Annual Operating Outlook (AOO) 2022–23* *was delayed until Quarter 3, due to flood operations continuing for all of Quarter 2*.

Quarter 3

Like much of Q1 and Q2, a key focus of quarter 3 (Q3) was continued management of full storages, with River Murray Operations (RMO) safely passing multiple floods at Dartmouth and Hume Dams, along with Yarrawonga Weir. This occurred off the back of record-breaking October and November 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 Dartmouth storage commencing December at 101% and Hume storage reaching 99% in December and exceeding 97% capacity during January 2023. This was only the 5th time that this has occurred since the 1960s (when Hume Dam was expanded to its current size), and after also reaching this level in January 2022.

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 upper reaches but persisting along lower reaches, although elevated inflows from the Murrumbidgee and Darling River were easing.

During Q3, significant focus was given to the management of water quality including low dissolved oxygen (DO) levels downstream of Hume Dam. This issue has occurred at times in recent years, driven by enhanced concentrations of bushfire residue entering the lake, 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 once again 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 informed 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. During Q3, water quality also became a concern on the Barwon-Darling River in the northern Basin as receding floodwaters brought organic material into the river that decreased DO along many reaches. This issue emerged as a likely challenge for Menindee Lakes operations and the lower Darling River late in Q3 as poor-quality water moved downstream.

Key achievements for Q3

Successful flood management at Dartmouth and Hume Dam and subsequent flows downstream, in which RMO was able manage releases during receding inflows to fill storages and transition from flood operations to consumptive and environmental water delivery.

Management of unregulated flows and operation of Lake Victoria in accordance with the Lake Victorian Operating Strategy in response to evolving inflow conditions, the passage of peak flows from the 2022–23 River Murray flood event and flood-related damage to some infrastructure.

The co-ordinated release of water through the Edward Wakool system to improve dissolved oxygen levels. This provided benefits to fish and other organisms within this system on the back of large quantities of carbon drawn back into the river channel as flood water receded.

Key external drivers influencing operations in Q3

During summer the following key drivers influenced river operations:

- **Key Driver 1 – 'Receding inflows and flood releases from Hume and Dartmouth Dams, variable weather conditions, summer storms and occasional heavy rain'-** RMO managed a broad inflow recession from tributaries and easing flood operations at Dartmouth Dam, Hume Dam and Yarrawonga Weir. Airspace and releases were managed to meet flood operations priorities including maximising stored water (to 99% capacity) at the end of the flood period in late December. RMO also managed persistent high storage levels across December and January to balance potential flood risks with water conservation priorities, whilst delivering both consumptive and environmental water. A record-breaking late January rain event at some locations around Hume Dam returned the storage close to FSL in early February and increased unregulated flows. On-going high storage levels saw an early re-commencement of airspace management at Dartmouth Dam and analysis for possible commencement of autumn airspace management at Hume Dam.
- **Key Driver 2 – 'Continuing high unregulated inflows and flooding 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, a large flood peak built from spring floods on the upper Murray, Ovens,

Goulburn, Murrumbidgee, and other tributaries continued moving through the mid and lower Murray as a historically significant flood event peaked at the South Australian border. Major flooding on the Darling River, managed by WaterNSW through the Menindee Lakes, continued to arrive at the Murray from the lower Darling River and Great Darling Anabranch. This both built on and extended flooding and high flows along the South Australian Murray through summer.

- **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 December, DO levels downstream of Hume dam were observed to fall below critical thresholds required for aquatic animals. The observed changes were similar to those seen at times during 2021 and 2022 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 manage water quality risks. The operational response involved the use of various release combinations (irrigation valves and power station) to help improve dissolved oxygen levels back 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 advise the best operational measures to mitigate the risk to aquatic life as much as possible.

- **Key Driver 4 – 'Infrastructure damage to major River Murray regulating structures'-** Q3 saw the continuation of flooding, river levels and an inundation extent not seen for decades along the River Murray flood plain. These conditions resulted in pressures and impacts to infrastructure along the river including weirs, embankments, and levees. RMO liaised closely with and supported State operating partners, including SA Water, WaterNSW and GMW as they worked to determine the extent of damage and risks to safety and operations at various locations. Further steps were taken to understand how best to adapt and maintain operations whilst managing impacts to water users and determining a pathway to repair damage and restore full operational capability.

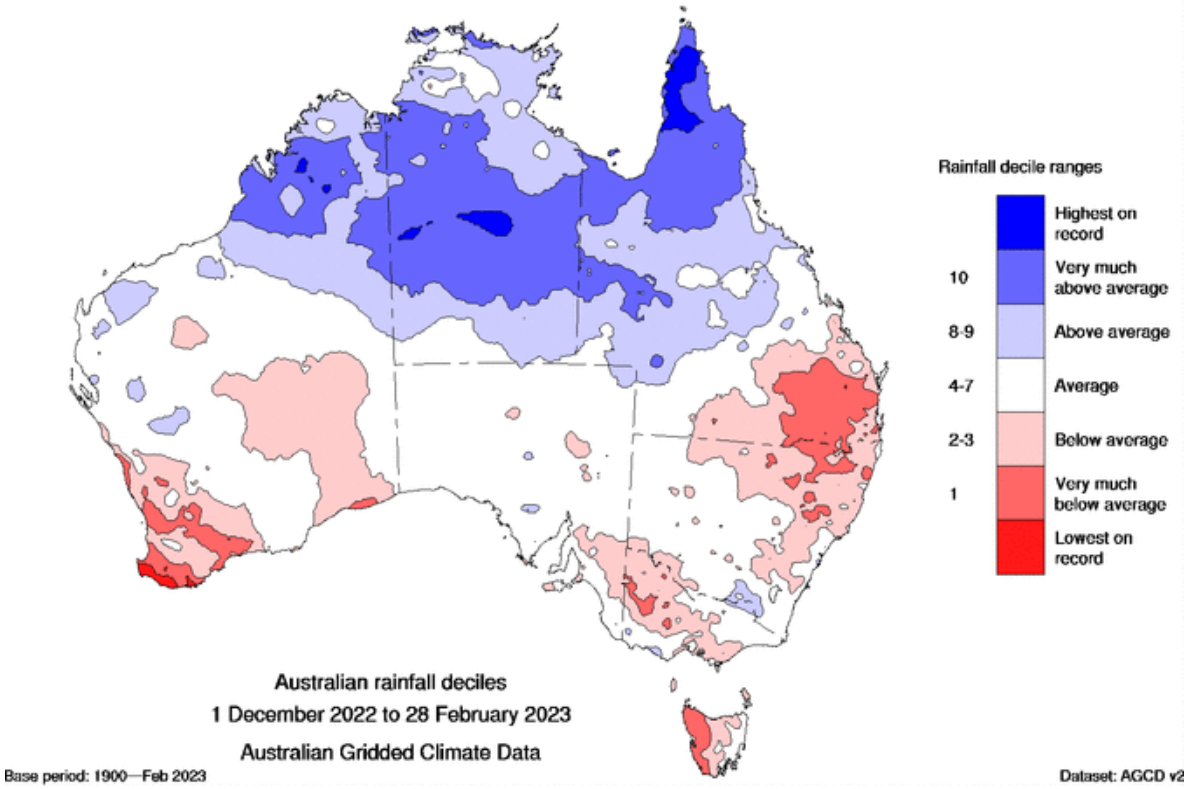


Figure 51: Murray–Darling Rainfall deciles for Q3 indicate a return to drier conditions across much of the Muray-Darling Basin.

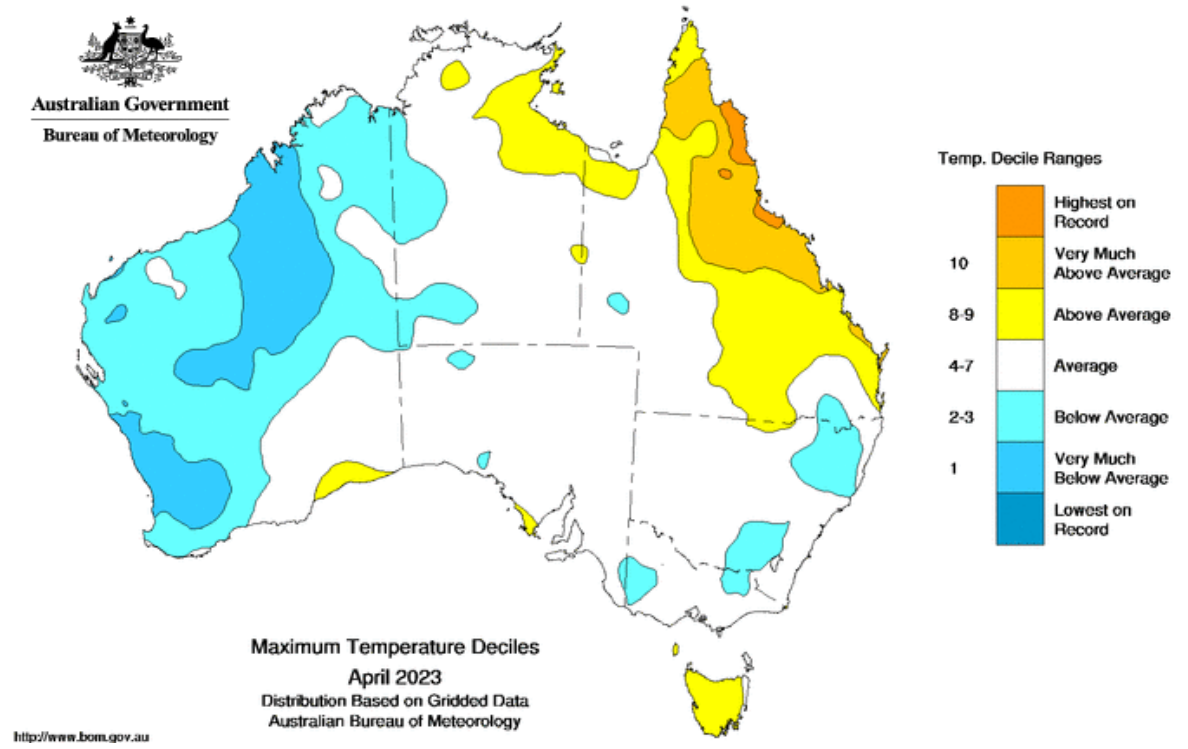


Figure 52: Maximum temperature deciles for Q3 show a return to average conditions through the basin with isolated areas of below average temperatures over eastern parts of Victotria and New South Wales.

Key metrics for Q3

The operational metrics in **Table 8** provide a snapshot summary of river operations for Q3**.** All figures should be considered within the context of the key drivers outlined above.

Table 8: Key metrics for River Murray system operations during Q3.

Metric		Quarter3 [i]
Total River Murray system inflows [ii]		3,556 GL (1% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↓ 158 GL due to returning to FSL after spill ↓ 8 GL due to capture of inflows and airspace management (spill) and E-Water releases ↓98 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS) ↓12 GL due to capture of inflows and airspace management (spill)
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii] Menindee Lakes Releases	329 GL comprising releases for airspace management (spill) and returning to FSL 1,102 GL comprising releases for airspace management (spill) and delivering water for the environment and downstream demands 58 GL due to the management of storage filling (spill) and the LVOS during unregulated flows 3411 GL releases to the lower Darling River comprising operational releases, including spill and 117 GL released to the Great Darling Anabranch for airspace management (spill)
	IVT	Murrumbidgee: 0 GL Goulburn: 0 GL
Total consumptive deliveries [iv]		397 GL Victorian Murray 527 GL NSW Murray
River Murray system loss [v]		2,900 GL (82%)
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]	10,421 GL 174 GL 454 GL 42 GL 201 GL 9,550 GL due to unregulated flows and additional dilution flows.

Metric	Quarter3 [i]
Publication of operational information	10 MDBA Weekly Reports 7 Media Releases on 'river operations' 1 Hume Dam operations 1 Basin in Brief/Flows in the River Murray system

ix. 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 as a result of hydrometric updates may result in the numbers in the above table changing.

x. 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.

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

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

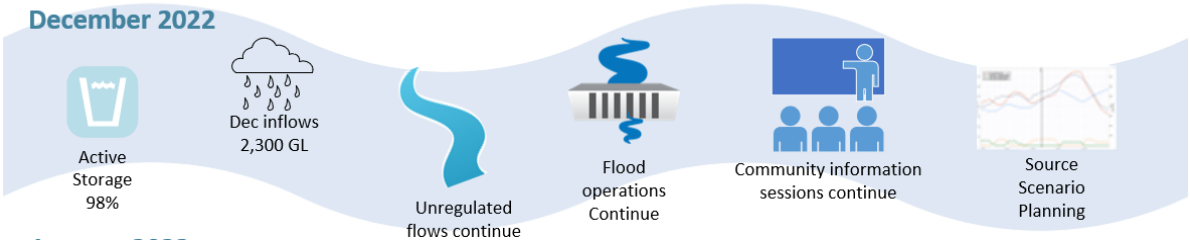
xiii. River Murray system (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific 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).

xiv. Sourced from River Murray system monthly environmental accounts.

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

xvi. 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 2022



At the start of Summer, the active storage in the MDBA's reservoirs was at 98% capacity (8,406 GL), compared to 95% the same time last year. Rainfall varied across the Murray–Darling Basin during December with large areas receiving around average rainfall whilst significant parts of the north, north-east and far south-west experienced below average conditions (**Figure 54**). Overall, Basin rainfall was 39% below average and the equal 33rd lowest on record at 27.7mm. Victoria's highest monthly rainfall totals were recorded at Mount Buller with 126 mm, Lake Eildon 115 mm (Goulburn catchment) and Corryong with 79 mm (upper Murray catchment). In New South Wales, the highest monthly rainfall total was recorded at Tooma with 110 mm, while Jingellic recorded 66 mm (both upper Murray catchment). River Murray system inflows for December (excluding Snowy, Darling, IVT and environmental inflows) were almost 2,300 GL (1% AEP). This was the 2nd highest December system inflow on record behind the volume recorded in 2010 and was driven mostly by the recession from very high inflows and flooding during October and November.

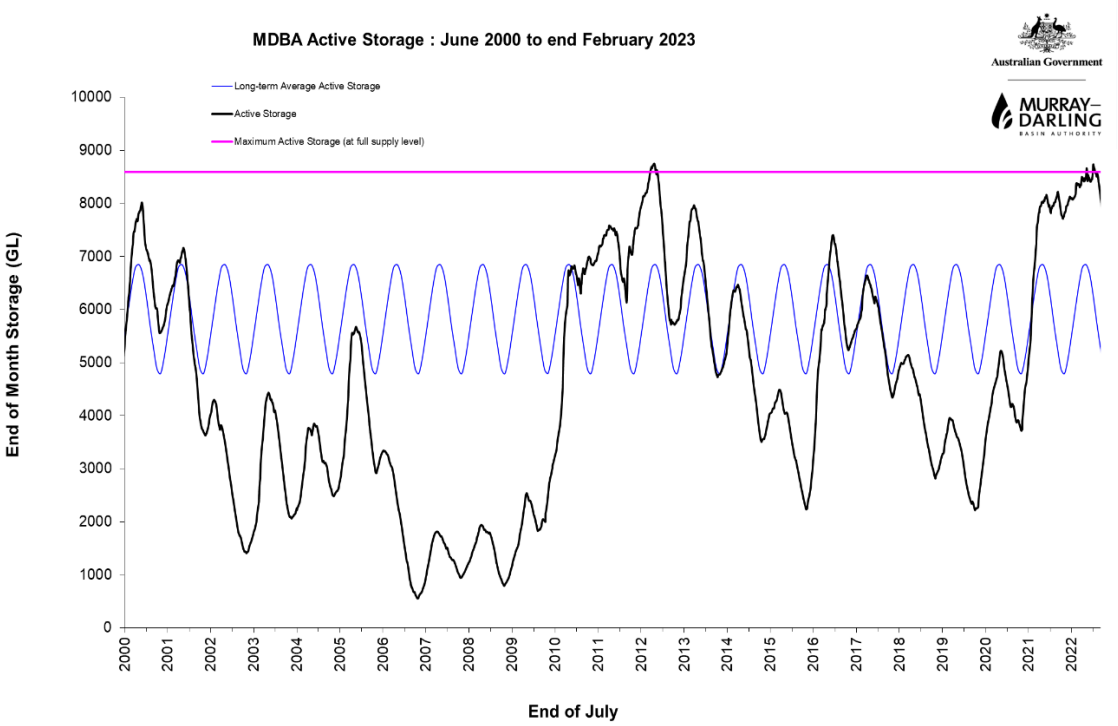


Figure 53: The River Murray system total active storage reduced below the maximum level by the end of Q3, as storage inflows receded, and system demands increased during summer.

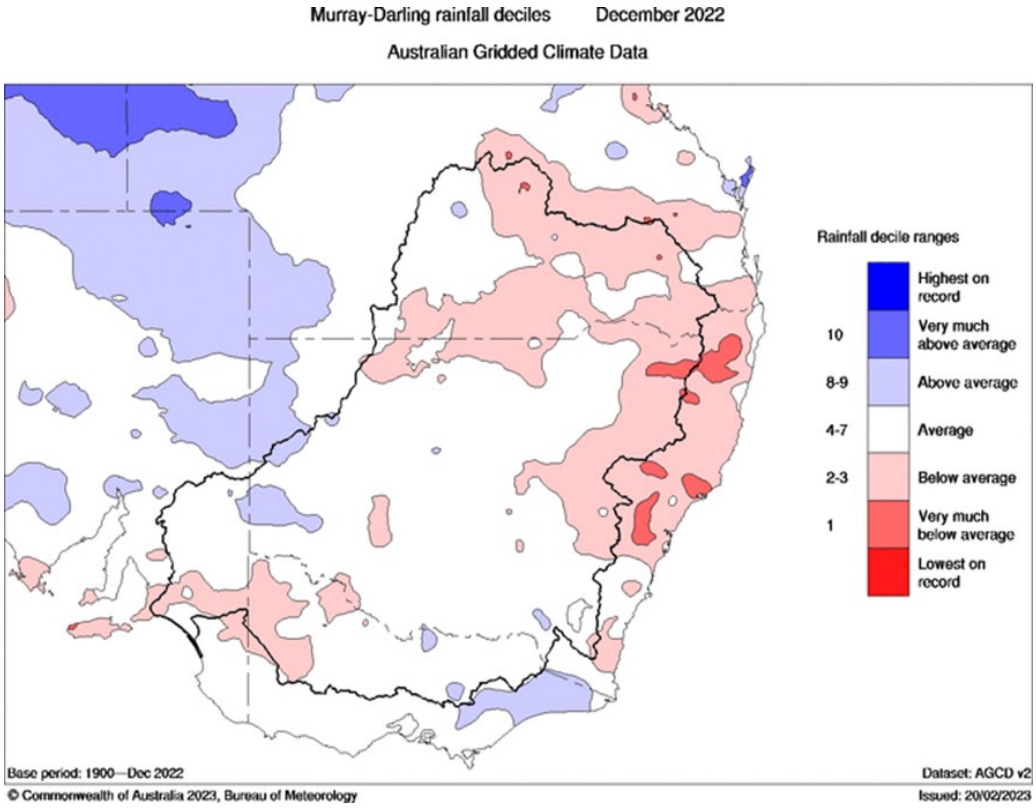


Figure 54: December 2022 Murray–Darling Basin rainfall deciles showing average to below average rain. (Source: Bureau)

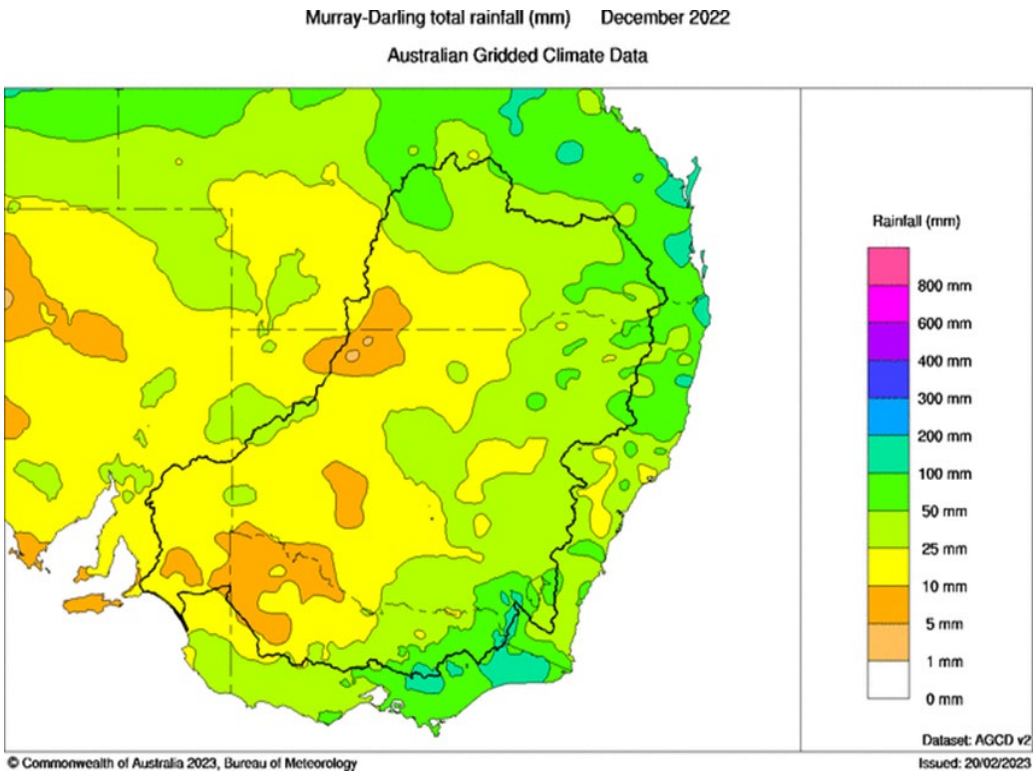


Figure 55: Murray–Darling Basin rainfall for December 2022 showing rainfall totals across the Basin (Source: Bureau)

The Bureau reports that the national mean temperature for December was 0.21 °C cooler than the 1961–1990 average for Australia as a whole. Across the Murray–Darling Basin, minimum temperatures were largely well below average with some areas recording lowest on record. Maximum temperatures were also mostly below average to very much below average in the northern basin and eastern Victoria, with parts of the central west of Victoria receiving average conditions. (**Figure 56 and Figure 57**).

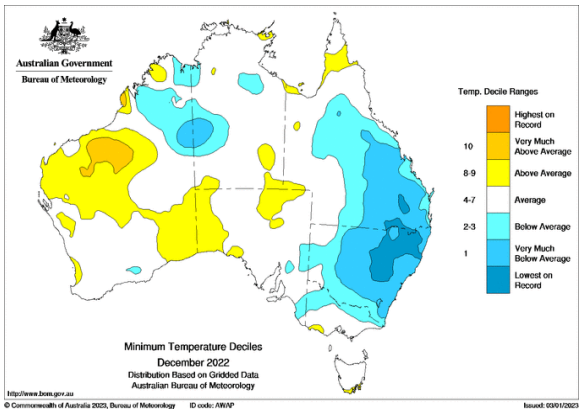


Figure 56: Murray–Darling Basin minimum temperature deciles December 2022 (Source: Bureau).

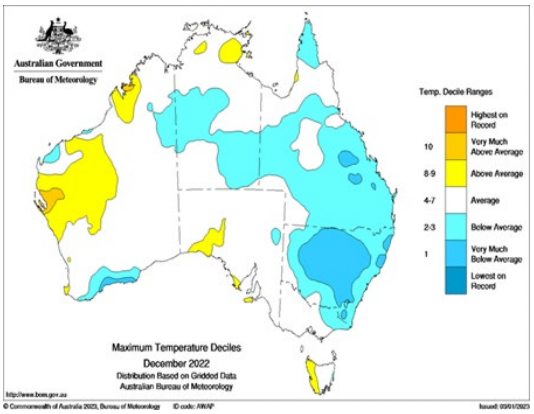


Figure 57: Murray–Darling Basin maximum temperature deciles November 2022 (Source: Bureau).

As rainfall weakened, spillway flows at Dartmouth Dam continued to decrease before ceasing on 13 December, when the storage level reduced below FSL. Flows at the Tallandoon Gauge returned to within channel capacity on 2 December after which additional releases were made through the valves to help bring the storage off spill more quickly whilst remaining within downstream channel capacity. By the end

of December, releases from Dartmouth dam had returned to 500 ML/day with airspace and releases being managed into January in accordance with 'above target' operations. This meant releases were adjusted to meet hydro power generation requirements of the Dartmouth Power Station operator, AGL Hydro, with on-going airspace management also considered as needed.

Rainfall over the Hume dam catchment also eased during December, and the focus turned to the filling of Hume dam to EFSL (99% capacity). An environmental water order was received on 19 December to target 12,000 ML/day release at Yarrawonga weir:

> *" Hold the flow rate at 12,000 ML/d downstream of Yarrawonga Weir until 9 January 2023 with variability (between 11,000 to 12,000 ML/d at MDBA RMO discretion) in the flow rate provided to allow flexibility for operational decisions.*
>
> *Commence the ramp down from 9 January 2023 (unless specified otherwise) at a rate of 1,000 ML/d, until flows reach bank full 9,000 ML/d or the operational requirement (whatever is greater).*
>
> *If unregulated flows are greater than 12,000 ML/d from the 9 January 2023 onwards, then the ramp down should be managed to 9,000 ML/d as soon as practical and not be held at 12,000 ML/d for any period unless for operational requirements.*
>
> *Hold flows at 9,000 ML/d until the 31 January 2023 unless specified otherwise with variability (between 8,500 to 9,000 ML/d at MDBA RMO discretion) in the flow rate provided to allow flexibility for operational decisions".*

Releases from Hume Dam to meet this order downstream of Yarrawonga weir commenced on 26 December 2022 as airspace management approached its conclusion. This enacted the 'with/without' environmental water scenario accounting approach for directed releases at Hume Dam. In the 'without' scenario, Hume dam filled to 99% capacity (EFSL) on 29 December 2022 and remained at EFSL until 3 January 2023 when demands exceeded inflows.

During early December, dissolved oxygen levels immediately downstream of the Hume Dam began decreasing at the Heywood's gauge. The observed changes were similar to those seen at times during the previous 2 summer-autumn periods 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 and power station) to help improve dissolved oxygen levels back to within healthy limits (**Figure 58**). 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.

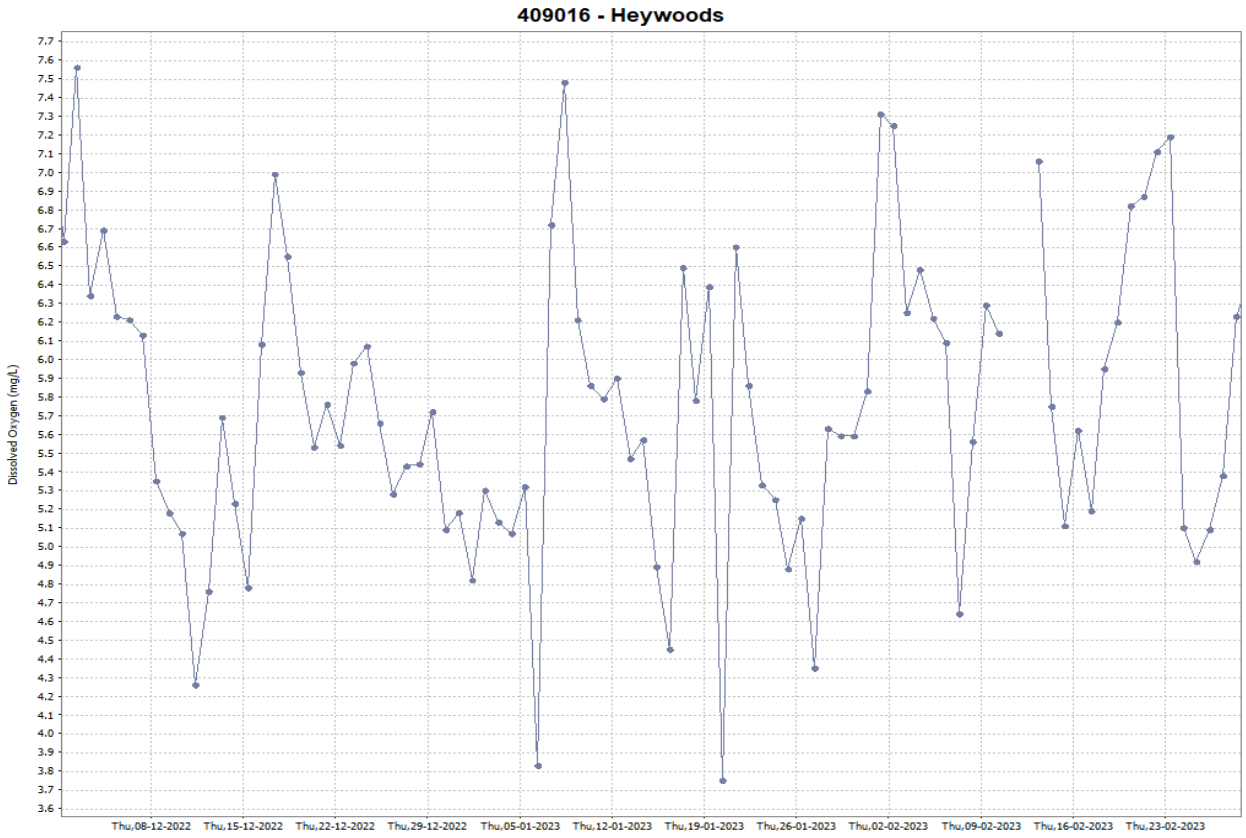


Figure 58: Recorded dissolved oxygen readings at the Heywood's gauge below Hume Dam. These readings show the dissolved oxygen levels decreasing below the first initial threshold of 5.0 mg/L then fluctuating.

By the end of December, flows at Yarrawonga weir had continued to reduce as drier conditions persisted, and despite a further rain event around 30 December that would briefly increase flows in early January, the flow was decreasing to the 12,000 ML/day environmental water target rate.

With lower flows returning to Yarrawonga weir following the extended period of flooding, weir staff became aware of potential inaccuracy with the current weir release rating tables. Weir staff suggested that the rating table was overstating the downstream flow, based on releases being made through the power station at that time. From this, plans were then initiated to undertake flow gauging's and have the rating table reviewed and adjusted if needed.

On 18 December, the gauge height at the Picnic Point, returned to below the maximum regulated height of 2.6 m AHD as levels fell away from an extended period of elevated levels that began in early September due to the high flows and flooding through the Barmah-Millewa Forest.

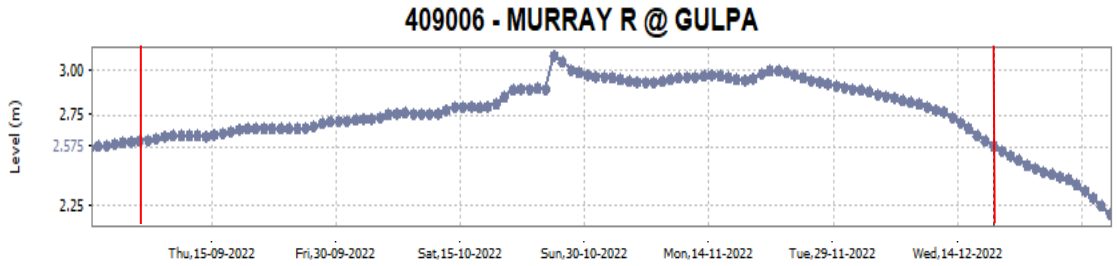


Figure 59: Recorded gauge height at Murray River at Gulpa (Picnic Point) – September – December 2022. The period between the red lines shows when the height increased above the normal regulated maximum level of 2.6 m due to prolonged upsteam flooding and widespread inundation of the Barmah-Millewa Forest.

On the Goulburn, Loddon and Campaspe rivers, inflows to the Murray continued to reduce after major flooding in October and November. By the end of December, inflows from the Goulburn River at McCoy's Bridge, had reduced to near 1,500 ML/day, the Campaspe River reduced to near 90 ML/day and the Loddon River to 430 ML/day. At Torrumbarry weir, flows had reduced to near 19,300 ML/day by the end of December, with all weir gates placed back into the water on 19 December.

As earlier flood peaks from the upper Murray and multiple tributaries arrived, combined, and moved downstream, a second substantial flood peak moved along the Edward-Wakool system. This peak was driven by the third (mid-November) flood peak at Yarrawonga moving its way down the Murray and through the Edward-Wakool System. This resulted in the flow at Stoney Crossing remaining at flow rates above 125,000 ML/day at the start of December following a peak in mid-November of 133,000 ML/day before peaking again at 135,000 ML/day on 3 December. By the end of December, the flow had reduced to near 42,000 ML/day.

During December, and as flows continued to reduce, further rating table anomalies became apparent at some gauge locations. Of particular note was the difference in flow between the reaches of Yarrawonga weir and Tocumwal. Other differences between observed flows and previous forecasts were observed at sites further downstream. Flow gauging's by field hydrographers were undertaken along the gauging network as the flood peak moved downstream. This provided important data to help understand why differences were taking place and to help calibrate and refine modelled forecasts at the very high river levels being experienced where there are typically larger flow uncertainties and rating table error margins due to the challenges in measuring flood flows and the infrequent occurrence of such large floods.

Challenges in measuring flows were also apparent on the Murrumbidgee River where continued wet conditions during November resulted in flows to the Murray measured at Balranald averaging near 48,500 ML/day in December. A peak flow exceeding 53,000 ML/day occurred on 4 December with major flooding throughout the month. By the end of December, the flow at Balranald had receded slowly with the rate still above 40,000 ML/day.

The broad nature of the flood hydrograph on the Murrumbidgee and the resultant large volume entering the Murray continued to be a major driver of flood conditions and on-going unregulated flows along the lower River Murray. Forecasting Murrumbidgee inflow also continued to be a key driver of uncertainty for forecasting on the lower Murray through December. This was due to several factors including determining the volumes and timing of water returning to the Murray across the lower Murrumbidgee flood plain and

the inherently reduced accuracy of rating tables at such high river levels. These differences and uncertainties were later highlighted and quantified during mid-2023 with hydrographic updates undertaken and provided by New South Wales. These updates indicated flows through the flood period across summer were significantly lower than was indicated at the time by the existing rating table **(Figure 60**).

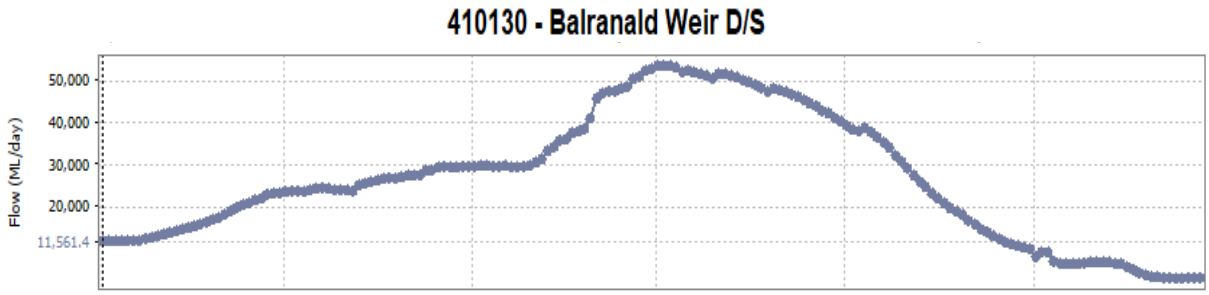


Figure 60: Observed gauge flow on the Murrumbidgee at Balranald showing a broad flow peak above 50,000 ML/day in early December 2022. Later hydrographic updates provided by NSW in mid-2023 indicated the flow was significantly less than the rating table indicated, with the peak flow revised down to about 40,000 ML/day.

As rainfall eased in the northern Basin, flooding generated by earlier rainfall progressed along the Barwon-Darling system and into the Menindee Lakes. The flow at Wilcannia increased more rapidly during early December as the peak of the flood approached and climbed to a rate of 45,000 ML/day on 27 December 2022. However, at these levels, an increasing proportion of flow upstream of Wilcannia moves into the Talyawalka Creek. In smaller floods, most, if not all of this water enters lakes and wetlands east of the river and remains 'lost' on the flood plain. However, during larger events, an increasing proportion will return to the river and the Menindee Lakes downstream, depending on the scale of the event and the antecedent conditions on the flood plain.

As WaterNSW monitored inflows to the Menindee Lakes system during December, it became apparent that increasingly large volumes from Talyawalka Creek were starting to enter the lake system downstream of Wilcannia. In response, WaterNSW adjusted its release plan and informed RMO that a significant step up to releases would be required to manage the peak of the flood. On 28 December 2023, WaterNSW advised stakeholders with the following statement:

> *"Observations over the past 7 days are indicating the trend of higher volumes of unaccounted water entering the Menindee Lake system is continuing. This unique occurrence is a direct result of flows entering the Darling River and flood plain below Wilcannia being heavily influenced by inflow from the Talyawalka Creek. As a result, these additional flows are filling the available airspace within the Lake system at a rate far greater than previously forecast. Inflows to the Menindee lakes system are currently being observed at a rate greater than 70 GL/d. These flows are continuing to see gains, indicating insufficient airspace is available in the lakes to absorb the flood peak. Adjustments to the operating arrangement will result in increased releases from the storages to pass inflows once storages are full. This will inherently result in a rise to the levels observed at the Menindee town gauge and community members should consult the BUREAU for the most up to date information on expected levels."*

Current System Status as of the 28th of December 2022

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.87	213	110%
Lake Pamamaroo + Copi Hollow	60.21	332	120%
Lake Menindee	60.38	718	114%
Lake Cawndilla	60.39	698	111%
TOTAL		**1,960 GL**	**113%**

Table 9: Menindee Lakes storage level as of 28 December 2022 (Source: Water NSW).

By 30 December 2023, WaterNSW advised that releases into the lower Darling River through Main Weir, would increase to 65,000 ML/day and then on 31 December to 75,000 ML/day.

As well as increasing river levels along the lower Darling River around Menindee town and downstream of Weir 32, river levels in the Great Darling Anabranch would also increase substantially as more water connected from the lower Darling. By late December, the Great Darling Anabranch at Wycot had reached a level of 4.3 m and was continuing to rise. As the flood moved downstream, the ultimate extent and duration of inflows into the Murray was expected to be significant but was also quite uncertain due largely to the lack of historic data available of flows to this magnitude.

At the South Australian border, flow rates continued to climb quickly through December as flood waters arrived from upstream. At the start of December, a flow of 152,000 ML/day was recorded and updated forecasts indicated flows would peak towards the end of the month at an historically significant level. Forecasting the peak of the event continued to be a focus for RMO with an aim to narrow down the likely range of peak flow rates and timing. RMO continued to run the Source Murray Operational model to regularly update forecasts and provide key stakeholders with advice and support their needs.

During this period, forecasting confidence and skill was impacted by a range of factors including levee and other bank breaches that moved significant additional water onto the flood plain and altered the flow in the river, further increasing uncertainties in gauge height readings and rating tables at many locations.

On 12 December, SA Water advised that a breach in a levee on the upstream side of the Lake Victoria Regulator had occurred. It was established that, as a result, uncontrolled water was bypassing the Inlet Regulator in Frenchman's Creek and entering below the regulator where it began entering Lake Victoria via Frenchman's Creek. On 13 December, the MDBA passed operational control of Lake Victoria to SA Water in response to the following situational advice:

> *"SA Water are implementing their contingency plan. The control regulator bulkheads are going in today and they will try and keep Lake Victoria at about 500 mm below FSL. With the Control Regulator blocked by the bulkheads it is likely that Bank 1 along Frenchman's Creek will overtop at the designated spillway section which is about 1 km long and 1 m below the general bank level".*

With the Inlet and Outlet regulators closed and bulk heads placed into the Lake Victoria Control Regulator to isolate it from upstream, SA Water was able to prevent uncontrolled flow into the lake that may have compromised dam safety and the integrity and security of operating assets.

With the river reaching levels at many locations not seen since the 1970s or earlier, a reduction in flow rating accuracy was expected. Field hydrographers were deployed to gauge flows at a range of river levels to help improve flow rating information and update rating tables using modern gauging equipment and techniques. A key outcome from this work was an indication the flow rates at these higher flood levels were generally less than indicated by the pre-existing rating table. Importantly, this meant that peak river levels observed as the flood moved downstream were higher than expected from earlier forecasts, based off the pre-existing rating tables.

Date	SI No.	Site	GH	Measured Flow	Total	Deviation	Comments
21/12/2022		Murray River @ Renmark		138,002			(GH 18.44m AHD)
		Bookmark Creek		15,458			
		Caravan Park Bridge 1		6,695			
		Caravan Park Bridge 2		6,106			
		Caravan Park Bridge 3		2,469			
		Caravan Park Bridge 4		4,057			
	426200A	Murray River D/S Lock 7	8.69		172,787	-3.88%	GH time adjusted
14/12/2022		Murray River @ Renmark		136,276			(GH 18.27m AHD)
		Bookmark Creek		12,243			
		Caravan Park Bridge 1		6,072			
		Caravan Park Bridge 2		4,991			
		Caravan Park Bridge 3		2,264			
		Caravan Park Bridge 4		3,846			
	426200A	Murray River D/S Lock 7	8.628		165,692	-1.24%	GH time adjusted
8/12/2022		Murray River @ Renmark		135,115			(GH 18.19m AHD)
		Bookmark Creek		11,420			
		Caravan Park Bridge 1		4,472			
		Caravan Park Bridge 2		4,024			
		Caravan Park Bridge 3		1,980			
		Caravan Park Bridge 4		3,577			
	426200A	Murray River D/S Lock 7	8.56		160,588	-3.30%	GH time adjusted

Table 10: A sample of the hydrometric readings (gauging's) performed at d/s Lock 7 (Rufus River) and Renmark, showing the downward deviation in flows compared with the existing rating table at high flows.

On 22 December, the flow peaked at the South Australian border at 185,860 ML/day.

With an historically significant flood event moving through the system, unregulated flows continued along the length of the River Murray system, and under the rules of the Lake Victoria Operating Strategy (LVOS), this allowed for a further delay to the filling of Lake Victoria. This meant that the breaches in Bank 1 on Frenchman's Creek and the resultant closure of Lake Victoria was not impacting on operational objectives for the system and water resource security.

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.

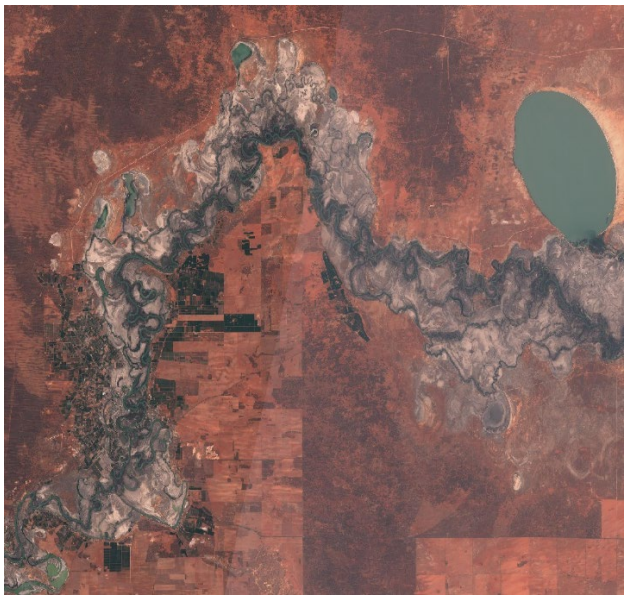


Figure 61: Sentinel imagery of the Lake Victoria to Renmark region, taken 19 December 2019, during drought conditions.

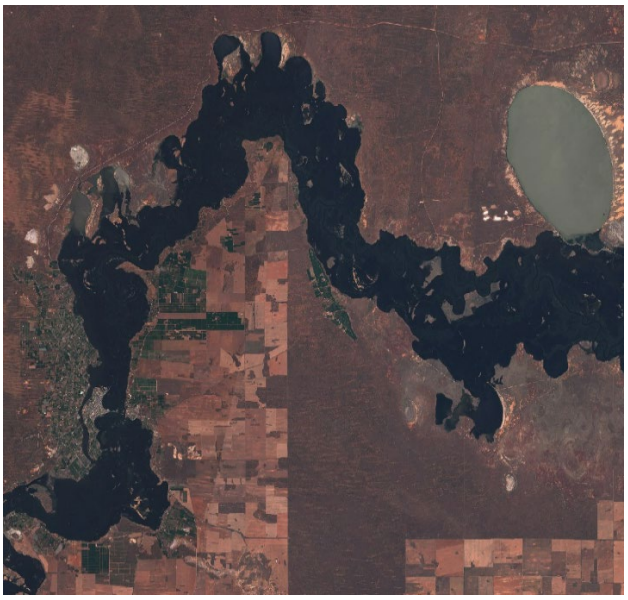


Figure 62: Sentinel imagery of the Lake Victoria to Renmark, region, taken 22 December 2022, as peak flows from the 2022–23 Murray flood cross the South Australian border.

Due to unregulated conditions, delivery of IVT from the Murrumbidgee and Goulburn Rivers was not required During December.

At the end of December, the updated Bureau climate outlook indicated the chance of above average rainfall conditions remained slightly elevated across summer. As the new year approached, the on-going wind down of flood operations on Murray storages, high releases continuing from the Menindee Lakes and the continuing passage of flood waters through the system meant it was likely that wet conditions would continue to drive operations into mid-summer.

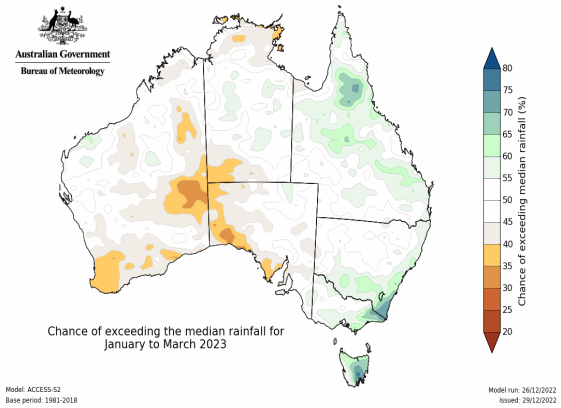


Figure 63: Chance of exceeding the median rainfall for January 2023 – March 2023 (Source: Bureau).

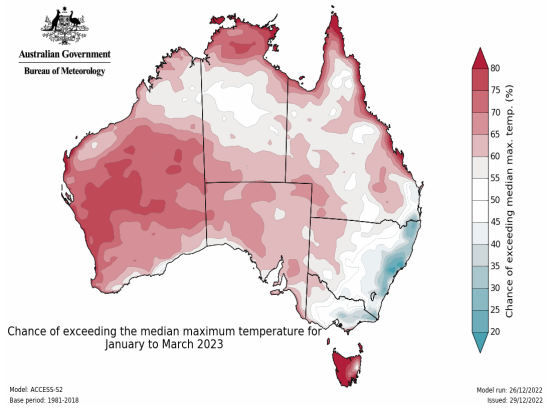
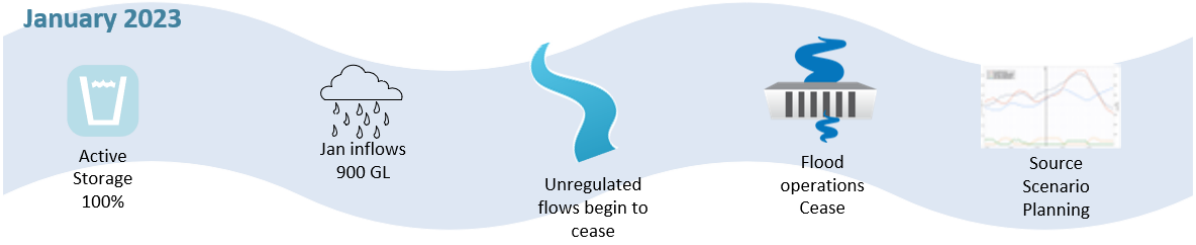


Figure 64: Chance of exceeding the median maximum temperature for January 2023 – March 2023 (Source: Bureau).

January 2023



Rainfall varied across the Murray–Darling Basin during January 2023. Below average conditions were experienced across south-east Queensland, north-eastern New South Wales, and the southern half of Victoria. However, rainfall was average to above average through much of southern New South Wales and north-east Victoria. Across a swathe of the upper Murray valley around Hume Dam, rainfall was very much above average **(Figure 65** and **Figure 66**). This was due to a heavy rain event late in the month that generated record daily totals for January at a number of localities in the greater Hume region around Albury.

Overall, Murray–Darling Basin rainfall was 23% below mean and ranked 67 of 124 on record with an area average rainfall of 43.2 mm. Some of the Basin's highest monthly rainfall totals were recorded across parts of the upper Murray. These included Hunters Hill with 237 mm, Indigo 186 mm, Corryong 168 mm, Albury with 201 mm, and Khancoban with 154 mm.

River Murray system inflows for January (excluding Snowy, Darling, IVT and environmental inflows) remained very high as flooding slowly receded and were around 900 GL (2 % AEP), whilst November-January 3-month inflows were the highest on record at over 8,500 GL.

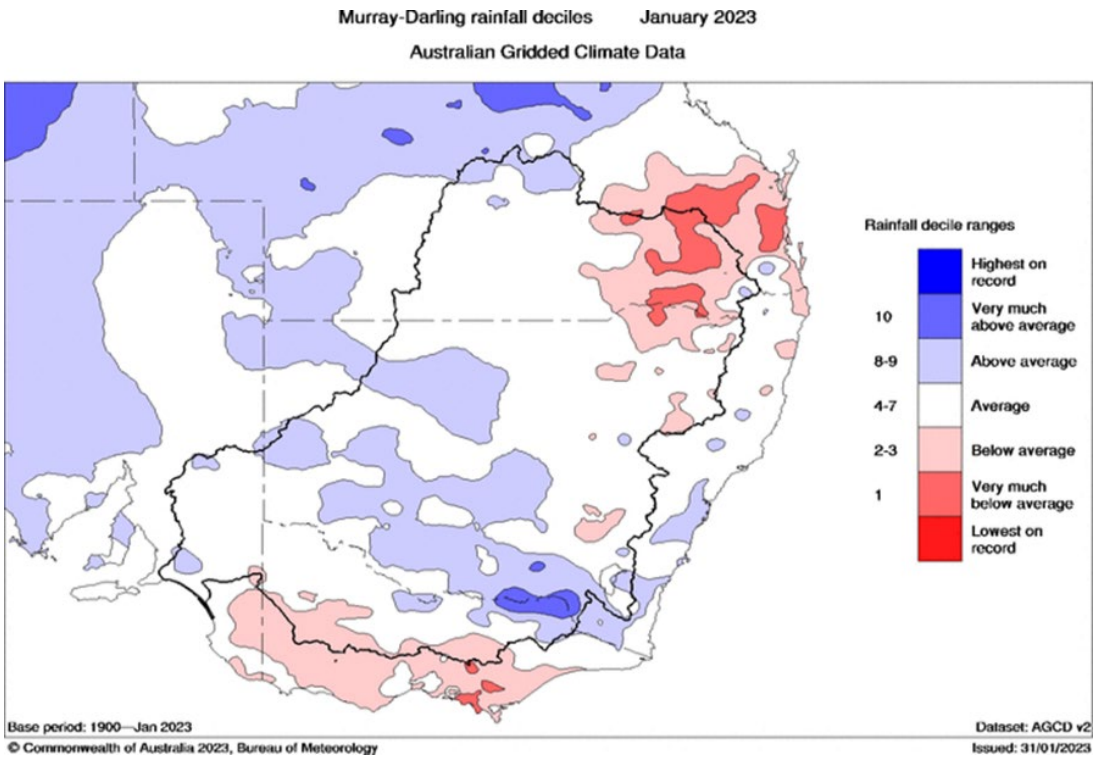


Figure 65: January 2023 Murray–Darling Basin rainfall deciles showing variable totals. (Source: Bureau)

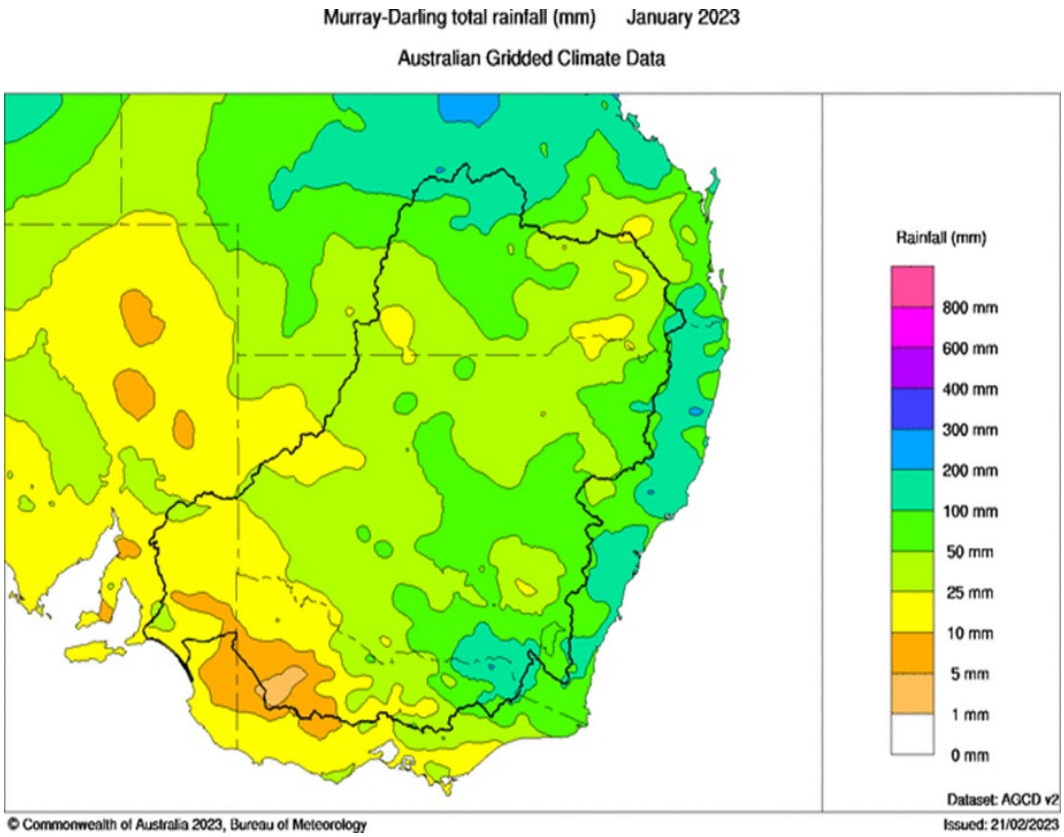


Figure 66: Murray–Darling Basin rainfall for January 2023 (Source: Bureau).

The Bureau reports that Australia's national area-average mean temperature for January was close to the long-term 1961–1990 average. Across the Murray–Darling Basin, minimum temperatures were above average across western New South Wales, south-west Queensland, and north-east Victoria. Maximum temperatures were average for much of the Basin, with above average conditions experienced across western New South Wales and Victoria and across south-east South Australia (**Figure 67** and **Figure 68**).

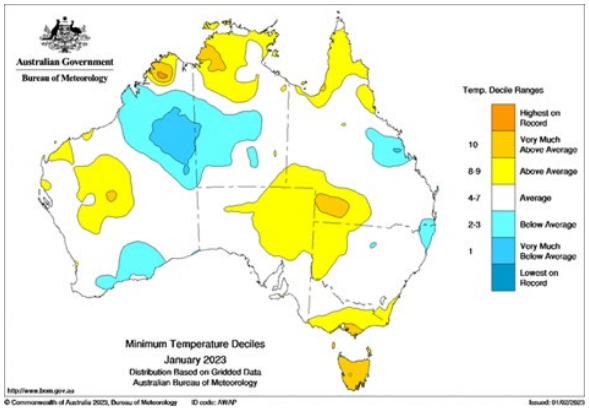


Figure 67: Murray–Darling Basin minimum temperature deciles January 2023 (Source: Bureau).

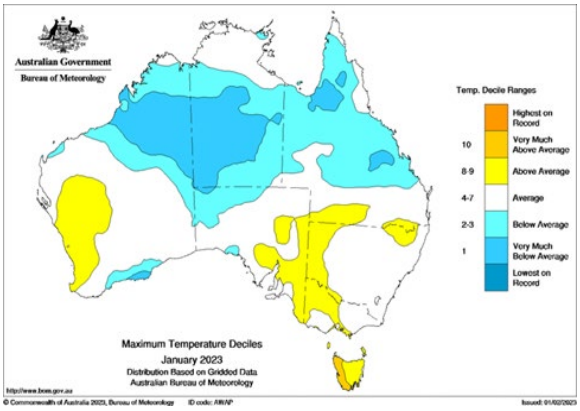


Figure 68: Murray–Darling Basin maximum temperature deciles January 2023 (Source: Bureau).

Little rain fell in the Dartmouth Dam catchment through the first half of January. In early January, the Dartmouth release was increased to 1,500 ML/day where it was maintained for much of the month. During this time, the Power Station operator indicated that power demands were relatively low, and that no specific 'above target' release was required for electricity generation. As a result, releases were managed by RMO to pass inflows and maintain airspace whilst monitoring for further rain.

Towards the end of January, a further release increase to 3,000 ML/day was required to help maintain airspace following 2 rainfall events in the second half of the month that increased inflows. On 30 January another rainfall event occurred over the catchment that further boosted inflows. Pre-release calculations indicated additional airspace could be targeted at this point from which the dam was projected to re-fill under all inflow and demand scenarios. An airspace management release plan was developed and commenced in early February.

During large parts of January, dry conditions across the Hume Dam catchment continued, with releases continuing to meet demands including environmental flow targets at Yarrawonga Weir. Hume storage decreased to 95% capacity on 29 January 2023, before a significant rain event on 30 January 2023 (**Figure 70**). On January 29, forecast rain over the Upper Murray catchment, suggested likely totals of between 15-25 mm (**Figure 69**).However, by 8 am on 30 January, Hume Dam had in fact recorded 134 mm, which was the highest single day rain total on record at the site.

The event caused a brief spike in inflows up to around 40,000 ML/day with inflows above 20,000 ML/day for a 3-day period, driven mostly by local catchment responses and direct run-off around the dam. The inflow response was not sufficient to re-fill the storage but did serve to delay the autumn drawdown by about a month in comparison with previous forecasts. And whilst most upper Murray gauges peaked at

relatively modest levels, intense rain over Cudgewa Creek caused the gauge at Berringama to briefly rise to a flow over 16,000 ML/day.

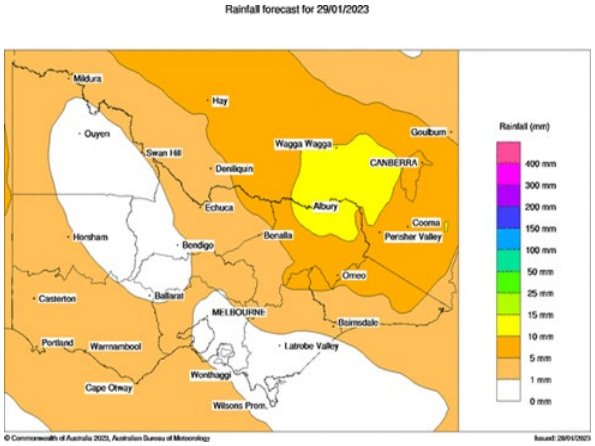


Figure 69: Total forecast rainfall Murray–Darling Basin 29 January 2023 (Source: Bureau).

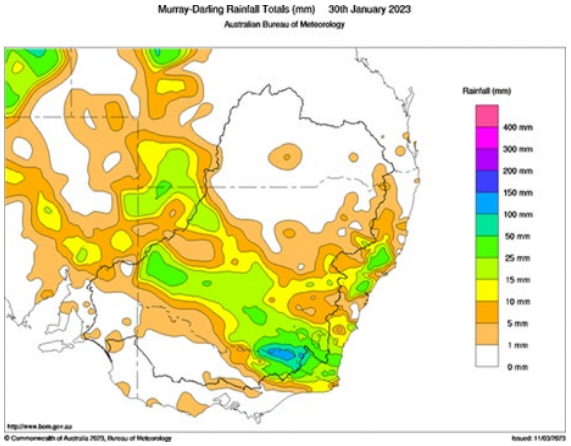


Figure 70: Total rainfall Murray–Darling Basin 30 January 2023 (Source: Bureau).

Flows at Yarrawonga weir continued to target an environmental water order of 9,000 ML/day for much of January. On 19 January, an updated rating table for downstream Yarrawonga Weir was adopted. The new table indicated that flows downstream of Yarrawonga Weir were about 500 ML/day less than the previous table indicated at this level. This change suggested that flooding in 2022 may have modified the river bathymetry to some degree.

Deviations from the rating table also continued to be observed between Yarrawonga Weir and the Tocumwal gauge, with plans in place to have further gauging's and rating tables checked and adjusted again.

In mid-Murray reaches, inflows from all tributaries had returned to more normal rates, with flows at Torrumbarry weir reducing to near 7,000 ML/day by the end of January. Higher flows continued through the Edward-Wakool system in early January, but steadily receded as the month progressed.

As wet conditions in the Murrumbidgee catchment eased, flows to the Murray also reduced, whilst still averaging near 23,400 ML/day in January. By the end of January, the flow into the Murray from the Murrumbidgee system had receded but remained above 9,000 ML/day.

At Euston Weir, the Navigable Pass was re-installed in January, however an integral inspection point on the weir had been damaged. To minimise risks to asset safety, the weir pool level was lowered and then maintained below FSL, on advice from WaterNSW.

High flows to the Menindee Lakes system continued in January with Main Weir releases of 75,000 ML/day continuing until 13 January, when releases were reduced to 65,000 ML/day. By the end of January, WaterNSW advised that flows though Main Weir, had reduced to 36,000 ML/day as inflows to the Menindee Lakes system reduced. On the lower Darling at Burtundy, high releases from Main Weir had increased the flow to near 23,500 ML/day, with a forecast peak in February of between 25,000 - 30,000 ML/day.

River levels at Wycot, in the upper Great Darling Anabranch, reached a peak height of 5.7 metres on 22 January with continued uncertainty around the extent of inflows and duration of this inflow into Murray system, largely due to the lack of historic data available of flows to this magnitude.

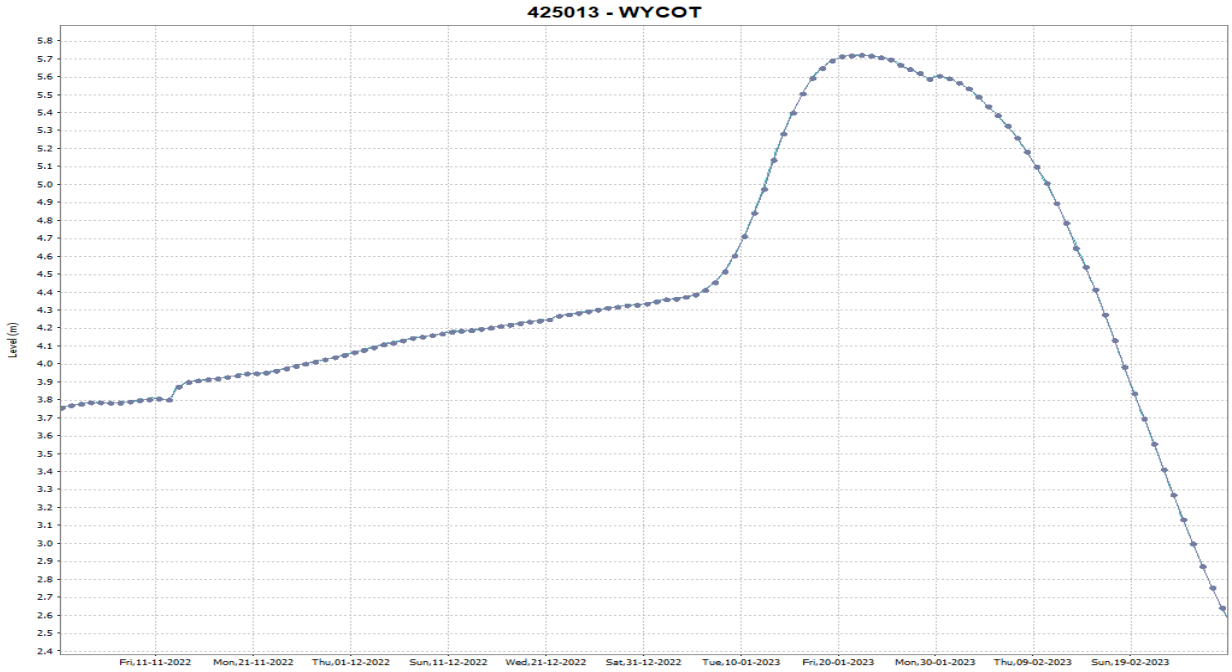


Figure 71: Recorded gauge height at Wycot (upper Great Darling Anabranch), showing the January 2023 flood peak.

At the start of January flow over the South Australian border had begun to recede, however major flooding was continuing across low-lying river areas along the Murray. At the start of January flow near 166,000 ML/day was recorded and continued to recede. By the end of January, the flow had receded to around 80,000 ML/day. MDBA and RMO continued to forecast flow into South Australia during this period, using the Source Murray Operational model, to regularly update forecasts and key stakeholders with advice and provide support for their needs.

At Lake Victoria, SA Water continued to maintain operational control, with the Inlet and Outlet regulators closed and bulk heads placed into the Lake Victoria Control Regulator, to prevent uncontrolled flow into the Lake, that may compromise the structural integrity of assets.

In early January, the breaches of Bank 1 of Frenchman's Creek could be observed on Sentinel satellite imagery. The image showed the uncontrolled water from upstream in Frenchman's Creek bypassing Lake Victoria and returning to the Murray system, below Lock 7. This was occurring in response to the management actions from SA Water to start preparing the channel for repair works following the breach upstream.

At the end of January, updated Bureau forecasts were indicating no clear bias for wet or dry conditions through late summer and early autumn across the Basin (**Figure 72**). With relatively high inflows and unregulated conditions persisting through the lower system, it appeared likely that releases to meet system demands would remain relatively low for the remainder of Q3 and there was quite a high chance

that airspace management releases at Dartmouth would continue and possible extend to Hume Dam in the months ahead.

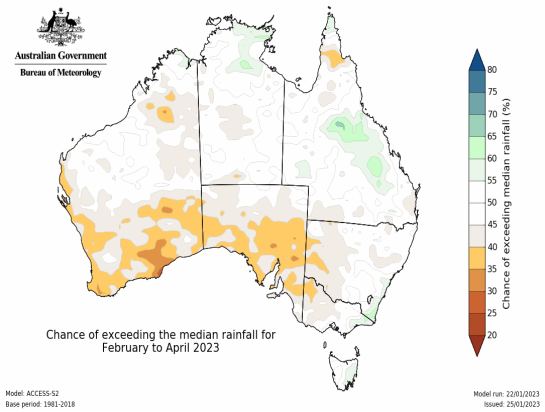


Figure 72: Chance of exceeding the median rainfall for February 2023 – April 2023 (Source: Bureau).

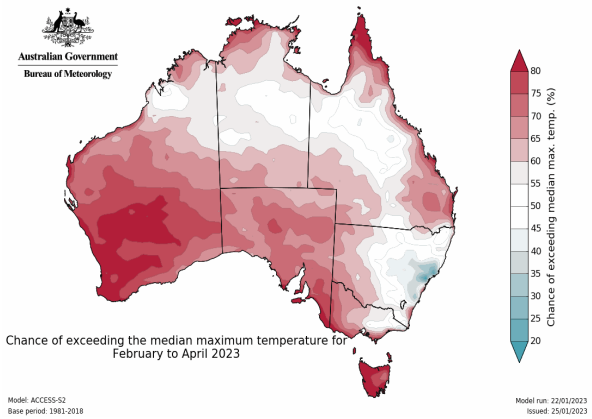
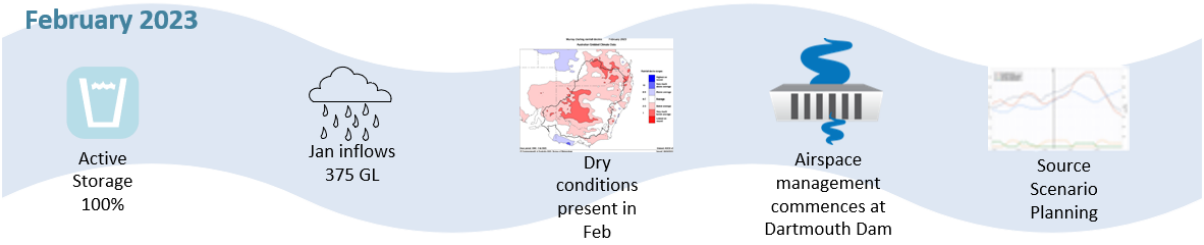


Figure 73: Chance of exceeding the median maximum temperature for February 2023 – April 2023 (Source: Bureau).

February 2023



Rainfall during February was largely below average across the Murray–Darling Basin. In parts of western New South Wales and southern Queensland rainfall was very much below average. In contrast, much of eastern and south-eastern New South Wales experienced average conditions (**Figure 74**).

Overall, Murray–Darling Basin rainfall was 63% below the mean and ranked 12th driest out of the 124 years on record with an area average rainfall of 14.5 mm. River Murray system inflows for February (excluding Snowy, Darling, IVT and environmental inflows) were around 375 GL (7% AEP). Across the 3 months of Q3, inflows totalled 6,267 GL (1% AEP).

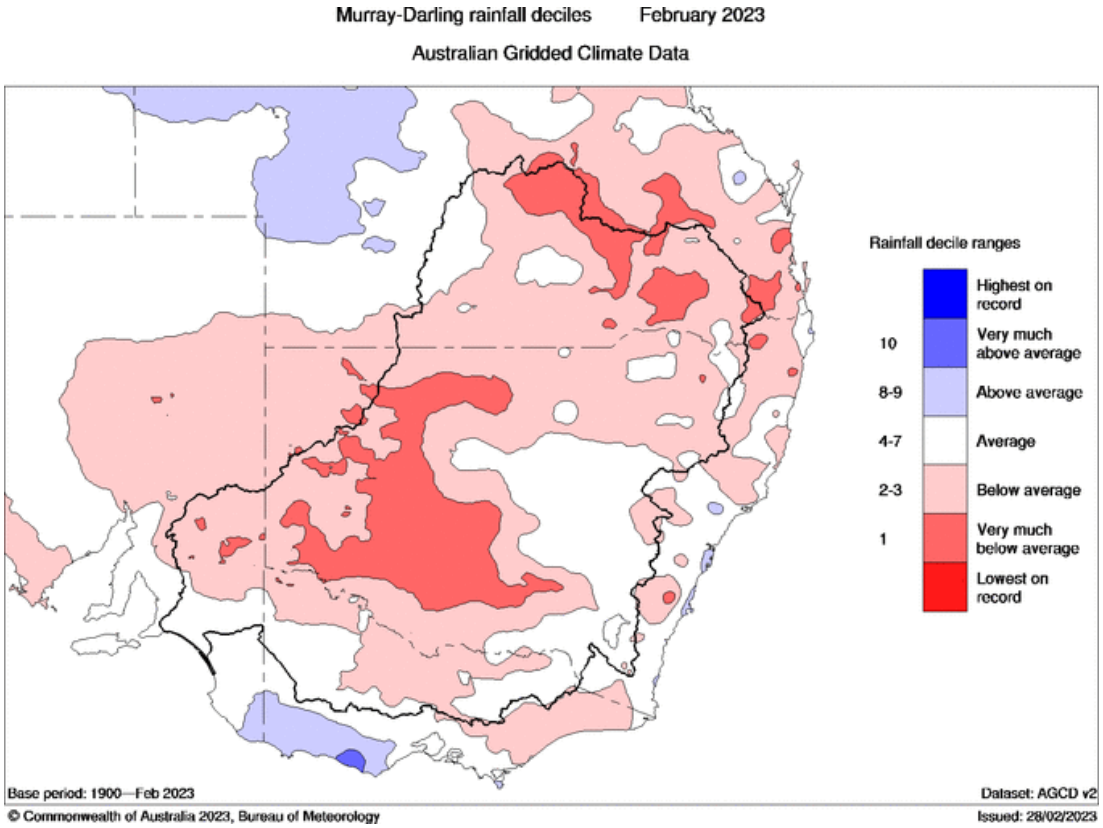


Figure 74: February 2023 Murray–Darling Basin rainfall deciles showing below average to very much below average conditions. (Source: Bureau)

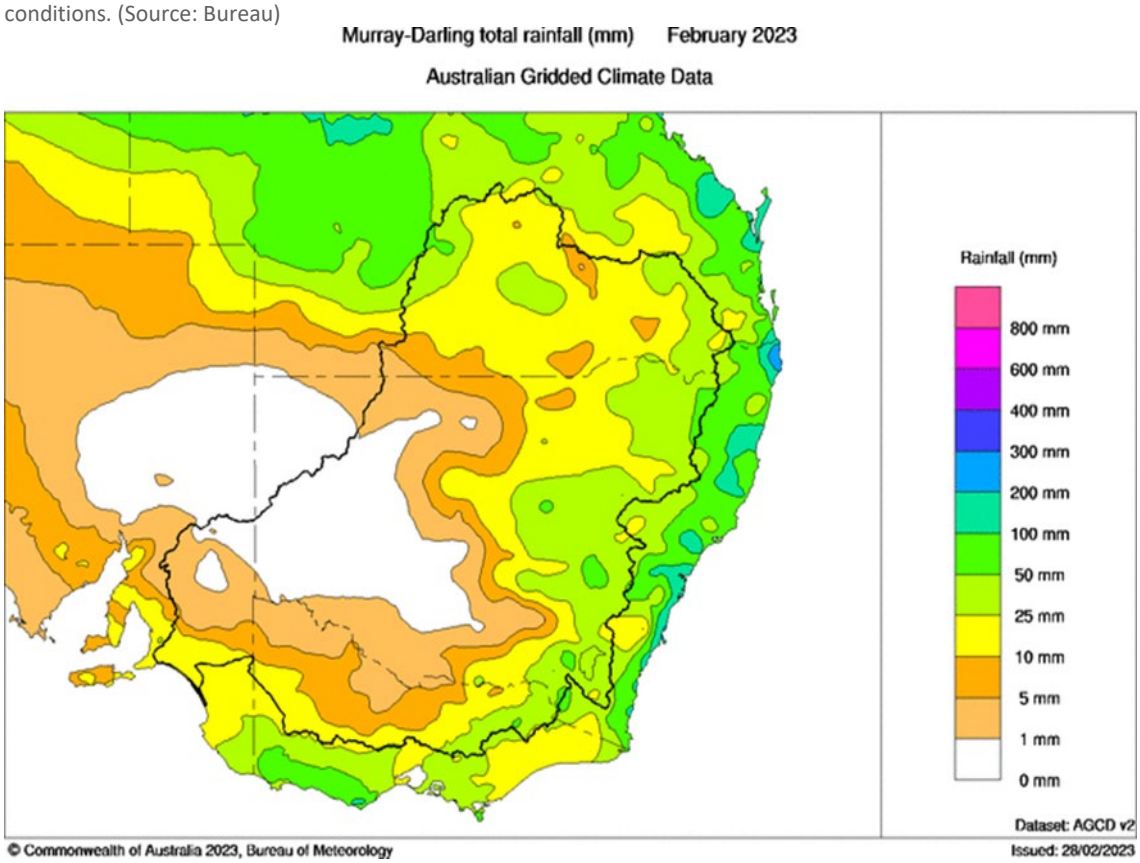


Figure 75: Murray–Darling Basin rainfall for February 2023 (Source: Bureau).

The Bureau reports that Australia's national area-average mean temperature was 0.41 °C above the 1961–1990 average for February. Across the Murray–Darling Basin, minimum temperatures were lowest on record in central New South Wales, and very much below average conditions spread across the centre of the Basin. Maximum temperatures were average for much of the Southern Basin, with above average conditions experienced across the Northern Basin (**Figure 76** and **Figure 77**).

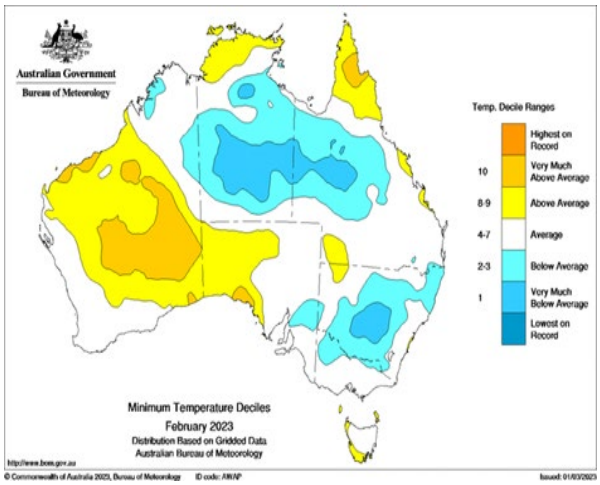


Figure 76: Murray–Darling Basin minimum temperature deciles February 2023 (Source: Bureau).

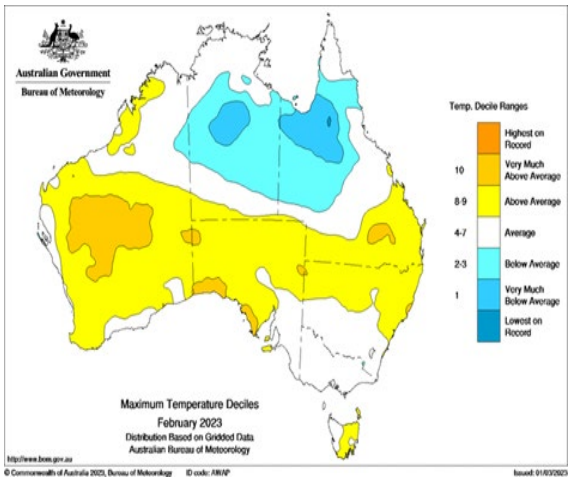


Figure 77: Murray–Darling Basin maximum temperature deciles February 2023 (Source: Bureau).

Drier conditions returned to the Dartmouth catchment in February after rainfall late January. A pre-release plan was developed in early February to begin reducing the storage to increase flood mitigation during the coming winter in a way that ensured the storage could be re-filled to 99% capacity (EFSL) with very high probability. The flow pattern to achieve this using pulsing and flow variability was developed to target environmental benefits along the Mitta Mitta River with specific advice from Goulburn Murray Water (GMW) and Victorian Fisheries helping in this regard. The initial pulse targeted a maximum release of 6,800 ML/day for 2 days, before receding to flows near 2,600 ML/day by the end of February. This action saw Dartmouth storage reduce to 97.1%. Airspace analysis would continue into Q4 with a continuation of releases to further reduce the Dartmouth level likely to occur under all but very dry scenarios.

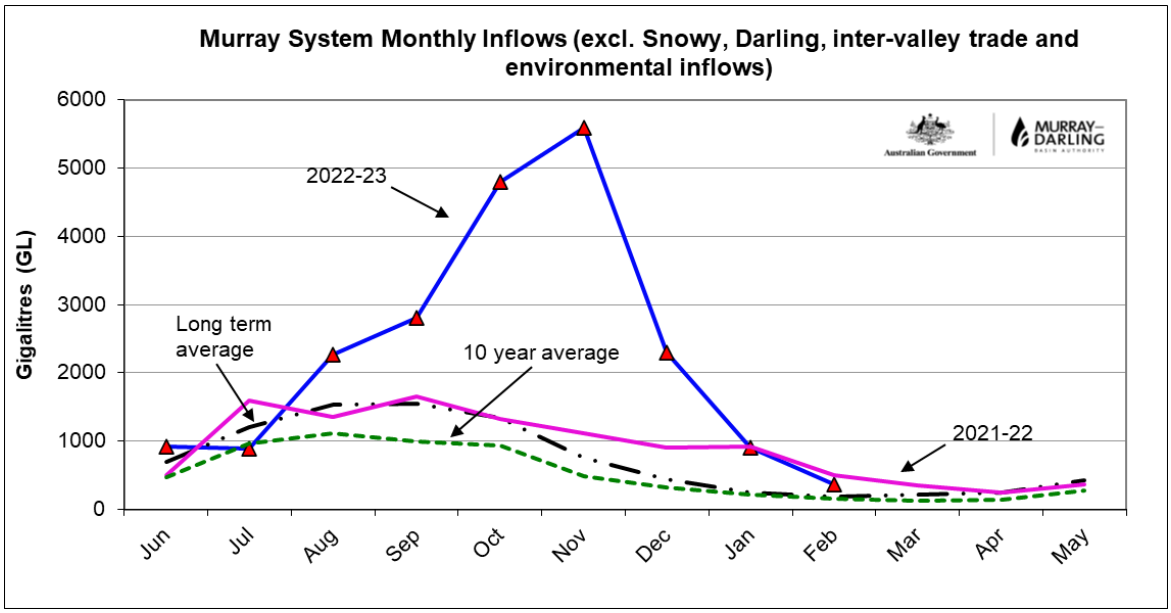


Figure 78: Murray System monthly inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) until the end of Quarter 3, 2022–23.

At Hume dam, dry conditions returned following the rain of late January. Releases continued to meet downstream demands, with directed releases to meet the target environmental flow at Yarrawonga Weir continuing until 14 February with the target flow of 9,000 ML/day concluding on 17 February, when relatively low system demands meant the release could be decreased to rates between 7,000 and 8,000 ML/day. Hume Dam decreased to 96% capacity by the end of February, with releases gradually increasing as dry and hot conditions drove up irrigation demand in the system.

In mid-Murray reaches, inflows from tributaries had returned to more normal summer rates, with flows at Torrumbarry weir reducing to near 4,600 ML/day by the end of February. During February the Edward Wakool system returned to regulated conditions downstream of Stevens weir.

However, flows into the Murray from the Murrumbidgee River continued to recede more slowly, averaging near 5,200 ML/day during February. By the end of the month, the flow at into the Murray from the Murrumbidgee remained above 2,800 ML/day. These elevated inflows and continuing high inflows from the lower Darling River and Great Darling Anabranch meant unregulated flows continued downstream of the Murrumbidgee junction to the South Australian border.

On the Darling-Barwon system, inflows to the Menindee Lakes system continued to recede, with WaterNSW advising on 3 February that releases at Main Weir would continue to be reduced and that total outflow from the storage was currently 28,400 ML/day.

> *"Flows through Main Weir are progressively being reduced from 20,000 megalitres per day to 10,000 megalitres per day (ML/day) from the 3rd of February 2023 over the next week. Total outflow from the storages is currently 28,400 ML/d and are expected to reach 20,000 ML/d by this time. Outflows are currently matching the upstream recession rate until flows at the Weir 32 gauge reach 20,000ML/d. From these flows reductions of release will be observed in line with operating rules. WaterNSW is working with our interagency partners in consideration of shaping this recession."*

On the lower Darling at Burtundy, a peak flow of near 25,500 ML/day was reached on 5 February, with a slow recession expected, as water from floodplains and wetlands expected to slowly return to the main river channel. By the end of February flows at Burtundy had reduced to 17,900 ML/day.

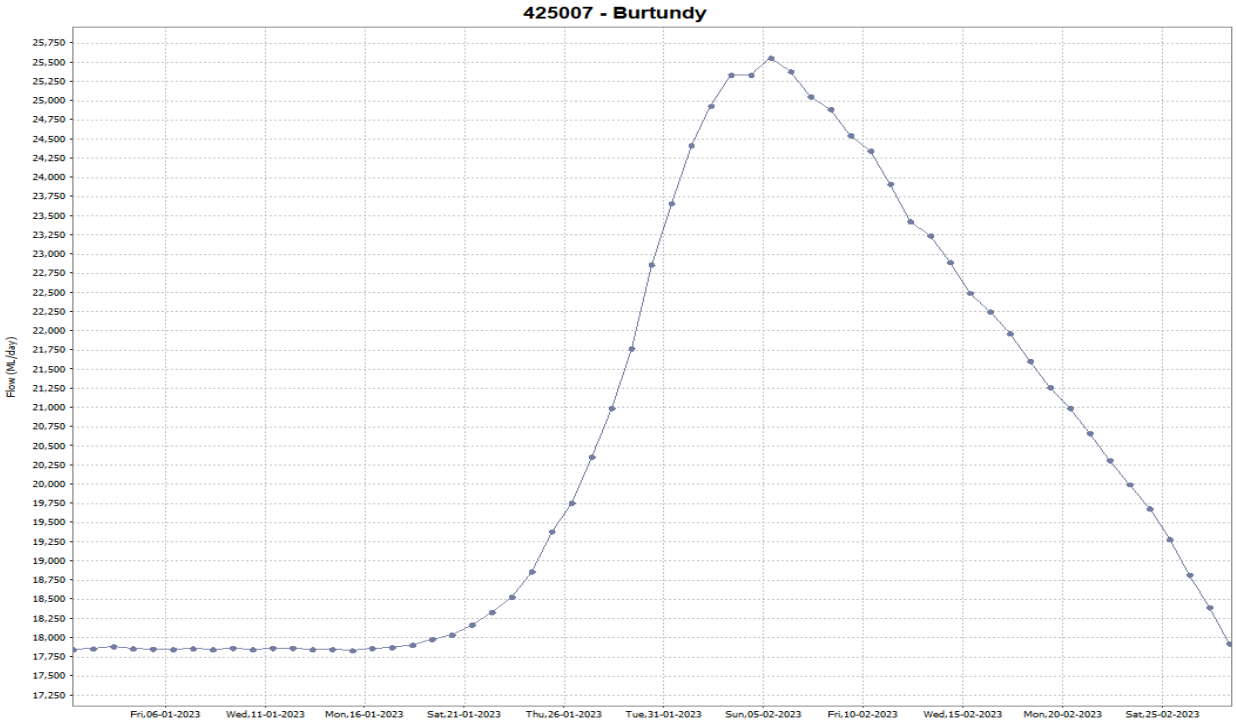


Figure 79: Recorded flow at Burtundy (Lower Darling-Barker), showing peak flows during February.

On the upper Great Darling Anabranch, the flow at Wycot continued to recede following a large flood peak in January and reached 5.5 m AHD at the start of February. By the end of February, the river height had reduced to 2.5m AHD. Further downstream, flows at Bulpunga had begun to steadily increase, reaching around 12,000 ML/day by the end of February as flooding worked its way down the anabranch. The familiar theme of rating table uncertainty at high flows also emerged on the Great Darling Anabranch. With very limited historic data to go off, there were wide margins of uncertainty in forecasting volumes and duration of flow into the Murray from the Anabranch. Gaugings were taken and used to re-set rating tables at some sites, however the time taken for flows of this magnitude to move through the multitude of lakes and wetland systems along the lower reaches of the Anabranch and arrive at the Murray was unclear.

At the start of February flow over the South Australian border had receded to 74,000 ML/day, however major flooding was continuing at many locations. By the end of February, the flow to South Australia had receded to near 36,000 ML/day. During February a number of navigable pass structures were re-installed, from Euston (Lock 15) and into South Australia, as flow receded. As water receded and inspections were performed on structures, damaged structures were discovered, with the issue at Euston Weir and the Bank breach at Frenchman's Creek being of most significant concern.

MDBA and RMO continued to forecast flow into South Australia during this period, using the Source Murray Operational model, to regularly update forecasts and key stakeholders with advice and provide support for their needs.

At Lake Victoria, SA Water continued to perform inspections of the damage related to Bank 1. During February the Inlet regulator remained closed, as plans commenced for repairs of to begin. At the start of February, the outlet regulator had commenced releases to begin the process of reducing the water level in Lake Victoria and Frenchman's Creek to assist initiation of Bank 1 repair works by SA Water. RMO liaised closely with SA Water to help facilitate this necessary action whilst taking account of forecasts and potential risks to water security and operational objectives across coming months.

By the end of Q3, the Bureau reported that drier conditions were more likely to occur across the Basin in autumn. This reflected a weakening of the La Niña event in the tropical Pacific Ocean and a return to neutral ENSO conditions. It was reported that there were indications of a potential EL Niño event developing during the coming months in several outlook models. Additionally, March to May maximum temperatures were likely to be above median for most of Australia. **Figure 80** and **Figure 81**).

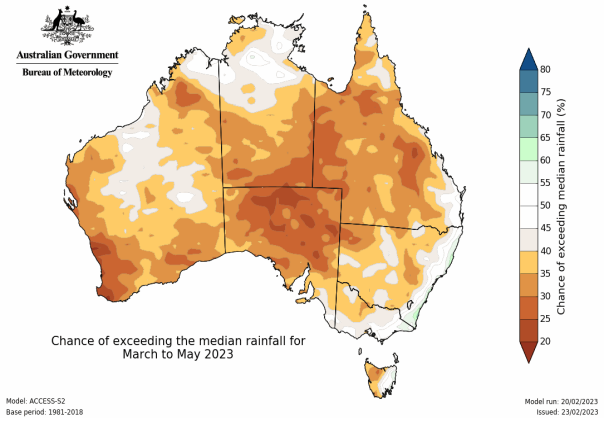


Figure 80: Chance of exceeding the median rainfall for March 2023 – May 2023 (Source: Bureau).

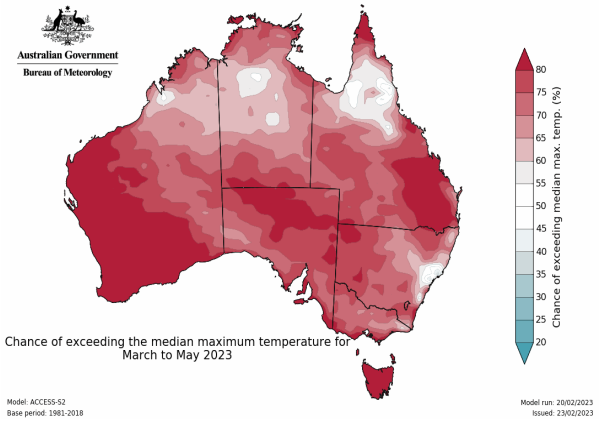


Figure 81: Chance of exceeding the median rainfall for March 2023 – May 2023 (Source: Bureau).

Quarter 4

The primary focus for River Murray Operations' activities for quarter 4 (Q4) was to balance the continuation of high flows through the lower system and elevated system inflows with efficient operations and the need to ensure water availability was maximised for all water users.

The Bureau of Meteorology (Bureau) reported that autumn rainfall for the Murray–Darling Basin was the 54th driest across the 124-year historic record with area-averaged rain of 93 mm.

During March, airspace analysis at Dartmouth Dam indicated additional releases to increase airspace could continue following their commencement in February, notwithstanding drier conditions emerging in February and Bureau forecasts indicating a likely trend to drier conditions in autumn. At Hume Dam, airspace analysis was reviewed regularly through March and April as conditions evolved. With relatively high inflows to the storage continuing and an easing of demands, additional releases to maintain airspace were able to begin on 20 April based on updated inflow and demand forecasts at that point and the requirement to ensure the storage could be re-filled with very high probability.

Increasing irrigation demands during early autumn resulted in a step up to Hume Dam releases that peaked above 17,000 ML/day in mid-March. Releases generally reduced through late March and into April as demands fell away towards the end of the irrigation season and in response to wetter weather across irrigation areas.

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

During autumn water quality issues along the Darling River linked to floodwater interaction with the floodplain extended progressively from areas upstream of the Menindee Lakes. In particular, dissolved oxygen (DO) levels were observed to decrease upstream of Main Weir during summer, before extending to the lower Darling River in March. Environmental impacts included significant fish mortality, particularly along river reaches immediately downstream of the Menindee Lakes. Responding to this issue was a shared, collaborative process led by New South Wales, and assisted by WaterNSW and MDBA River Management staff, environmental water holders, and other relevant stakeholders. The primary actions used to mitigate impacts were the release of both 'planned' and 'held' environmental water and varying outlet configurations to help flush and dilute the river downstream.

With the continuation of high tributary inflows and unregulated inflows from the Darling system, unregulated flows on the Murray continued through until the end of autumn. This meant that unregulated flow to South Australia had persisted continuously for almost 2 years. On May 31, Lake Victoria (Tar-Ru) reached 395 GL capacity, just under the end May Lake Victoria Operating Strategy (LVOS) ceiling. Achieving this level was a significant outcome given the challenges of the Frenchman's Creek repair works, and the uncertainties in forecasting directed releases and unregulated flows.

By the end of Q4, the Bureau was forecasting a likelihood of drier conditions for the Basin over winter, with a 60 - 80% chance of below median rain for much of the River Murray system. Despite this outlook, a key focus heading into winter was on-going airspace management and preparing simultaneously for possible flood operations and the potential emergence of dry conditions.

The **end October update** to the *River Murray system Annual Operating Outlook (AOO) 2022–23* , was adopted on 27 February. 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, and an update on assumptions and the outlook for summer and autumn including the likelihood of a change in climatic conditions indicated by BoM climate outlooks, including the return to dryer conditions.

Key achievements for Q4

Analysis and implementation of airspace management at Dartmouth and Hume Dams relatively early in the year in response to on-going high storage levels and persistent above-median inflows.

Management of unregulated flows and operation of Lake Victoria in accordance with the Lake Victorian Operating Strategy in response to forecasting uncertainties and management of Lake Victoria (Tar-Ru) repair work to maximise water resource.

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

During autumn the following key drivers influenced river operations

- **Key Driver 1 – 'Continuing wet conditions and elevated inflows'** – Autumn brought further rainfall across much of the Murray–Darling Basin, with above average conditions experienced in parts of the southern Basin. This helped deliver strong system inflows for autumn at around 978 GL, or 26% annual exceedance probability (AEP). Additionally, the conditions continued boosting inflows to Dartmouth and Hume Dam, with airspace management beginning during autumn. This aimed to provide a buffer against large rain events and reduce flooding risks over winter-spring, whilst also ensuring the storage could be filled later in the season with very high confidence.

- **Key Driver 2 – 'Continuing unregulated flows and Lake Victoria operations'** – Unregulated flows continued through to the end of the water year, with a continuation of high tributary inflows. Furthermore, high inflows from the Great Darling Anabranch provided a further boost to unregulated flows over the South Australian border. Despite the conditions and a range of forecasting uncertainties, RMO managed Lake Victoria (Tar-Ru) operations to successfully reach the higher end of May LVOS target range of 396 GL.

- **Key Driver 3 – 'Water quality issues on the Darling River'** – Q4 saw water quality impacted in various locations including low DO in parts of the Northern Basin as flood flows mobilised large amounts of organic material from the floodplains. Low DO water moved into the Menindee Lakes and then downstream where impacts included significant fish mortality. RMO assisted New South Wales and partner agencies in the response to this issue.

- **Key Driver 4 – 'Operational adaptation and risk management during post-flood repairs to key operating structures'** – Q4 saw collaborative work and liaison between RMO and state partners to manage risks and adjust operations to facilitate actions to reduce structural safety risks and enable repair processes to occur at Lake Victoria and Euston Weir.

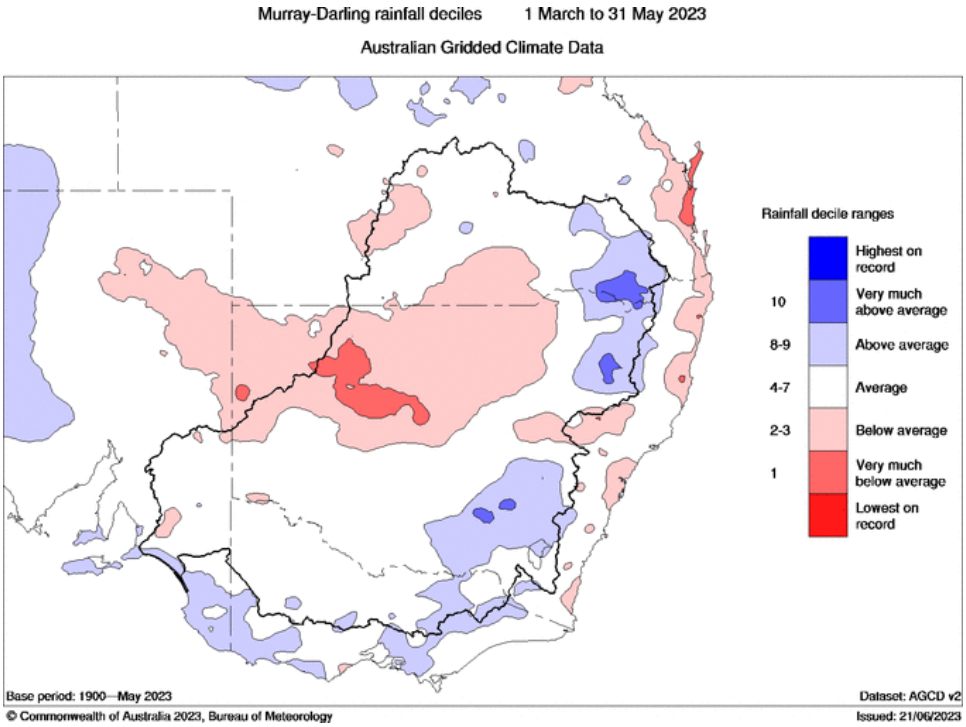


Figure 82: Murray–Darling Rainfall deciles for Q4 indicate variable conditions across of the Muray-Darling Basin.

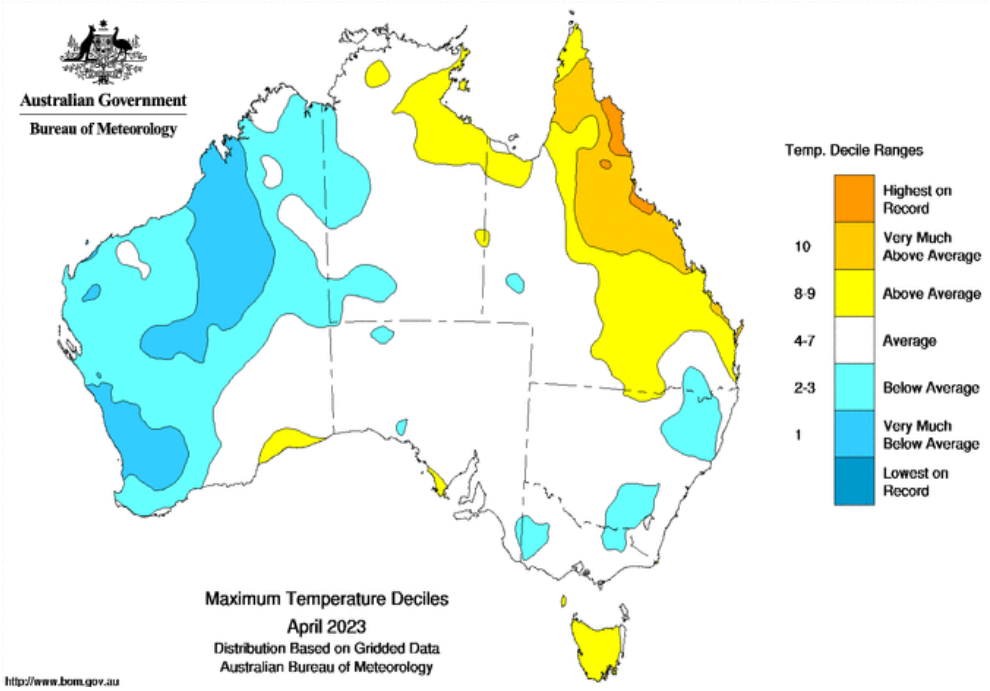


Figure 83: Maximum temperature deciles for Q4 show a return to average conditions through the basin with isolated areas of below average temperature over eastern parts of Victotria and New South Wales.

Key metrics for Q4

The operational metrics in **Table 11**: Key metrics for River Murray system operations during Q4 Provide a snapshot summary of river operations for Q4**.** All figures should be considered within the context of the key drivers outlined above.

Table 11: Key metrics for River Murray system operations during Q4

Metric		Quarter 4 [i]
Total River Murray system inflows [ii]		978 GL (26% AEP)
Storages	Net change at Dartmouth Net change at Hume Net change at Lake Victoria Net change at Menindee Lakes	↓ 20 GL due airspace management (spill) ↓ 150 GL due to releases to supply demands and for airspace management (spill) ↓62 GL due to the management of the lake in accordance with the Lake Victoria Operating Strategy (LVOS) ↓334 GL due to airspace management (spill) and releases of environmental water and for operational requirements
Storage releases	Dartmouth Releases Hume Releases Lake Victoria Net Releases [iii]	130 GL comprising releases for airspace management (spill) 767 GL comprising releases for airspace management (spill) and delivering water for the environment and downstream demands. 59 GL due to the management of storage filling (spill) and the LVOS during unregulated flows

Metric		Quarter 4 [i]
	Menindee Lakes Releases	272 GL releases to the lower Darling River comprising operational releases and releases for the environment, including spill. 55 GL released to the Great Darling Anabranch comprising of environment water.
	IVT	Murrumbidgee: 0 GL Goulburn: 28 GL
Total consumptive deliveries [iv]		349 GL Victorian Murray 411 GL NSW Murray
River Murray system loss [v]		-341 (-32%)
Environmental directed releases from Hume [vi]		0 GL
Flow to SA	Total SA Flow Dilution & Loss Entitlement Flow Consumptive trade deliveries Environmental water deliveries [vii] Rolling Adjustment [viii]	2,147 GL 174 GL 240 GL 36 GL 423 GL 1,275 GL due to unregulated flows and additional dilution flows.
Publication of operational information		14 MDBA Weekly Reports 9 Media Releases on 'river operations' 1 Hume Dam operations Update

xvii. 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 as a result of hydrometric updates may result in the numbers in the above table changing.

xviii. 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.

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

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

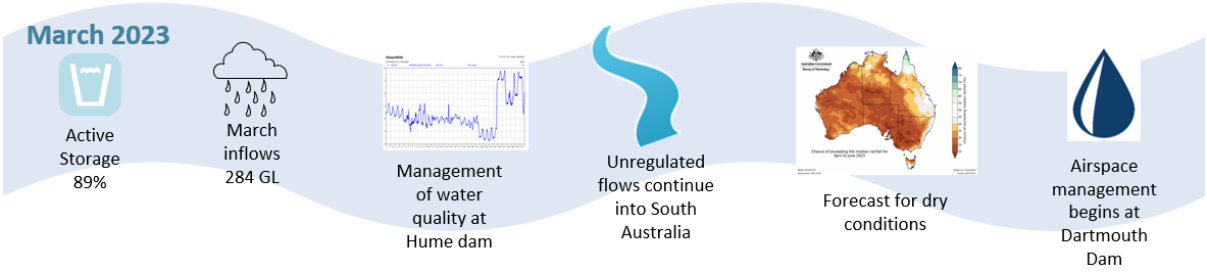
xxi. River Murray system (RMS) losses are defined as the losses incurred in the RMS between Hume Dam and the South Australian border. Loss estimates are derived from the River Murray Monthly Accounts. Losses exclude environmental use debited against environmental water holder accounts for their specific 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).

xxii. Sourced from River Murray system monthly environmental accounts.

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

xxiv. 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 2023



Rainfall was largely average across the Murray–Darling Basin. North-west New South Wales experienced very much below average conditions, whilst much of eastern New South Wales, Victoria and Queensland experienced above to very much above average conditions (Figure 85). Overall, Murray–Darling Basin monthly rainfall was 8% above mean and ranked 80th driest during the 124 years of the historic record with an area average rainfall of 46.1 mm.

River Murray system inflows for March (excluding Snowy, Darling, IVT and environmental inflows) were around 284 GL, which was well above the month's long-term median of 147 GL. In comparison with the historical record since 1896, only about 19% of previous monthly totals for March have been higher than the inflows observed in March 2023.

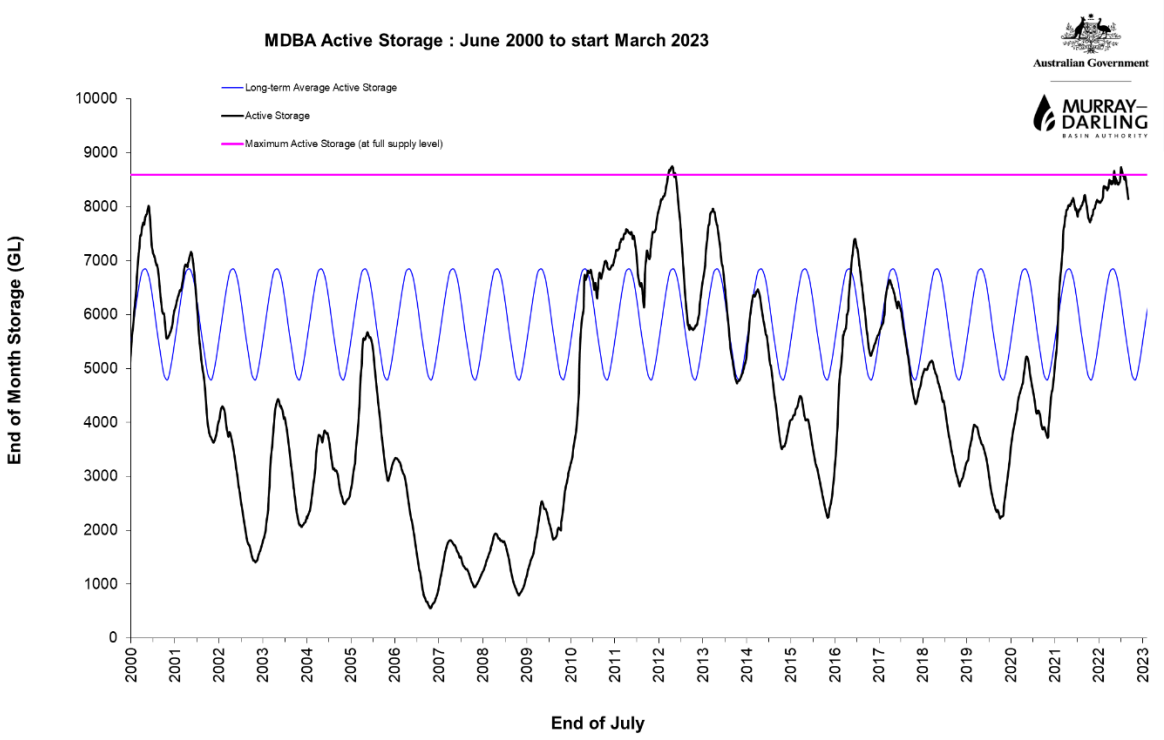


Figure 84: The River Murray system total active storage at the start of Q4

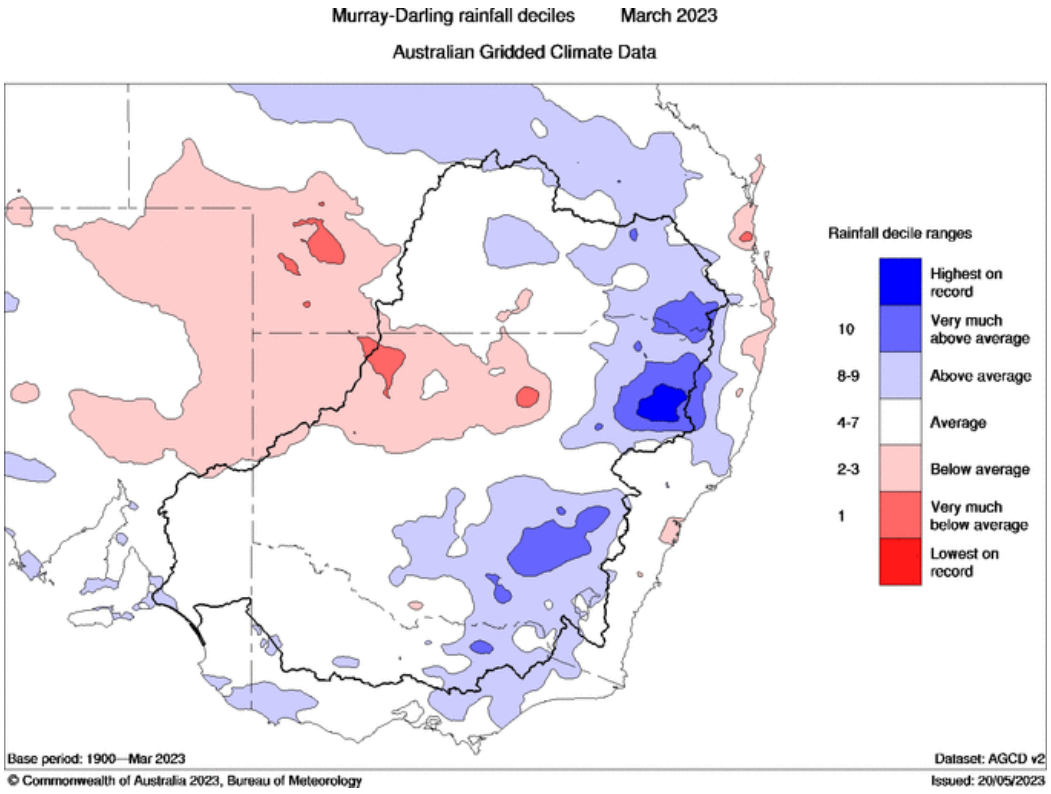


Figure 85: March 2023 Murray–**Darling Basin rainfall deciles showing average to below average conditions (**Source: Bureau**).**

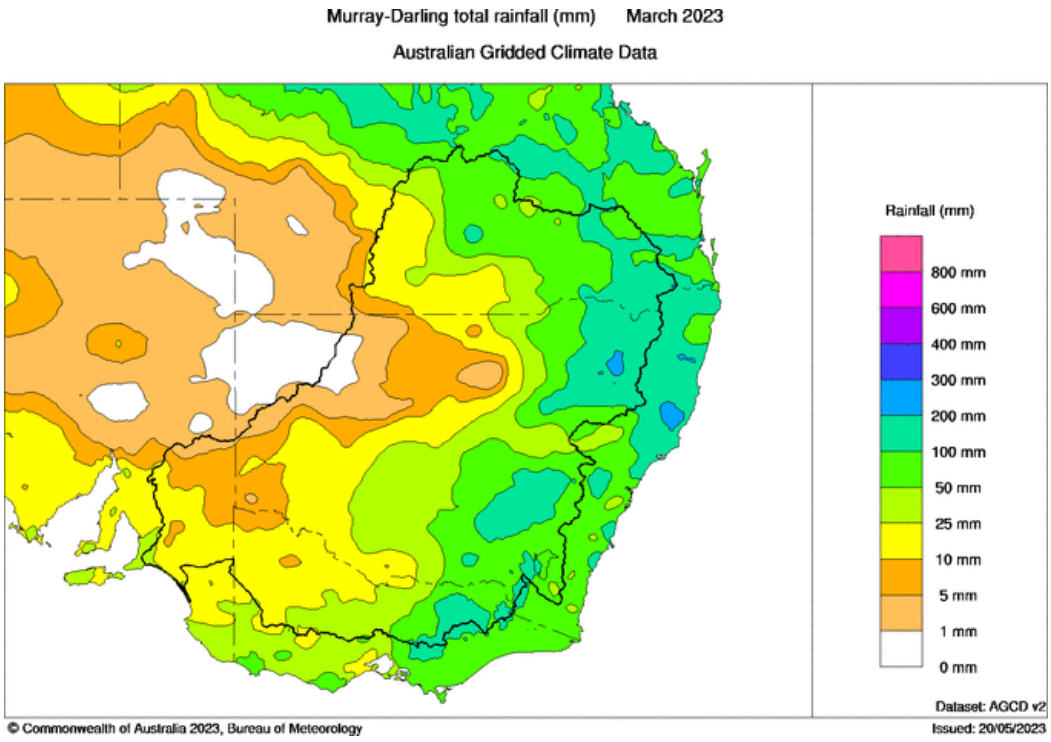


Figure 86: Murray–Darling Basin rainfall for March 2023 showing rainfall totals across the Basin (Source: Bureau).

The Bureau reports that Australia's national area-average mean temperature for March was 1.11 °C above the 1961–1990 average, the equal-tenth-highest on record. Across the Murray–Darling Basin, minimum temperatures were average for much of western Victoria and New South Wales, with above to very much above average conditions experienced across the Northern Basin. Maximum temperatures were average for much of Victoria, with above average conditions experienced across most of the Northern Basin **Figure 87** and **Figure 88**

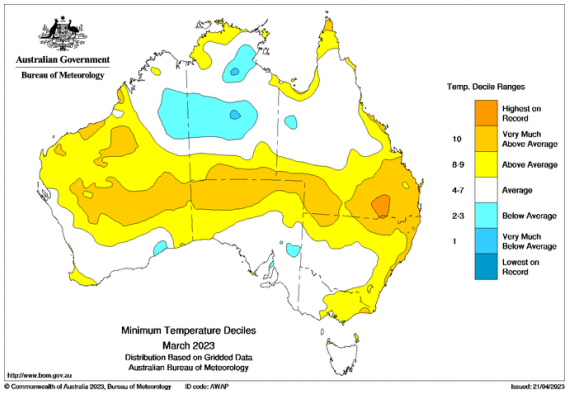


Figure 87: Australian minimum temperature deciles March 2023 (Source: Bureau).

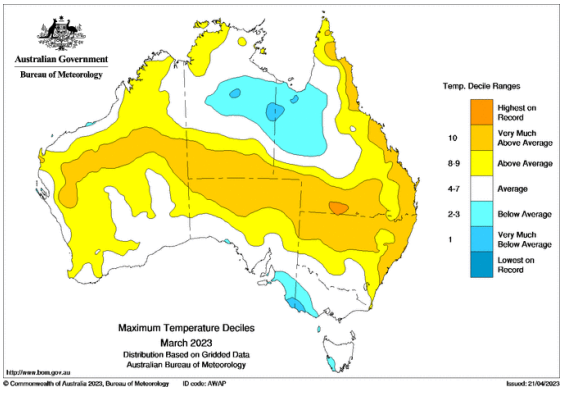


Figure 88: Australian maximum temperature deciles March 2023 (Source: Bureau).

In early March, releases from Dartmouth Dam were reduced to 1,300 ML/day as inflow receded upon a dry end to February. Pre-release analysis continued into March, with calculations based on inflows through February to target filling Dartmouth Dam to the 99% effective full supply level (EFSL) in winter-spring. Towards the end of March, a number of rain events occurred with inflows increasing to a peak of 3,400 ML/day. This helped maintain the need for airspace management across the month.

At Hume Dam, releases continued to meet downstream demands. Hume storage reduced to 88% capacity during March, with releases also easing to near 8,500 ML/day following a period of higher releases above 17,000 ML/day in the middle of the month.

Releases at Yarrawonga weir targeted around 7,500 ML/day during March. This was well below channel capacity and was reflective of relatively low demands through the system due to the wetter conditions and unregulated flows continuing along downstream reaches.

In mid-Murray reaches, the relatively low demand and flows downstream of Yarrawonga Weir meant the river came back to fairly low levels as March progressed. For example, the flow downstream of Torrumbarry Weir was mostly below 5,000 ML/day. Advice from WaterNSW indicated this had the potential to impact pump access for some New South Wales water uses downstream of the Barmah Choke, including through the Merran Creek system.

In response to this advice, RMO looked at options to assist New South Wales in improving pump access whilst managing any potential impact on water use and operational efficiency. RMO discussed the situation with WLWG to reach agreement that operations could be adjusted to use Goulburn Inter-valley trade (IVT) delivery co-ordinated with Hume Dam releases that maintained flows at Yarrawonga Weir to slightly elevate river levels and provide flows downstream of Torrumbarry Weir of at least 5,000 ML/day

that would meet water user needs. RMO coordinated the operation with Goulburn Murray Water and WaterNSW provided engagement and advice on water user needs. The additional water required to support this operation was tracked by RMO and accounted as New South Wales use with agreement from WLWG. WaterNSW posted several updates on their Water Insights portal to keep stakeholders informed.

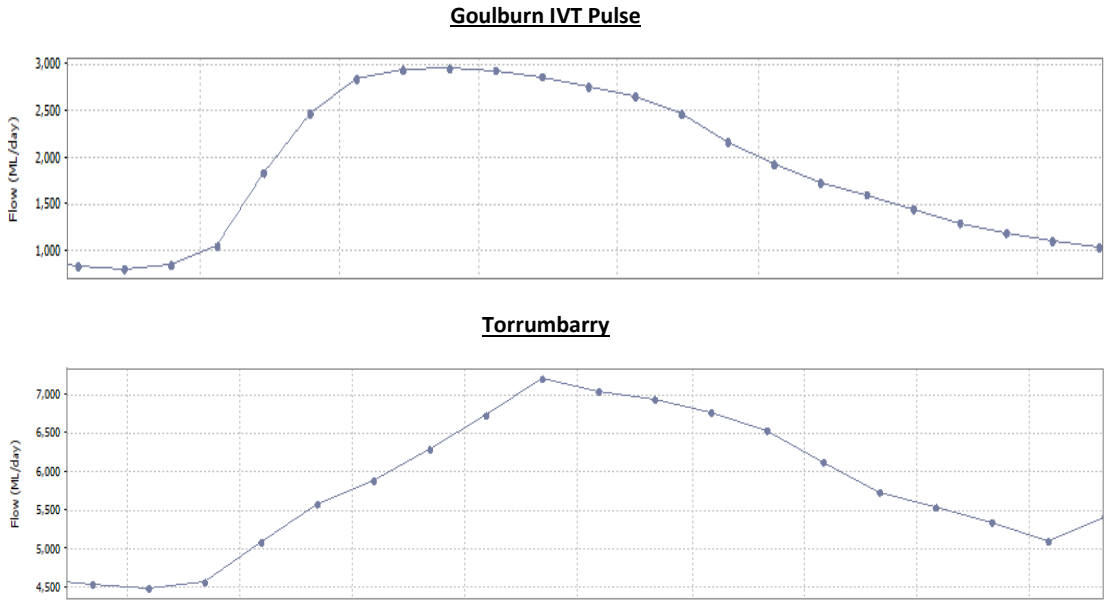


Figure 89: Goulburn IVT delivery pulsed to the Murray and the resultant flows downstream of Torrumbarry Weir. This operation including the IVT delivery met NSW requirements with the water use tracked and accounted to NSW.

At the end of March, releases from Torrumbarry Weir had increased to 7,200 ML/day, as the IVT pulse reached the Murray system.

Flows into the Murray from the Murrumbidgee River continued to recede during March with flows averaging around 3,000 ML/day.

Inflows to the Menindee Lakes system also continued to recede in March, with WaterNSW advising on 3 March that releases at Main Weir would continue to be reduced. The advice below was received from WaterNSW and outlines the release strategy devised to manage the inflow recession and mitigate poor water quality issues downstream of the Menindee Lakes system.

> *"Operationally, when the flow at Weir-32 is less than 10,000 ML/day, the rate of fall will be a maximum of 500 ML/d. When the flow at Weir-32 is less than 5,000 ML/day then the reduction would be at a maximum rate of 250 ML/day until the flows reach the base flow targets. Operational plans for the coming weeks are as follows:*
>
> - *Pamamaroo outlet regulator gates to be kept open to release flows into the lower Darling River ensuring better quality water into the system.*
> - *Menindee Outlet regulator will continue to meet the majority of system targets at Weir 32*
> - *Flows below Weir 32 will continue to reduce until mid-March 2023 for base flow and environmental delivery.*

- *Lake Cawndilla outlet regulator to maintain a flow of 750 ML/d to meet environmental orders to Great Darling Anabranch throughout March into April. The Menindee storages are currently at full supply level (FSL) and are expected to reduce to 90% by the end of March 2023 as per the current demands and operations plan".*

Current System Status as of the 3 March 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.25	156	81%
Lake Pamamaroo + Copi Hollow	60.67	293	106%
Lake Menindee	59.88	636	101%
Lake Cawndilla	59.85	632	100%
TOTAL		**1,718 GL**	**99%**

Table 12: Release and storage data at Menindee Lakes, 3 March 2023. Source WaterNSW

As Menindee inflows fell away quickly during February and in March, WaterNSW steadily reduced releases with the aim of following the required downstream rates-of-fall. However, due to on-going concerns with water quality, higher releases were maintained and water from the system's Environmental Water Allowance (EWA) was used to mitigate the evolving water quality conditions. On 29 March 2024, WaterNSW updated the community on operating strategies, issues and objectives, driving the release plan:

"The operations and release of water are currently being guided by advice from the Department of Planning and Environment (DPE) and other New South Wales and Commonwealth partner agencies. The use of the Environmental Water Allowance (EWA) and eWater are contributing to the active management and monitoring response being undertaken. Water releases into the Darling-Baaka River are being targeted to ensure the best chance of achieving better dissolved oxygen levels, to reduce the chance of further fish deaths. As part of this strategy, recommendations have been made to increase releases from Lake Pamamaroo in an effort to assist the situation within the Menindee town weir pool. Flows at Weir 32 are currently around 5,000 ML/day and are expected to experience minor fluctuations as system changes are made to releases over the next 24 hours, these changes are a result of balancing water delivery between the Pamamaroo and Menindee outlets".

Current System Status as of the 29 March 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.41	169	88%
Lake Pamamaroo + Copi Hollow	60.10	253	91%
Lake Menindee	59.39	546	87%
Lake Cawndilla	59.39	577	82%
TOTAL		**1546 GL**	**89%**

Table 13: Release and storage data at Menindee Lakes, 29 March 2023. Source WaterNSW.

Downstream on the lower Darling at Burtundy, flows receded slowly to near 6,500 ML/day by the end of March. This slow fall resulted from a more gradual reduction in releases from the Menindee Lakes as well as water returning to the river channel from floodplains and wetlands following the long period of elevated flows passing through the system.

As high flows continued down the Great Darling Anabranch, large uncertainty regarding the extent and duration of these flows into Murray continued. Initially, data indicated the flow had peaked around 16,500 ML/day at the Bulpunga gauge. However, a gauging and rating table update adjusted this estimate down considerably (**Figure 90**). Downstream modelling and forecasts were consequently updated with a revised peak of 10,700 ML/day, which highlighted the level of uncertainty being managed through this event.

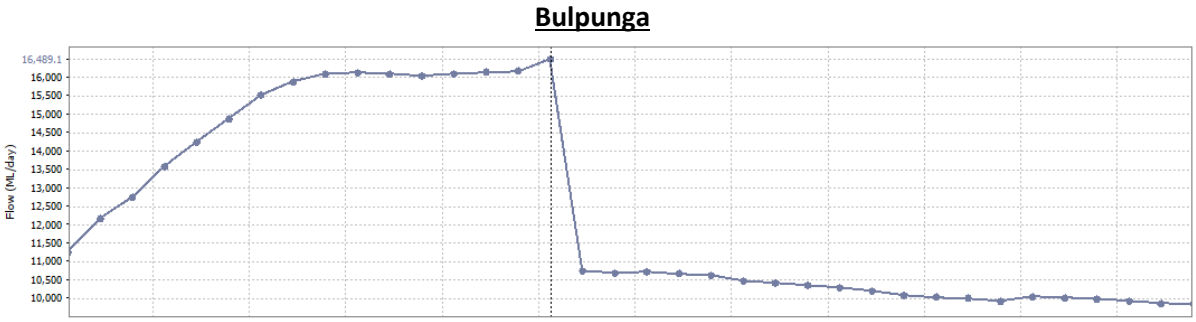


Figure 90: Rated flow on the Great Darling Anabranch at Bulpunga was reduced from around 16,500 to 10,700 ML/day following gauging's and rating table adjustments as the peak moved through.

At the start of March, flow over the South Australian border was still receding and had declined to around 35,000 ML/day, with only the Lock 7 Navigable pass remaining removed.

RMO continued to forecast flow into South Australia during this period, using the Source Murray Operational model, to regularly update forecasts and key stakeholders with advice and provide support for their needs. On 7 March a directed release order for Lake Victoria (Tar-Ru) was enacted on behalf of environmental water holders, to slow the rate of fall over the South Australian border (**Figure 91**). This order was later revoked due to unregulated flows persisting across the water year.

Lake Victoria (Tar-Ru) Outlet Releases

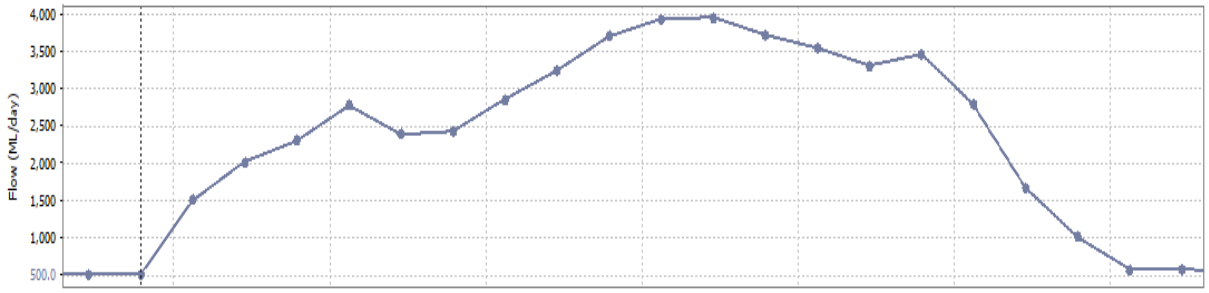


Figure 91: Directed releases from Lake Victoria (Tar-Ru) during March, aimed at slowing the rate of fall over the South Australian Border.

At Lake Victoria (Tar-Ru), SA Water continued works on the damage to Bank 1. On 17 March, SA Water advised that a base inlet flow of 500 ML/day could commence as works progressed. During March scenario planning based on inflows continued, with an end to unregulated flows over the South Australian border forecast for mid-April under a dry scenario. However, large uncertainty around the timing continued, as recessions extending on some tributaries and inflow from the Great Darling Anabranch receding at even slower rates than first forecast. During this time, River Murray Operations (RMO) planned scenarios continued to target a level at Lake Victoria (Tar-Ru) at the end of May of between 350-396 GL, as per the Lake Victoria Operating Strategy (LVOS).

Due to the on-going unregulated conditions, IVT delivery from the Murrumbidgee River was not required however, 28GL was delivered in total from the Goulburn River, 21 GL in March and 7 GL in April, as part of the operational adjustments made to supply New South Wales water users in the mid-Murray.

At the end of March, the updated Bureau climate outlook indicated a reduced chance of above average rainfall and the drier than normal conditions were probable. However, with high storages, catchments remaining relatively wet and flow recessions still playing out on some tributaries, it was likely that further airspace management releases would be required at Dartmouth and Hume Dams heading towards winter even if rainfall was relatively modest.

On 14 March, a Bureau statement was released suggesting that the La Niña event had ended and returned to a neutral position. This means there is around a 50% chance of an El Niño event occurring in 2023.

On 28 March, a further statement was released suggesting that an El Niño event has around a 50% chance of developing later in the 2023 calendar year. At this time the Bureau moved the ENSO (El Niño-Southern Oscillation) to a watch level for an El Niño event to occur.

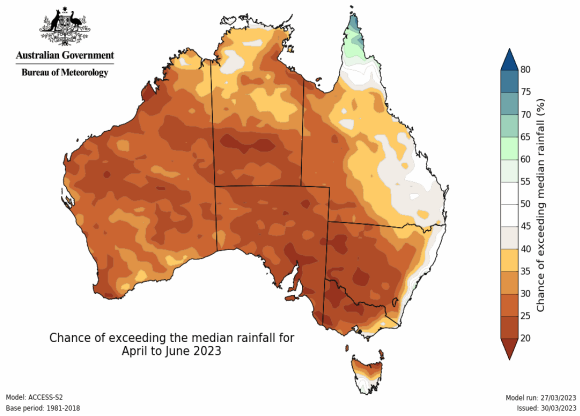


Figure 92: Chance of exceeding the median rainfall for April 2023 – June 2023 (Source: Bureau).

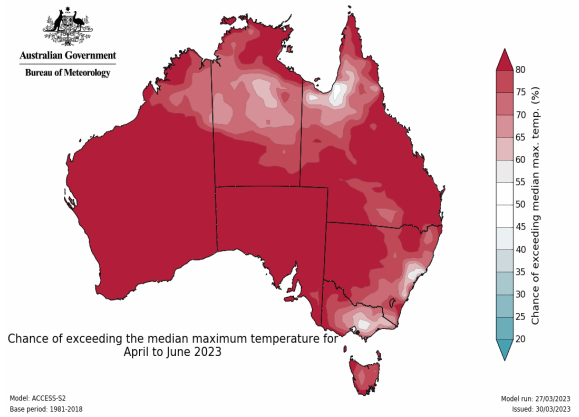
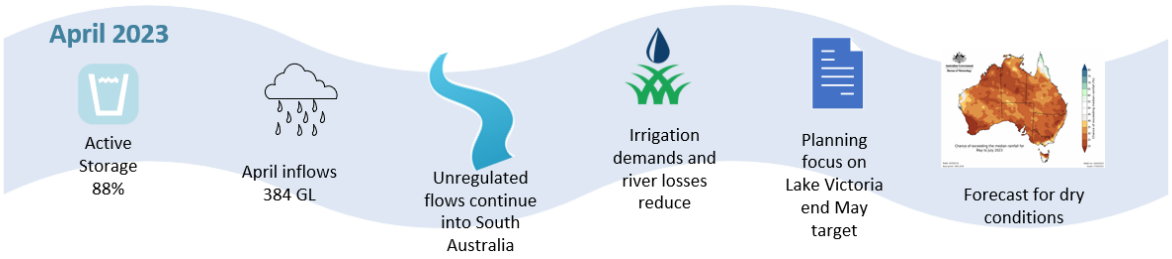


Figure 93: Chance of exceeding the median maximum temperature for April 2023 – June 2023 (Source: Bureau).

April 2023



The Bureau of Meteorology (the Bureau) reports that for April 2023 rainfall was average to above average across the southern Murray–Darling Basin and mostly average to below average in the northern Basin (**Figure 94**). Across the Basin as a whole, the Bureau reported an area-average rainfall for the Murray–Darling Basin in April totalling 27.5 mm. This is 29% below the long-term April average for the Basin.

River Murray system inflows for April (excluding Snowy, Darling, IVT and environmental inflows) remained high at around 384 GL, which is well above the month's long-term median of 166 GL. In comparison with the historical record since 1896, only about 12% of previous monthly totals for April have been higher than the inflows observed in April 2023.

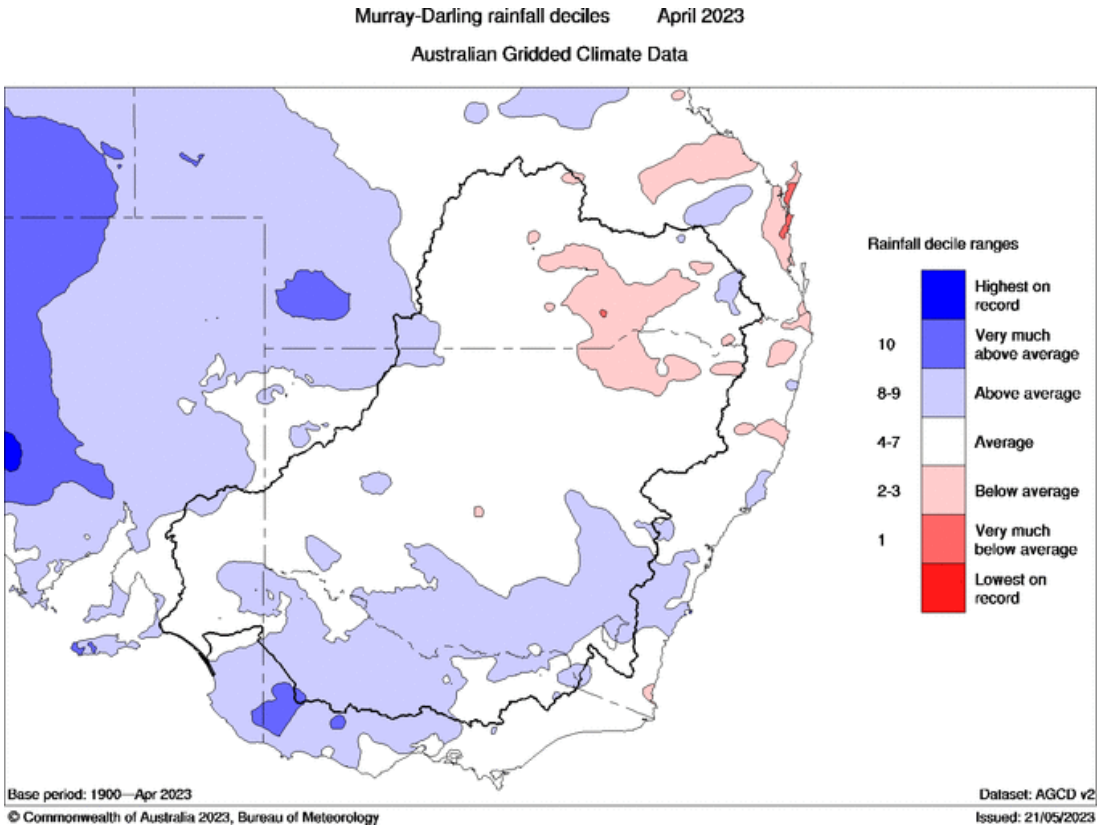


Figure 94: April 2023 Murray–Darling Basin rainfall deciles showing average to below average conditions. (Source: Bureau)

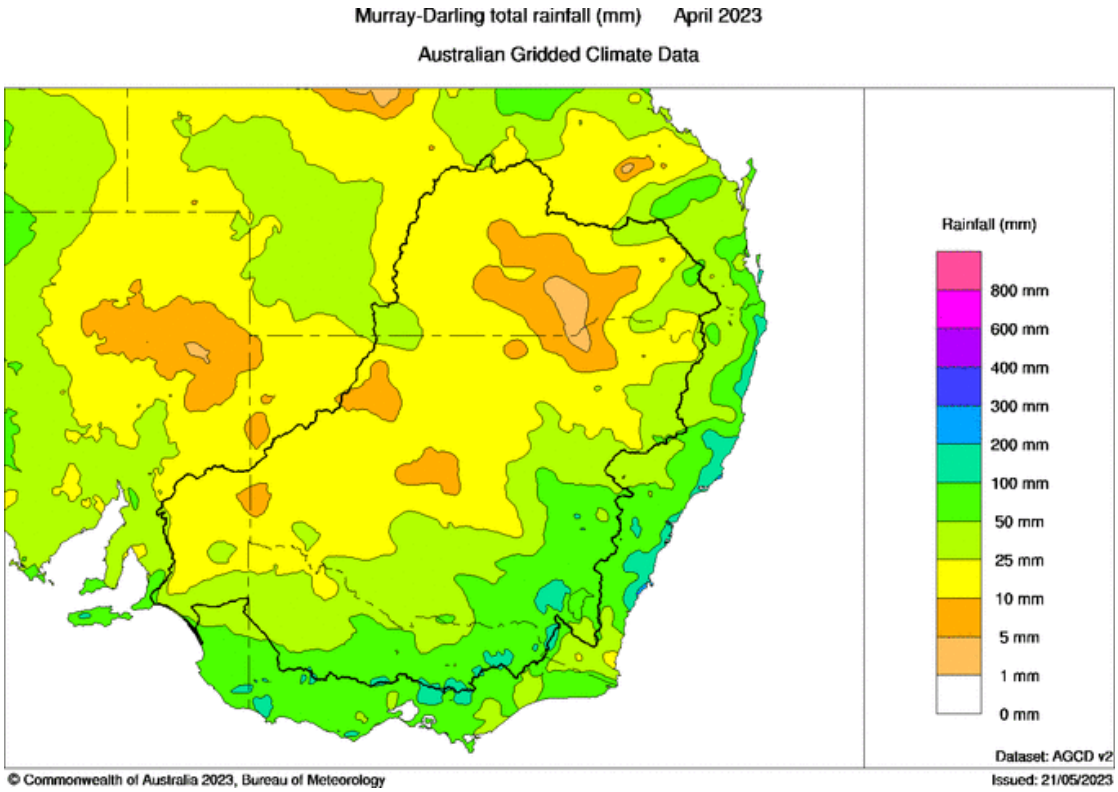


Figure 95: Murray–Darling Basin rainfall for April 2023 showing rainfall totals across the Basin (Source: Bureau).

Temperatures during April were generally quite benign across April. The Bureau reports that Australia's national area-average mean temperature for April was around the long-term (1961–1990) average. Across the Murray–Darling Basin, minimum temperatures were mostly around average, while maximum temperatures were mostly average to below average, except for parts of southern Queensland which experienced above average maximum temperatures (**Figure 96** and **Figure 97**).

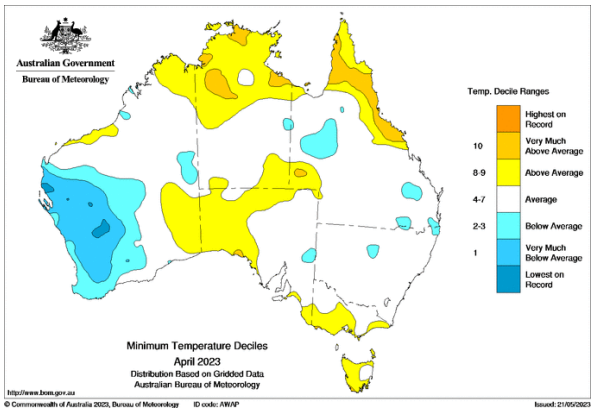


Figure 96: Australian minimum temperature deciles, April 2023 (Source: Bureau).

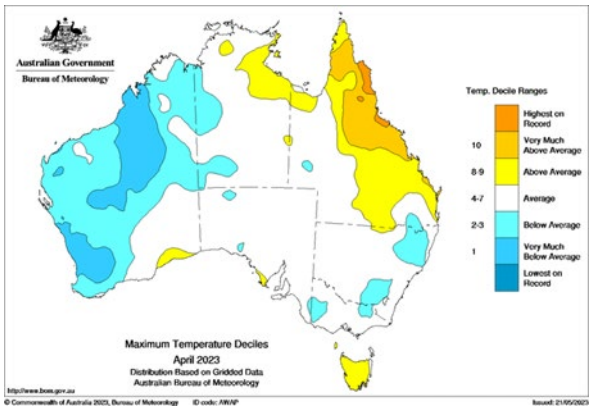


Figure 97: Australian maximum temperature deciles, April 2023 (Source: Bureau).

In early April, airspace management releases from Dartmouth Dam continued at around 1,500 ML/day as rain brought modest pulses of inflow across the month. This additional inflow enabled a larger volume of water to be released to keep target airspace on track. A number of factors were considered in determining how best to release this water. These included the environmental benefits achieved through delivering a pulsed flow, community and recreational interactions and a maintenance outage for essential asset works planned by AGL Hydro to occur from 18 April – 12 May during which release rates below 1,700 ML/day were preferred.

To best accommodate this range of factors, a pulse was released from Dartmouth Dam starting with 3 days at 6,400 ML/day before receding to 1,700 ML/day (**Figure 98**). The pulse was timed to occur after the Easter long weekend to minimise recreational impacts and prior to the proposed AGL outage.

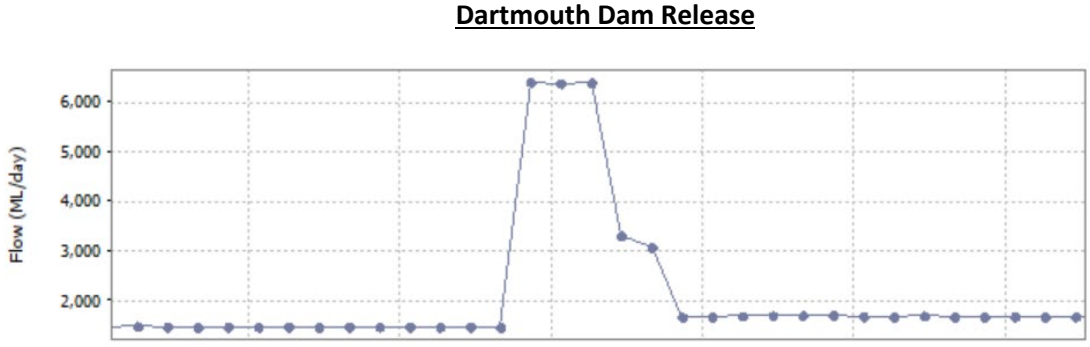


Figure 98: Release from Dartmouth Dam recorded at the Colemans Gauge.

At Hume Dam, reasonable rainfall through the month helped maintain elevated inflows, whilst releases continued to reduce, declining to minimums by mid-April as downstream fell away. This brought airspace

management analysis into focus, and it was quickly determined that airspace management releases, at low rates, could begin practically straight away. By the end of April, Hume storage was increasing and had reached 91% capacity whilst releases had been increased to rates above 6,000 ML/day to help slow and delay storage filling. Updated inflow forecasts indicated Hume Dam could be re-filled by late August upon a transition to dry conditions with modest releases continuing into May that would likely be extended further if rain continued to boost inflow.

Yarrawonga weir releases continued to meet downstream demands and pass pulses of tributary inflow during the first half of April. However, the flow had declined to around 5,000 ML/day by the middle of April and remained around this rate until the end of the month.

In the mid-Murray the flow into the Edward-Wakool system reduced to 1,100 ML/day whilst at Torrumbarry Weir the flow reduced to 3,800 ML/day by the end of April. Downstream at the Murrumbidgee junction, inflows from the Murrumbidgee also continued to recede. However, the April average flow at Balranald of around 3,700 ML/day remained well above the end-of-system water sharing plan target.

During April, the Menindee Lakes storage continued to reduce, as releases to manage environmental risks from poor water quality continued. By the end of April, Menindee Lakes storage had declined to 82% capacity, whilst releases at Weir 32 were targeting 1,200 ML/day. On the Lower Daring at Burtundy, flows declined to around 2,600 ML/day by the end of April, with a slow recession expected to continue.

Meanwhile on the Great Darling Anabranch, an even slower recession was persisting. At the Bulpunga gauge, the flow was falling away slowly but remained at rates above 7,000 ML/day.

The persistence in flows from the Murrumbidgee River and lower Darling helped extend unregulated flows to South Australia across the month. In particular, the extensive high flow persisting from the Great Darling Anabranch helped hold up the recession at the South Australian border where the flow was close to 25,000 ML/day by the end of the month. RMO continued to forecast flow into South Australia during this period, using the Source Murray Operational model, to regularly update forecasts and key stakeholders with advice and provide support for their needs.

At Lake Victoria (Tar-Ru), SA Water continued works on the damage to Bank 1, with a base inlet flow of 500 ML/day continuing through April. During April, scenario planning based on inflows continued, with a potential end to unregulated flows at the South Australian border during May. However, large uncertainty around this timing continued as inflows from the Great Darling Anabranch and elsewhere continued to hang on and push back the duration of higher flows. During this time, River Murray Operations (RMO) planning scenarios continued to target a level at Lake Victoria (Tar-Ru) at the end of May of between 350-396 GL, as per the Lake Victoria Operating Strategy (LVOS).

At the end of April, the updated Bureau climate outlook indicated a growing trend towards drier conditions was expected.

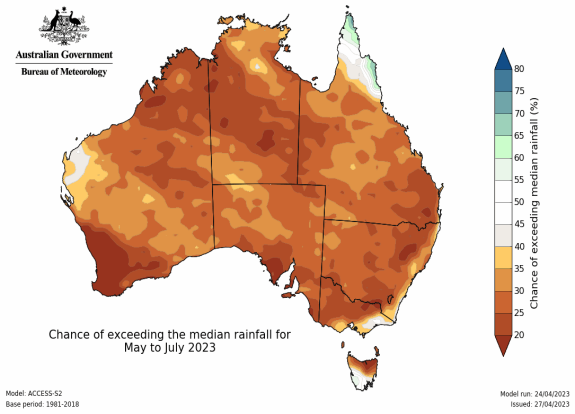


Figure 99: Chance of exceeding the median rainfall for May 2023 – July 2023 (Source: Bureau).

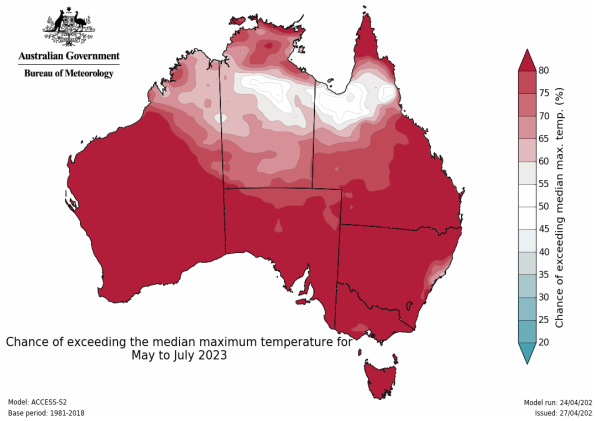
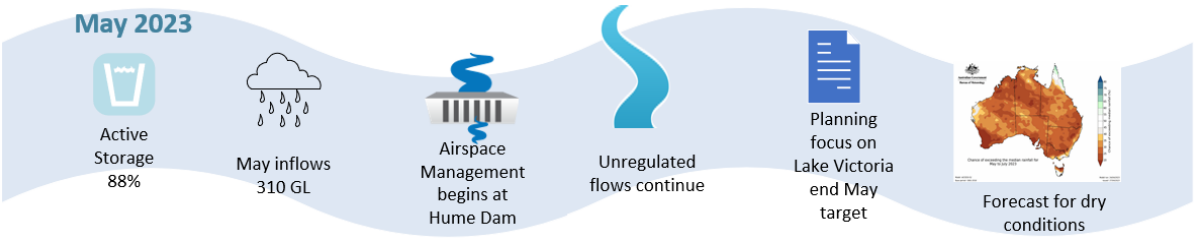


Figure 100: Chance of exceeding the median maximum temperature for May 2023 – July 2023 (Source: Bureau).

May 2023



Rainfall was largely below average across the Murray–Darling Basin, with central parts of New South Wales experienced very much below average conditions. However, there were areas with higher rainfall that was around average across the month, including most of the upper Murray and Victorian tributary catchment areas (**Figure 101**). Overall, Murray–Darling Basin rainfall was 60% below mean and ranked 25th driest during the 124 years of the historic record, with an area average rainfall of 17.6 mm.

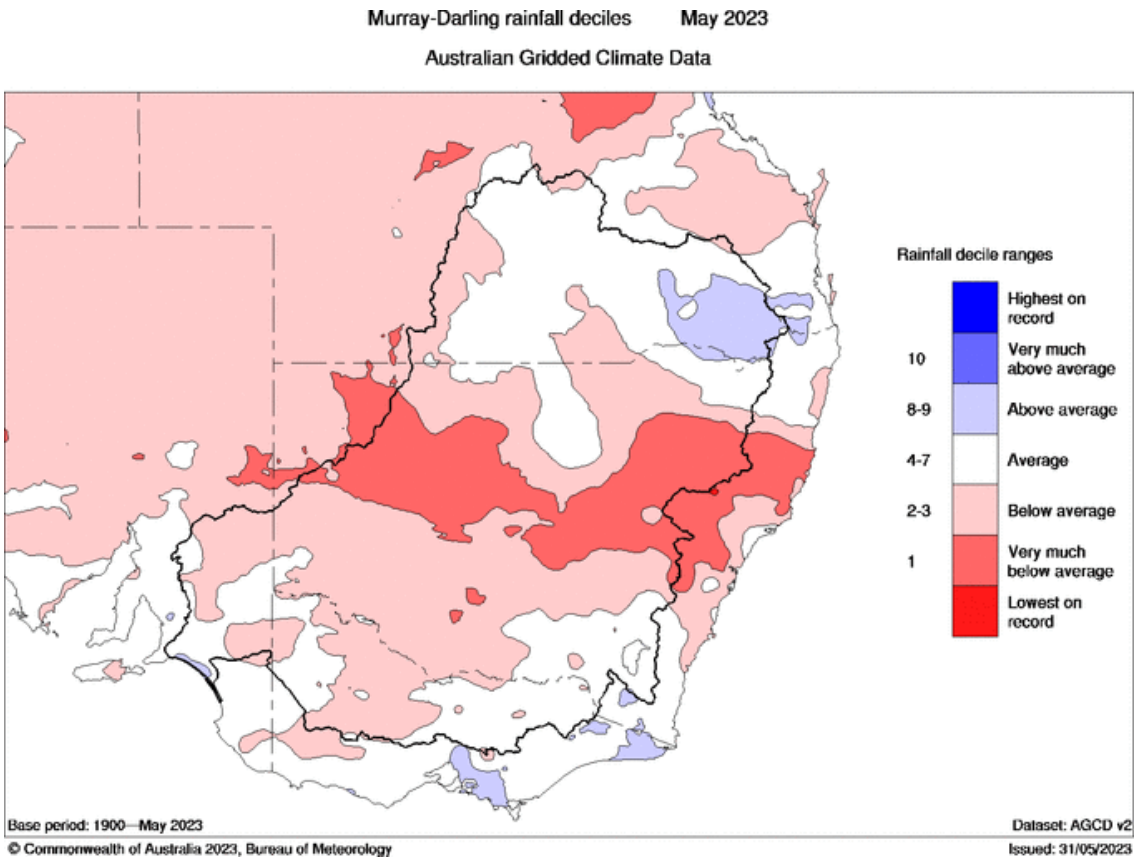


Figure 101: May 2023 Murray–Darling Basin rainfall deciles showing below average to very much below average conditions across much of the Basin, but more average conditions across the north and south-east. (Source: Bureau)

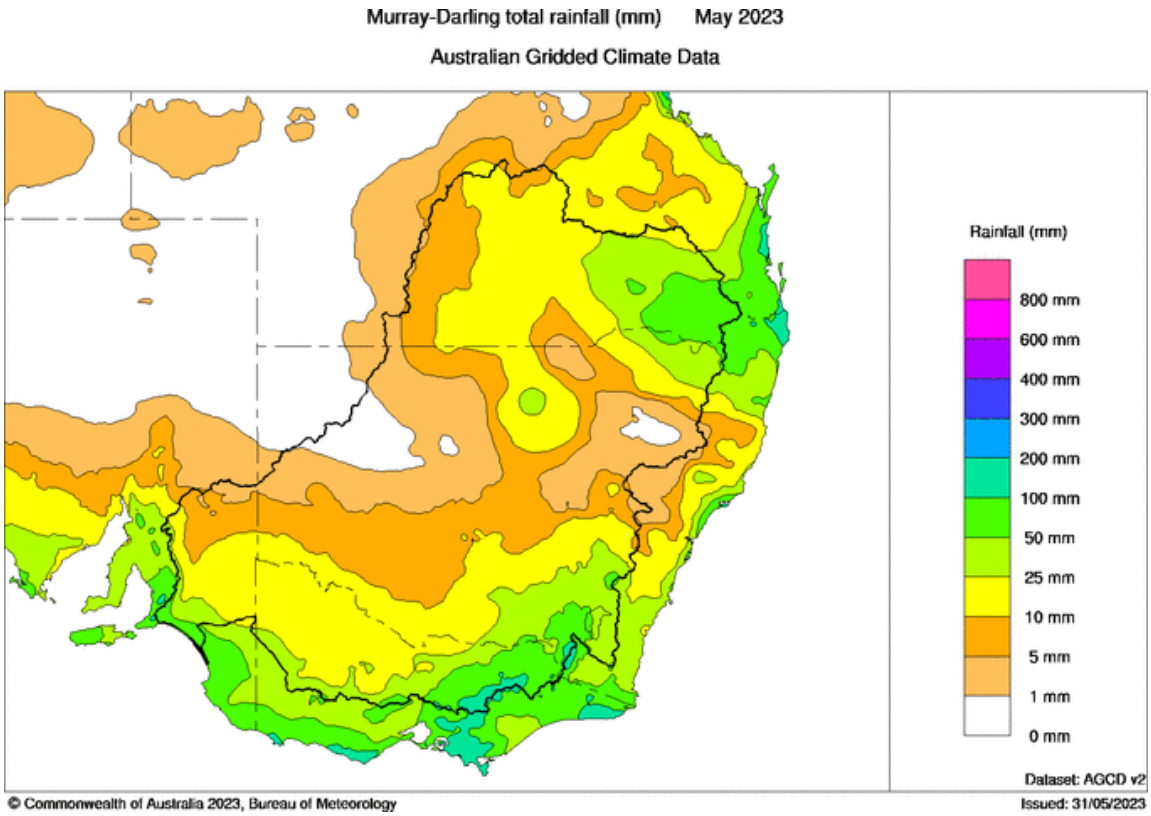


Figure 102: Murray–Darling Basin rainfall for May 2023 showing rainfall totals across the Basin (Source: Bureau).

Temperatures across the Murray–Darling Basin during May were relatively cool. Minimum temperatures were particularly cool with some areas in northern New South Wales observing their coldest night-time temperatures on record. Maximum temperatures were closer to average, although somewhat lower than average across the south-east (**Figure 103** and **Figure 104**).

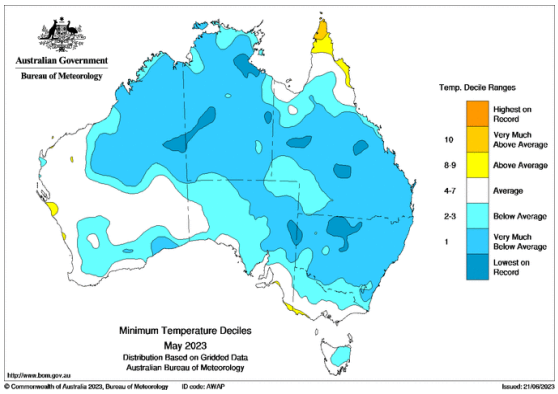


Figure 103: Australian minimum temperature deciles, May 2023 (Source: Bureau).

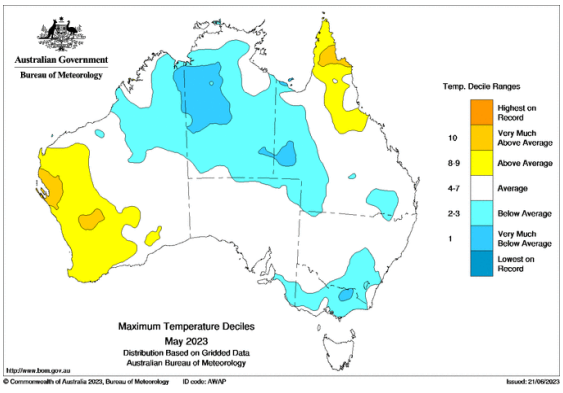


Figure 104: Australian maximum temperature deciles, May 2023 (Source: Bureau).

River Murray system inflows for May (excluding Snowy, Darling, IVT and environmental inflows) were around 310 GL (45% AEP), which was, once again, above the month's long-term median of 267 GL.

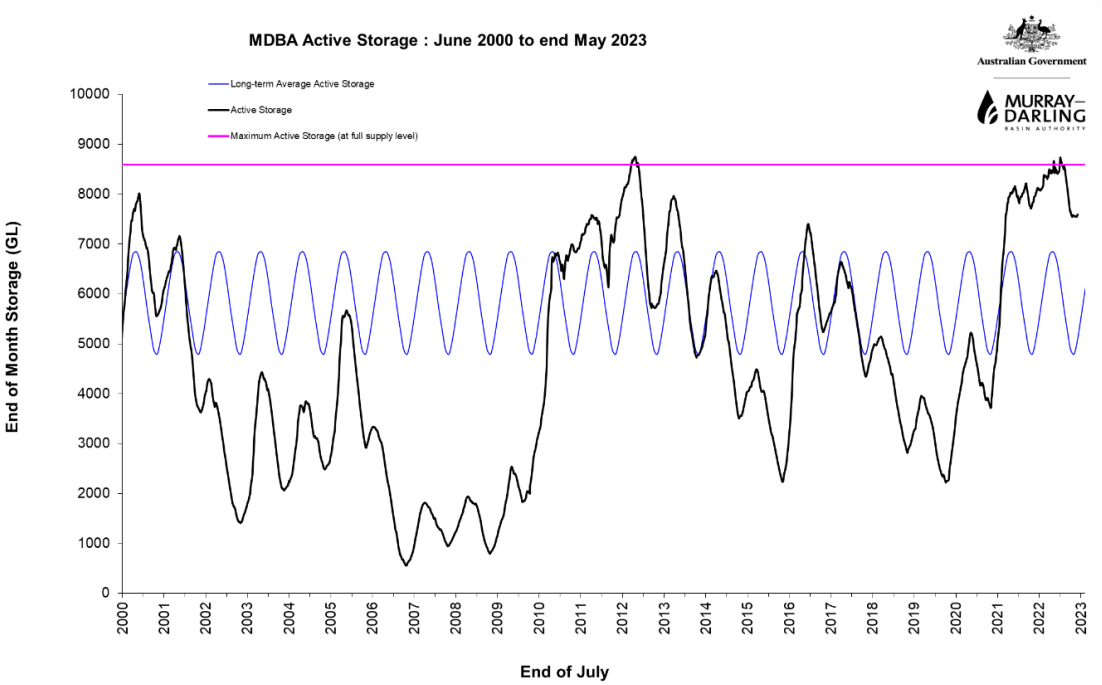


Figure 105: The River Murray system total active storage at the end of Q4

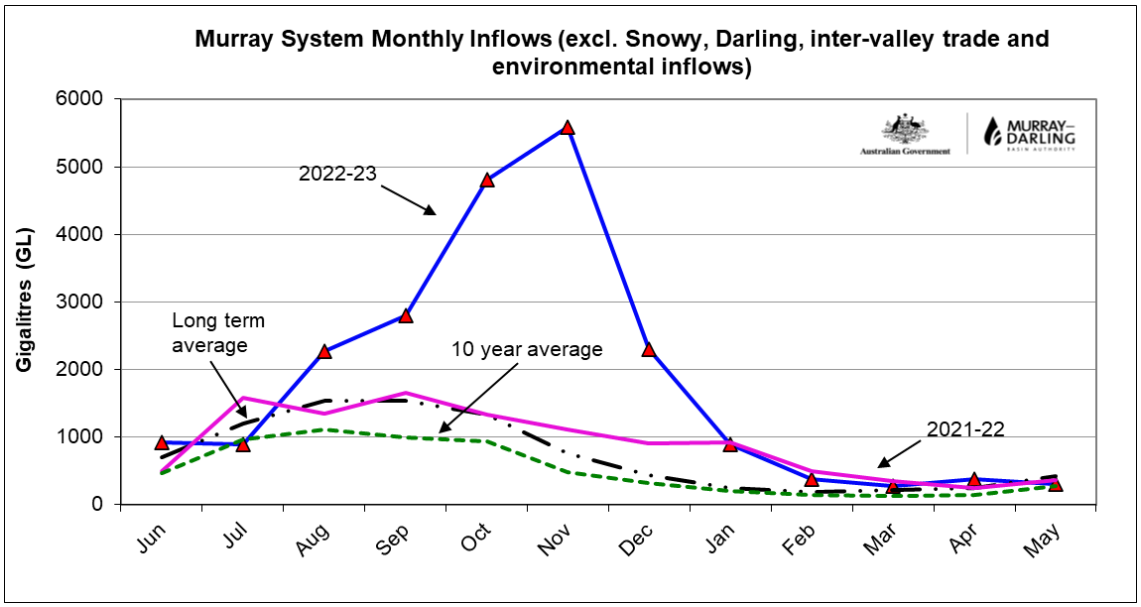


Figure 106: Murray System monthly inflows (excluding Snowy, Darling, inter-valley trade and environmental inflows) until the end of Quarter 4, 2022–23.

In early May, releases to manage airspace at Dartmouth Dam continued with a release around 1,600 ML/day.

Airspace management analysis continued to be revised during May with the addition of updated inflow data to the end of April and was challenged by a range of factors including:

- The relatively high starting storage levels, early commencement of airspace management releases and the resultant larger range of uncertainty in inflows and demands inherent with planning storage filling across multiple months.
- The persistence of quite high inflows for autumn coupled with a strengthening Bureau outlook for conditions to trend dry across winter.
- The potential for early season demands to be quite high and increase quickly under a dry scenario that could bring forward the timing for when storages needed to be filled.
- The interaction and feedback between releases and airspace in Dartmouth and Hume Dams when airspace was being managed in both storages.

With airspace management underway at Hume Dam, forecasts and planning became a focus, particularly in light of its close interaction with Dartmouth Dam. One outcome of this situation was that the dry-scenario timing for Hume Dam filling was earlier in comparison with that previously planned for Dartmouth Dam. This change meant release planning needed to adjust at Dartmouth to bring forward its planned timing for filling (to EFSL or 99% capacity) under a transition to dry conditions from October to August. This was necessary to ensure both dams could be filled simultaneously, which ensures that the overall volume of water stored in both dams will be as high as possible once demand-driven releases re-start. As a result of Hume airspace management commencing, releases from Dartmouth Dam were reduced during May to 500 ML/day and then to 200 ML/day by the end of May to target an earlier timing for Dartmouth storage filling that would coincide with Hume filling if dry conditions emerged in winter.

Despite May being a relatively dry month across much of the Basin, near average rainfall conditions across the upper Murray resulted in a persistence of elevated inflows to both Dartmouth and Hume Dams.

During May, Hume releases averaged near 6,900 ML/day. Releases were managed initially to steer Hume towards a target of around 300 GL airspace by the end of May. However, towards the end of the month, updated forecasting using progressive inflows for May and updated demand forecasting resulted in a slight reduction of this target and Hume being steered to around 91% capacity (265 GL airspace) by the end of May. By the end of May, around 260 GL had been released from Hume Dam since the re-commencement of airspace management on 20 April.

At Yarrawonga Weir, releases increased through early May to a rate around 8,200 ML/day. At this rate, flows through the Barmah Choke were observed to be approaching channel capacity measured at Picnic Point. Noting the trend in recent years of channel capacity decreasing through the Choke, RMO took the opportunity to investigate this change further by requesting a series of flow gauging's at Picnic Point and other relevant locations. This helped to increase data on Choke capacity and improve understanding of likely capacity heading into the new water year. Enabling these gauging's required co-ordination between River Murray Operations, Goulburn Murray Water and WaterNSW to manage variables such as outflow to the Edward-Wakool system to help target a flow around Choke channel capacity over a number of days.

Murrumbidgee River inflows continued to recede during May, however the average flow of around 1,400 ML/day continued to exceed the normal Water Sharing Plan end-of-system target.

During May operations at the Menindee Lakes stabilised, as releases reduced to a rate that matched inflows and the storage levelled out. Releases to the lower Darling River to mitigate downstream water quality risks were continued and by the end of May, the Menindee Lakes system was storing 81% of capacity with releases from Weir 32 near 800 ML/day. Downstream on the lower Darling River at Burtundy, flows receded to near 1,300 ML/day by the end of May and were expected to remain near this level into June.

Flows on the Great Darling Anabranch also continued to recede further during May but remained near 4,300 ML/day at Bulpunga by the end of the Month. This very slow recession helped persist unregulated flows into South Australian which decreased across May from 23,300 to 13,400 ML/day by the end of the month.

At Lake Victoria (Tar-Ru), SA Water concluded works on the damage to Bank 1 that occurred during the 2022–23 flood event. The repair was a significant and timely outcome given the magnitude of the works required. To test and confirm the stability and integrity of the repaired bank, SA Water requested an initial rise in inflow into Frenchman's creek to 700 ML/day. These inflows would then be increased towards 7,000 ML/day on the assumption that monitoring of bank performance indicated the repair works stability and integrity was appropriate. Inflows of 7,000 ML/day were reached by 24 May and this meant Lake Victoria was back to full operational capability.

During May, scenario planning and flow forecasting continued, with the forecast conclusion to unregulated flows over the South Australian border pushed back into the new water year. Large uncertainty around exact timings continued, as forecast flows, particularly from the Great Darling Anabranch continued to be revised. During this time, River Murray Operations planned scenarios to achieve a level at Lake Victoria (Tar-Ru) at the end of May of 396 GL (Lake Victoria (Tar-Ru) operating Ceiling), which would maximise stored water in the lake under the rules of the Lake Victoria Operating Strategy (LVOS).

As the end of May approached, RMO worked with SA Water to adjust inflows and outflows to the lake to steer it towards the end-May target. At 8 am on 31 May, the observed Lake Victoria (Tar-Ru) storage volume was 395.13 GL and rising. This equated to storage level within 5 mm of the target level, highlighting the coordination between RMO and SA Water and significant operational precision achieved.

By the end of Q4, Bureau forecasts continued to show a more likely trend to drying conditions heading into the 2023 winter. The outlook reflected a strengthening outlook for El Niño conditions to develop in the tropical Pacific with an El Niño Watch issued by the Bureau. It was reported that global models were continuing to align in their prediction for an El Niño event to emerge through 2023 that could suppress rainfall across the Murray–Darling Basin in the coming months. In addition, the Bureau indicated that June to August maximum temperatures were very likely to be above median for most of Australia. (**Figure 107** and **Figure 108**).

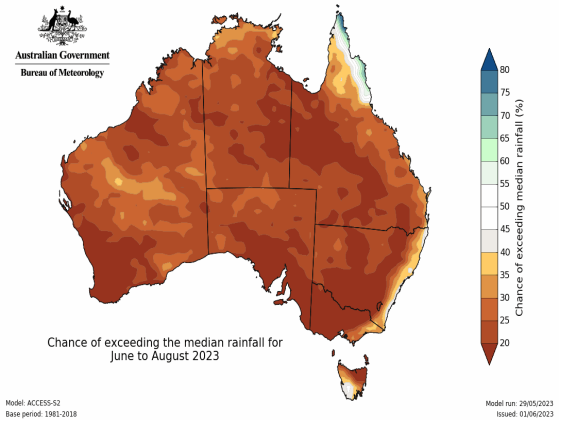


Figure 107: Chance of exceeding the median rainfall for June 2023 – August 2023 (Source: Bureau).

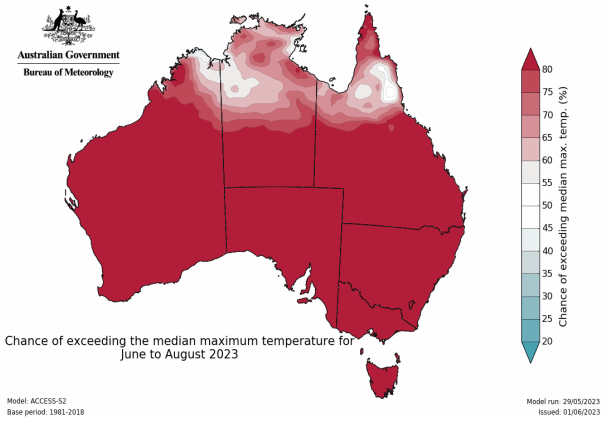


Figure 108: Chance of exceeding the median maximum temperature for June 2023 – August 2023 (Source: Bureau).

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*
Wodonga – *Dhudhuroa Country*

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