Options Summary Report

BARMAH-MILLEWA FEASIBILITY STUDY

December 2022

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for the **Murray-Darling Basin Authority** under the contract titled '**Barmah-Millewa Feasibility Study**'.

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Cover image: abstract river image, Shutterstock

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1 Background

1.1 Purpose

Alluvium Consulting Australia Pty Ltd (Alluvium) has been engaged by the Murray-Darling Basin Authority (MDBA) to undertake the Barmah-Millewa Feasibility Study (BMFS). The BMFS project was established to investigate options for mitigating the risks arising from declining flow capacity in the Barmah-Millewa Reach of the River Murray.

The MDBA has identified six options which may contribute to addressing these risks.

This Options Summary Report introduces each of the six options and provides a summary of what they involve, how they could contribute to managing risk, what studies have been completed to date, and what future stages would involve. Technical reports are separately available, which detail the studies being undertaken for each option, and are referenced throughout this document.

A key objective of the BMFS project is to assess how each of the six options may contribute to managing risks and how a range of complementary options (or 'suites of options') may be needed to achieve the best outcomes. The comparative assessment of each of the options and consideration of how the options could be grouped is detailed in a separate 'Suite of Options Report'.

A 'Feasibility Study Report' has also been prepared to collate and present the findings of the study.

Figure 1 summarises this range of reports which are available as part of the Barmah-Millewa Feasibility Study.

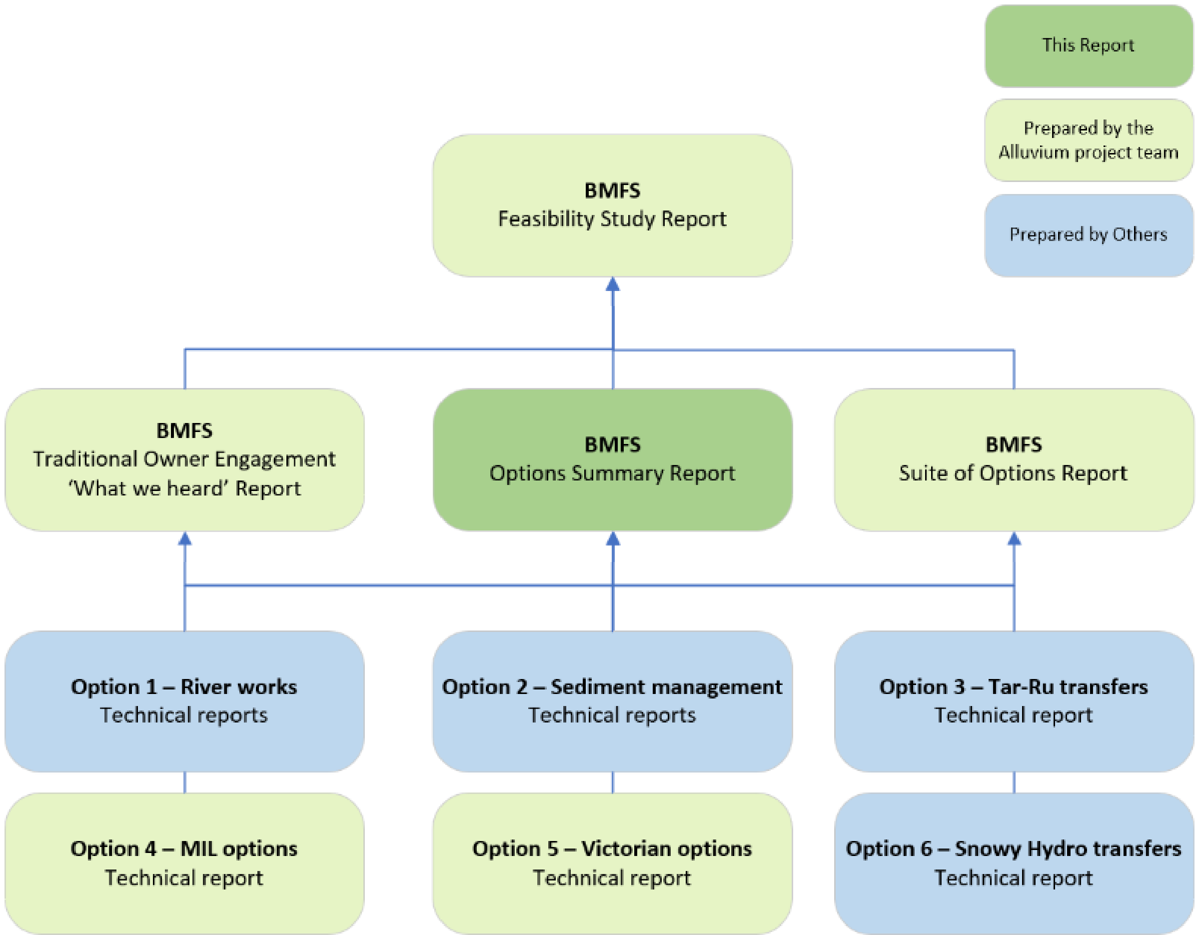

Figure 1. *The various reports being prepared to support the Barmah-Millewa Feasibility Study*

1.2 Project background

Murray-Darling Basin

The Murray–Darling Basin is a one million square kilometre area in the southeast of Australia spanning an area that includes parts of New South Wales, Queensland, South Australia, Victoria, and the Australian Capital Territory.

The Basin is the most relied upon water catchment in Australia, providing water to 2.3 million people and two thirds of Australia's irrigated farming, and is an area of significant cultural importance to First Nations people[1]. The Basin is home to diverse ecosystems that provide habitat for rare and endangered animals and migratory birds[2].

River Murray

The main river in the Murray-Darling Basin is the River Murray, Australia's longest river. The River Murray is 2,530km long, flowing from the Australian Alps in northern Victoria, forming the border between New South Wales and Victoria for much of its length, and then flowing through South Australia before entering the sea in the Great Australian Bight.

Flows in the mainstem of the River Murray and many of its major tributaries are regulated by dams and weir storages. The mainstem of the river receives regulated and unregulated flows from its tributaries and from the Snowy Scheme, located in the upper catchment of the Murray and Murrumbidgee.

River Murray System

The River Murray System is Australia's largest regulated water supply system, supplying around 4,000 GL of water entitlement, valued at an estimated $20.3B[3], to water consumers and environmental water holders in New South Wales, South Australia, and Victoria.

Water entitlements are delivered from system storages and tributary inflows through the main river channel of the River Murray to urban and irrigation river offtakes in Victoria and New South Wales, to supply South Australia's entitlement flow, and to deliver environmental flows.

Water resource management in the River Murray System is governed by the Murray Darling Basin Agreement (2008), an agreement between the Commonwealth, NSW, South Australia and Victoria. The agreement is a long-standing arrangement that sets out how water is shared in River Murray between the states. It also establishes the Murray Darling Basin Authority to administer the agreement and manage river operations in the River Murray System[4]. The River Murray System encompasses[5]:

- the River Murray and all its effluents (outflowing streams) and anabranches (streams that leave and re-enter the river).
- tributaries entering the River Murray upstream of Albury.
- the main storages in the River Murray system — Dartmouth Dam, Hume Dam, Yarrawonga Weir and Lake Victoria.
- the weirs and locks along the River Murray from Lock 15 at Euston to Lock 7 at Rufus River.
- the Darling River downstream of Menindee Lakes (management is shared with NSW).

The states have responsibility for the other large storages on the tributaries that flow into the Murray, including Lake Eildon, Burrinjuck Dam, Snowy scheme storages, and Menindee Lakes. **Figure 2** shows the approximate location of the major storages in the River Murray System.

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[1] https://www.mdba.gov.au/importance-murray-darling-basin/where-basin
[2] https://www.water.vic.gov.au/murray-darling-basin/mdbp/overview
[3] Aither (2021), *Water Markets Outlook, 2020 – 21 Review and 2021 – 2022 Outlook*
[4] https://www.mdba.gov.au/water-management/allocations-states-mdba/murray-darling-basin-agreement
[5] https://www.mdba.gov.au/water-management/allocations-states-mdba/managing-murray-river

Figure 2. *Location of the major storages in the River Murray System*

Barmah-Millewa Reach

The Barmah-Millewa Reach is a 122 km section of the main channel of the River Murray where it passes through the Barmah-Millewa Forest, between the towns of Tocumwal (NSW) and Barmah (Victoria) (**Figure 3**).

In this reach, the west-flowing River Murray meets the Cadell Fault and abruptly changes course turning south around the natural fault line. Distributary (e.g. Edward-Kolety River) and floodplain channels leave the mainstem of the river, either carrying water away from the main river channel or returning to the main river channel further downstream within the reach[6].

Under natural conditions, the river in this reach regularly flooded during winter and spring, inundating the Barmah-Millewa Forest, Australia's largest river red gum forest, a site of significant environmental and cultural heritage value[7].

[6] Ian Rutherfurd, Thom Gower, James Grove, Christine Lauchlan Arrowsmith, Geoff Vietz, Alex Sims, Ben Dyer (2020), *Choking the River Murray: explaining the declining flow capacity through the Barmah-Millewa Forest*, 10th Australian Stream Management Conference 2021

[7] Rutherfurd, I.D. & Kenyon, C.E., 2005. *Geomorphology of the Barmah-Millewa Forest*. Proceedings of the Royal Society of Victoria 117(1)

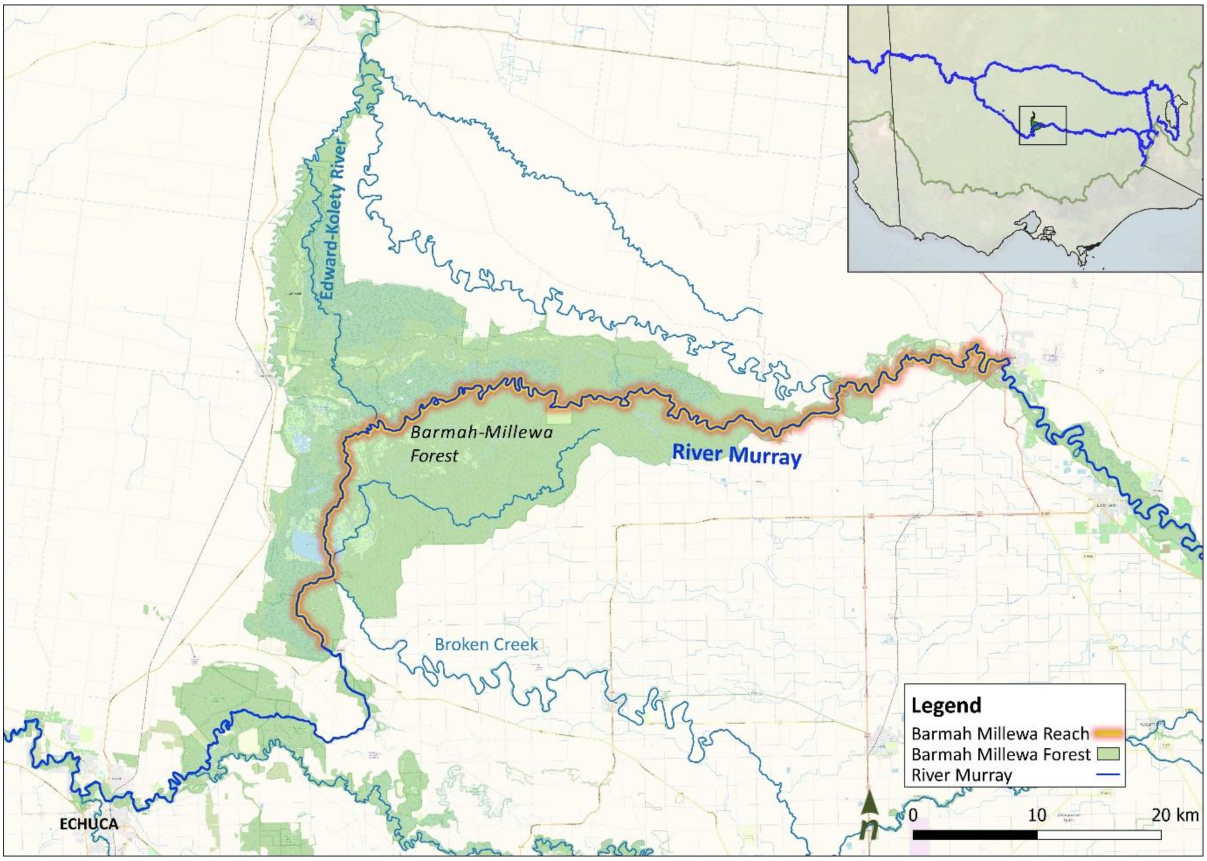

Figure 3. *Location of the Barmah-Millewa Reach of the River Murray*

1.3 Problem statement

Limited flow capacity in the Barmah-Millewa Reach

The size of the Murray's main channel in the Barmah-Millewa Reach naturally declines as a result of the outflow to distributary channels. The width of the river channel decreases from 120m at Tocumwal to 40m at the narrowest point below Picnic Point before widening again downstream of the reach (see **Figure 4**).

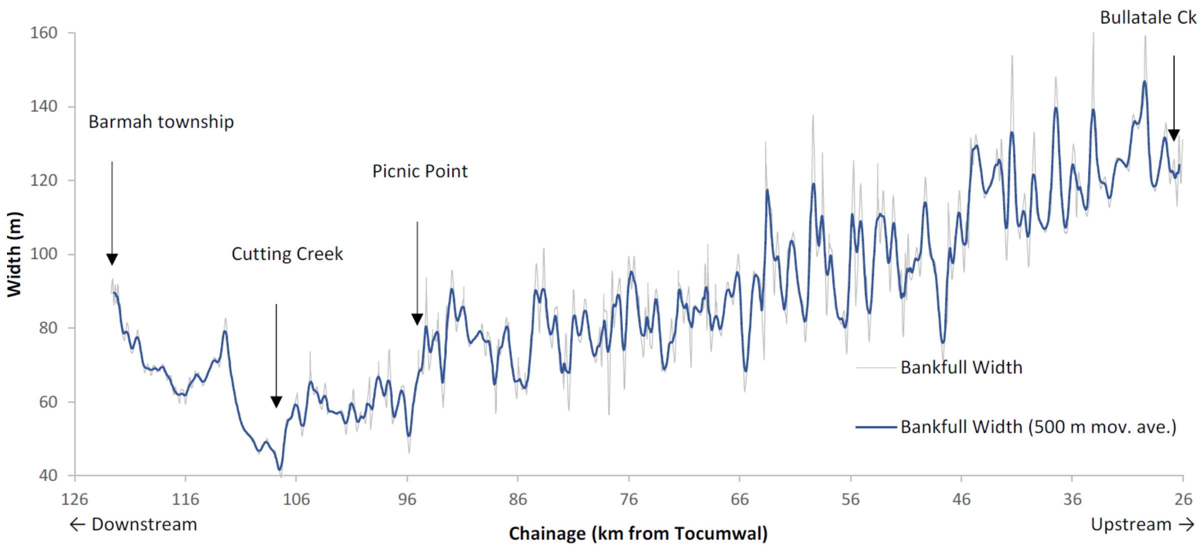

Figure 4. *Change in the bankfull width of the River Murray channel through the Barmah-Millewa Reach*[8]

[8] Streamology (2020), *Barmah Choke Sediment Transport Investigation*

The maximum bankfull depth of the River Murray also decreases through the Barmah-Millewa Reach, although not as steadily as width. Depth generally increases from Tocumwal until it peaks at about 10m around 37km downstream of Tocumwal, before decreasing to about 5m near Picnic Point.

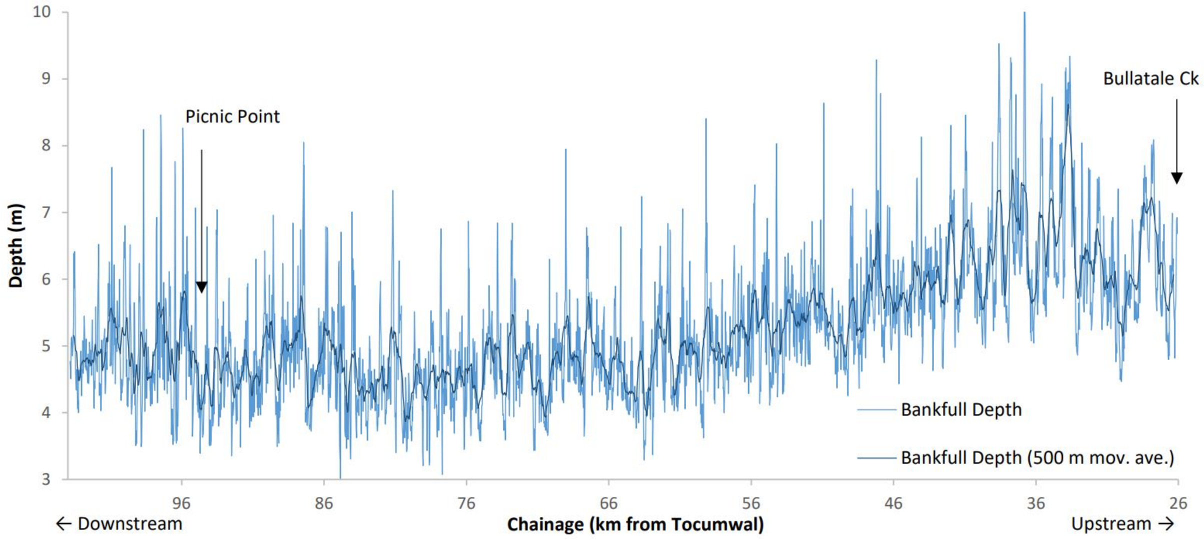

Figure 5. *Change in the bankfull depth of the River Murray channel through the Barmah-Millewa Reach*[9]

As a consequence of this narrowing and decrease in the river depth, the main river channel in the Barmah-Millewa Reach has the lowest flow capacity of any stretch of the river downstream of Hume Dam[10] .

To prevent river flows in the Barmah-Millewa Reach from overtopping the river channel, the MDBA operates the upstream Yarrawonga Weir so that flows do not exceed defined limits within the reach. There are two key operational constraints are:

- From January to April, when flooding of the Barmah-Millewa Forest is undesirable, flows downstream of Yarrawonga are generally operated within the channel capacity of the reach.
- During other months of the year, the maximum regulated flow downstream of Yarrawonga is 15,000 ML/d, and a proportion of the river flow is conveyed through Barmah-Millewa Forest floodplain channels.

Declining flow capacity

Despite operating the River Murray in the Barmah-Millewa Reach within defined operating constraints, over the past 30 years there has been an increased frequency of overbank events from flows that would have previously been accommodated within the channel[11].

Additionally, there has also been a reduction in the commence to flow rates for several of the distributary channels in the reach and more extensive ongoing erosion of riverbanks and levees[12].

Studies undertaken by the MDBA indicate that the flow capacity through the reach has reduced by around 20% from approximately 11,300 ML/day in the 1980s and 1990s to 9,200 ML/day currently, as measured downstream of Yarrawonga Weir[13] (**Figure 6**).

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[9] Streamology (2020), *Barmah Choke Sediment Transport Investigation*
[10] https://www.mdba.gov.au/water-management/water-markets-trade/barmah-choke
[11] Water Technology (2020), *Barmah Choke Channel Capacity and Geomorphic Investigation*
[12] *Ibid.*
[13] HARC (2022), *Historical flows in the southern connected Murray Darling Basin*

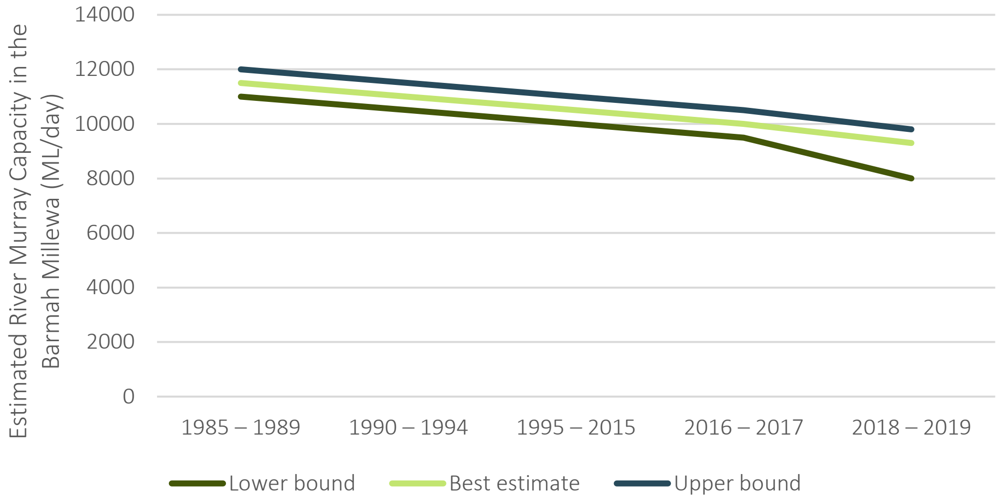

Figure 6. *Change in estimated River Murray capacity in the Barmah-Millewa Reach*[14]

Sand accumulation in the Barmah-Millewa Reach

To investigate the cause of the decline in flow capacity, the MDBA has engaged numerous independent experts in fluvial geomorphology, stream management, and river research. These studies concluded that there is 20 million m^3 of coarse sand on the riverbed between Yarrawonga and Picnic Point that largely originates from historical historic gold mining and land use change in the upper catchments above the Barmah-Millewa Reach[15].

Because the River Murray in the Barmah-Millewa Reach loses flow to distributary channels, the sand is accumulating in this section of the river[16]. The sand is believed to be moving as distinct dunes, with the deepest sand (3 - 5m) occurring at the outside of river bends, infilling former scour holes (**Figure 7**). The highest concentration of thick deposits of sand are found downstream of the Edward-Kolety River diffluence from the River Murray where the channel capacity is narrow and constrained.

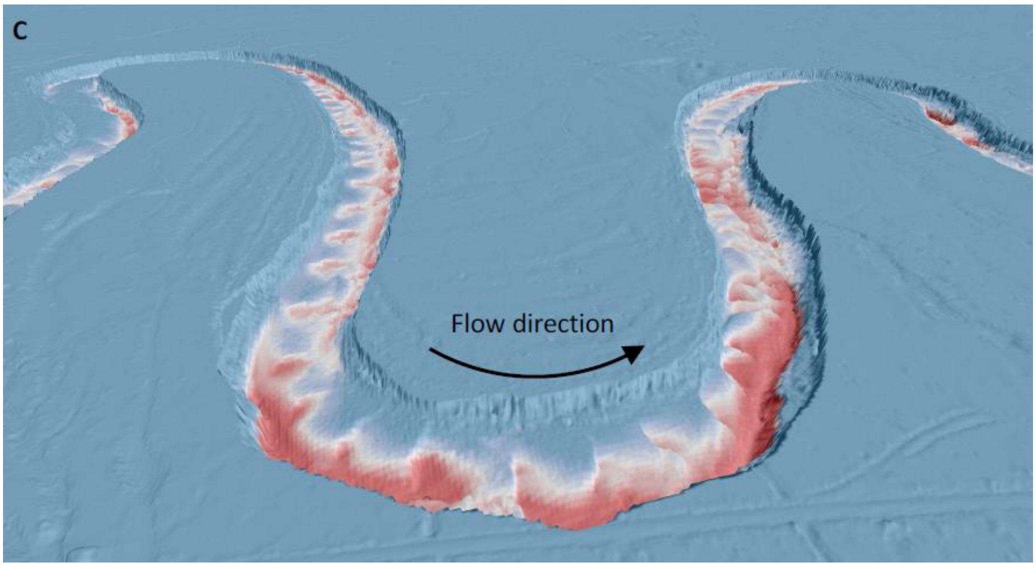

Figure 7. *Example of dune bedforms migrating around a bend in the Barmah-Millewa Reach*[17]

[14] *Ibid.*
[15] Grove James R (2021), *A fluvial geomorphic investigation into channel capacity changes at the Barmah choke using multiple lines of evidence*
[16] *Ibid.*
[17] Streamology (2020), *Barmah Choke Sediment Transport Investigation*

Most of the sand likely originates from historical historic gold mining and land use change in the upper catchments above the Barmah-Millewa Reach. Gold mining started around the 1870s and peaked in the 1930s. Sand mobilised by goldmining has been transported down the river prior to the construction of Lake Mulwala in 1936[18].

It is estimated that more than 8 million m^3 of coarse to medium sand has been deposited on the riverbed of the Barmah-Millewa Reach, reducing the depth of the river by 0.6m[19]. There is an estimated further 12 million m^3 of sand upstream of the Barmah-Millewa Reach (and downstream of the Lake Mulwala) that is continuing to migrate downstream into the reach and accumulate on the riverbed[20].

This build-up of sand on the riverbed is expected to:

- cause a further decline in the flow capacity of the River Murray in the Barmah-Millewa Reach with up to a 25-35% reduction in channel capacity in the next 30 years[21].
- increase the risk of unseasonal flooding and negative impacts on cultural sites as well as environmental and recreational values.
- increase the risk of accelerated bank erosion with the river reach.
- increase the risk of an avulsion and the River Murray changing its course.

Figure 8. *Photograph showing sand visible at Fishermen's Bend, River Murray. Photo credit: Streamology (2022).*

[18] Grove James R (2021), *op cit.*
[19] *Ibid.*
[20] *Ibid.*
[21] Ian Rutherfurd, Thom Gower, James Grove, Christine Lauchlan Arrowsmith, Geoff Vietz, Alex Sims, Ben Dyer (2020), *Choking the River Murray: explaining the declining flow capacity through the Barmah-Millewa Forest*, 10th Australian Stream Management Conference 2021

Shortfall risks

The declining flow capacity in the Barmah-Millewa Reach is a key factor which is contributing to an increasing risk of shortfalls in the lower Murray[22].

In the 2014-15 and 2015-16 water years, flows in the River Murray through the Barmah-Millewa Reach were close to capacity for long periods. In 2018, during a prolonged heatwave in January, river operators were able to narrowly avoid an irrigation delivery shortfall by calling on water supplies from the mid-river storages, from surcharged weir pools, and from tributaries.

The term shortfall has been adopted within the River Murray System to describe the situation when water allocations cannot be delivered to users below the Barmah-Millewa Reach when and where it is needed. Two types of shortfalls have been identified[23]:

- Delivery shortfalls – these short-lived events occur when actual water use is higher than it was forecast to be when water was released from the Hume and Dartmouth storages, weeks earlier, to meet the forecast demand for irrigation and environmental water. This is commonly caused by an unexpected spike in irrigation demands due to heatwave conditions.
- System shortfalls – in these shortfalls, the combined capacity of the system is unable to supply all downstream requirements over the full season.

Actual restrictions for consumptive demands as a result of shortfalls are very rare and to date risks have been managed with no shortfall events since 2002. In 2018, environmental flows were restricted due to channel capacity limits in the Barmah-Millewa Reach. The risks of shortfall events cannot be managed to zero. Changes in climate, timing, and location of demand and land use, combined with the river system's diminishing capacity to carry the same volume of water, mean these events are increasing in probability[24].

Impact of shortfalls

Water users located downstream of the Barmah-Millewa Reach hold approximately 56% of the total water entitlement in the River Murray System. Entitlement holders include urban water authorities, irrigators growing high value vine and tree crops, and government environmental water holders who use entitlements to water ecologically valuable wetlands. South Australia's annual entitlement under the Murray-Darling Basin agreement is also in part delivered through the Barmah-Millewa Reach.

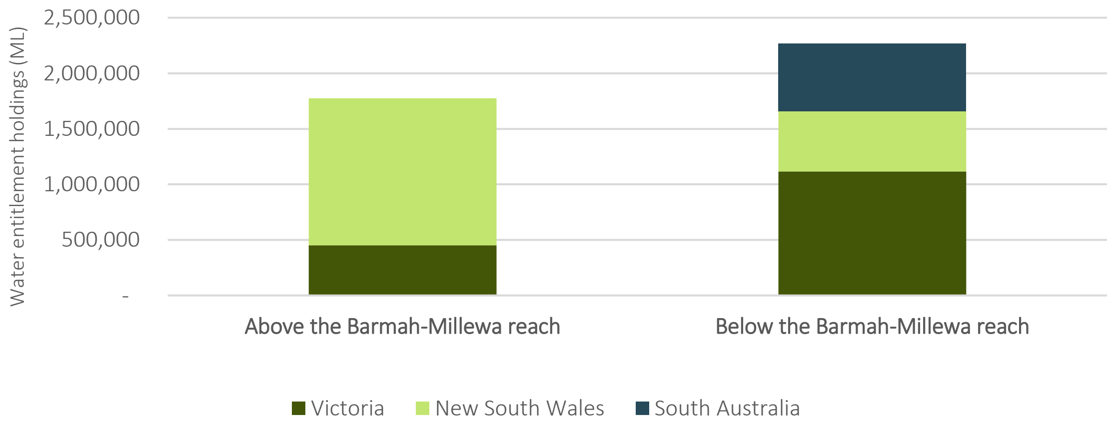

Figure 9. *Holdings of Murray water entitlement above and below the Barmah-Millewa Reach*[25]

*NSW – sum of general and high security, Victoria – sum of low reliability and high reliability, SA – high security.

[22] Independent Panel for the Murray-Darling Basin Authority (2020), *Managing Delivery Risks in the River Murray System*
[23] https://www.mdba.gov.au/water-management/river-operations/water-demand-shortfalls
[24] *Ibid.*
[25] Aither (2021), *op. cit.*

Irrigation is the primary use of water in the River Murray System below the Barmah-Millewa Reach with water supplied to traditional irrigation districts and more recently expanding private irrigation diversions irrigating high valued permanent tree crops, including almonds and other nuts. For example, in the lower River Murray System across Victoria and New South Wales and South Australia, permanent plantings increased from 95,905 to 131,480 hectares from 2003 to 2021, a 37% increase[26].

If a shortfall happens and water delivery is affected, temporary water restrictions on the diversion of water from the river may be placed on water users. Restrictions are directed and managed by state water agencies and will vary depending on state agency policy. The most likely form of restrictions is the temporary rationing of water to irrigation, with irrigators taking less water for the period of the restrictions[27]. Restrictions can result in the loss of crop yield with negative impacts on investment decision-making and consequential flow on impacts for regional economies.

These system shortfalls can occur when flows through and around the Barmah-Millewa Reach are at full capacity over the summer-autumn period, towards the end of the season, when there is not enough water in Menindee Lakes and Tar-Ru (Lake Victoria) to meet the South Australian entitlement flow.

1.4 Barmah-Millewa Feasibility Study (BMFS)

Scope

In recognition of the increasing risks of River Murray shortfalls and damaging Barmah-Millewa Forest flooding from reduced capacity in the reach, the MDBA is undertaking the Barmah-Millewa Feasibility Study (BMFS). The project is examining the feasibility of a range of infrastructure options to mitigate delivery shortfall and unseasonal forest flooding. The six options being explored are:

- Option 1 - River works within the Barmah-Millewa Reach: river works to stabilise banks and remediate potential areas of new breakaways, preventing further losses into the Barmah-Millewa Forest.
- Option 2 - Sediment management: selectively removing the sand from key locations in the reach.
- Option 3 - Tar-Ru (Lake Victoria) transfers: proposed implementation of a risk-based framework for making decisions on the timings and source of water transfers to Tar-Ru (Lake Victoria).
- Option 4 - Optimisation of the existing MIL System: optimisation of the Murray Irrigation Limited (MIL) channel system to deliver water to bypass the Barmah-Millewa Reach.
- Option 5 - Options for delivery through Victorian infrastructure: using existing and new infrastructure in Victoria to bypass the Barmah-Millewa Reach or mitigate the risk of delivery shortfall.
- Option 6 - Use of the Snowy Hydro to transfer Murray Release to the Murrumbidgee: transferring River Murray releases from the Snowy Releases to the Murrumbidgee for delivery to water users downstream of the Barmah-Millewa Reach.

The location of the six options relative to the Barmah-Millewa Reach are shown on Figure 11. Note that there is an additional potential option discussed in this report relating to the use of the Murrumbidgee Weirs to help mitigate delivery shortfall risks. This is discussed as a complementary opportunity as part of the Snowy Hydro option and it is recommended that this be explored in more detail in any future investigations.

The study is predominantly desktop in nature and builds on work that has been undertaken by the MDBA over a number of years to investigate why the regulated capacity in the Barmah-Millewa Reach is declining.

This report presents a summary of each of the six options under consideration. The key ‘development and implementation considerations’ for each of the options are listed. These are matters which, if not appropriately considered and managed, could risk the viability of implementing the option. This report also identifies the

[26] Sunrise (2022). *Irrigated crop area data for the lower Murray Darling 2003 to 2021*, Phase 1 report
[27] https://www.waterregister.vic.gov.au/images/documents/Fact-sheet---Shortfalls-in-the-Victorian-Murray-below-Barmah.pdf

relevant policies which may affect the delivery of each option or may require amendment to enable implementation of the option.

Governance

The MDBA is managing the Study on behalf of the Basin Officials Committee (BOC), following a Terms of Reference agreed to by Ministerial Council. A feasibility-level options analysis is to be prepared and provided to the Murray-Darling Basin Officials Committee (BOC) and the Murray–Darling Basin Ministerial Council. The study will help inform Basin government decision making around mitigation options.

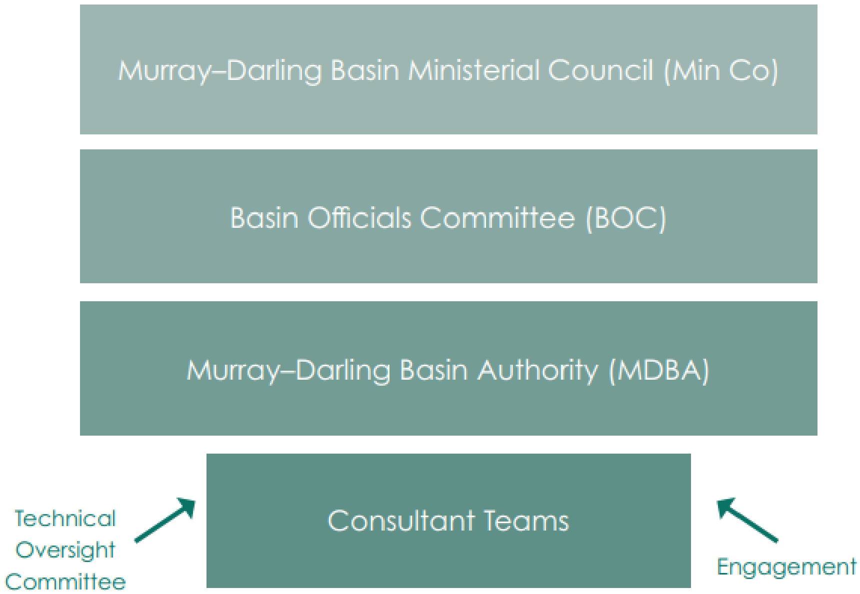

Figure 10. *Governance arrangement for the BMFS project*

Policy implications

The MDBA's Capacity Policy Working Group (CPWG) has reviewed the contents of the BMFS and has prepared advice on water policy issues arising from the options developed as part of this Study. This advice is provided for each option below and has been specifically produced for consideration by BOC, to assist in their decision making.

The CPWG supports the approach of developing the projects selected by the Ministerial Council (MinCo) for further investigation via a series of investment gateways and decision points. This approach will allow any policy issues that arise to be assessed before the next stage of investment occurs.

The CPWG notes that a key common issue arising from the BMFS is reaching agreement on how the cost of the options would be met (e.g. construction, operations and maintenance and any conveyance charges). Agreement will need to be reached *between* the jurisdictions, and also *with* entitlement holders, where there may be cost recovery, whether this is uniform for a class of entitlement holder, or whether it is differentiated to reflect specific beneficiaries.

Additional projects

There are several current or proposed additional projects which are related to the Barmah-Millewa Feasibility Study, but do not form part of the study itself. These studies include the Enhanced Environmental Water Delivery (EEWD) project, the Yarrawonga to Wakool (Y2W) constraints measures program, the Murray and Murrumbidgee National Parks project, the review of Schedule D to the Murray-Darling Basin Authority – water trading, and the understanding drivers for development study.

The 'Understanding the drivers for development' study is an engagement program undertaken by the MDBA to understand the drivers for why developments to date have been established downstream rather than upstream of the Barmah-Millewa Reach. This includes investigating crops with significant increases in plantings downstream of Barmah, including almonds, table grapes and citrus. This study was completed in June 2022 and confirmed that there were nine key factors driving continued horticultural expansion downstream of the Barmah-Millewa Reach, including climatic and soil conditions, trafficability, proximity to infrastructure, services and labour, water availability and reliability, amenity, and regulatory approvals[28].

Whilst related to this study, these additional projects are not part of the Barmah-Millewa Feasibility Study. They do however have an influence on the operational and social environment in which decisions will need to be considered for any future stages of the BMFS.

[28] Tim Cummins & Associates (2022), *An Investigation into the Location of Horticultural Water Demands – Drivers of Horticultural Development in the Murray-Darling Basin. A report for the Murray-Darling Basin Authority.*

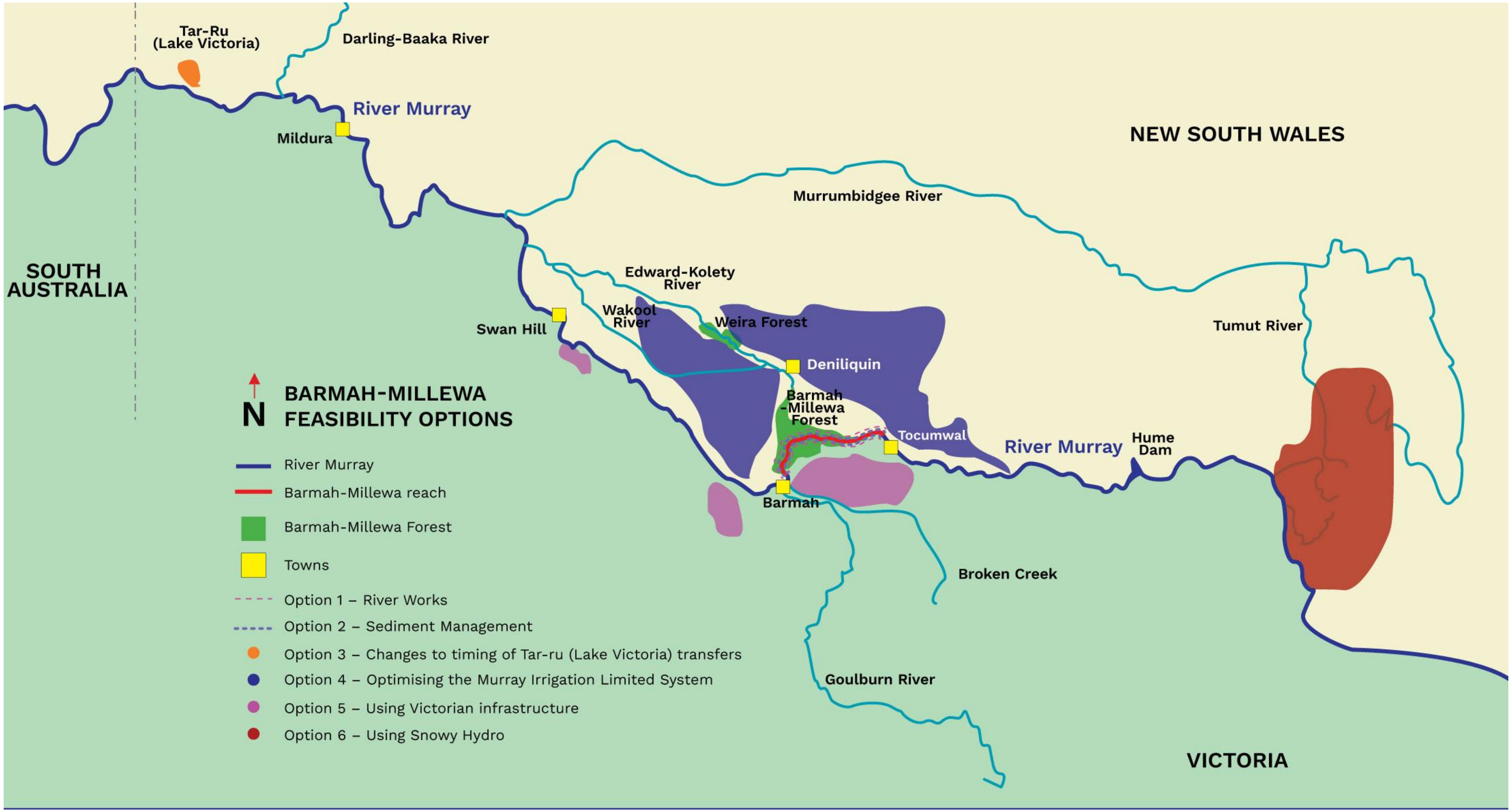

Figure 11. *Location of the six options being considered in the Feasibility Study, relative to the Barmah-Millewa Reach*

2 Option 1 – River works within the Barmah-Millewa Reach

2.1 Option overview

This option proposes a program of remedial riverbank works to prevent further loss of channel capacity arising from breakaway flows from the River Murray.

The option will be delivered through the Yarrawonga to Torrumbarry Riverworks Program, a 5-year interim project (2022-27). The program has been established to assist in the strategic planning, management, and implementation of on-ground works. The reach of river between Bullatale Creek and the Barmah Sand Dunes (around 36km downstream of the Edward-Kolety River) has been identified to contain the highest risk of bank erosion and is the initial focus of the program.

A detailed program of works is currently being developed by Water Infrastructure NSW (WI NSW) with oversight from the MDBA's Riparian Program.

2.2 Background

As it passes through the Barmah-Millewa Forest, the River Murray becomes perched above the floodplain[29] and is characterised by effluent channels which distribute water onto the floodplain (see **Figure 12**). Water is held in the main channel of the river by natural levees on the channel bank.

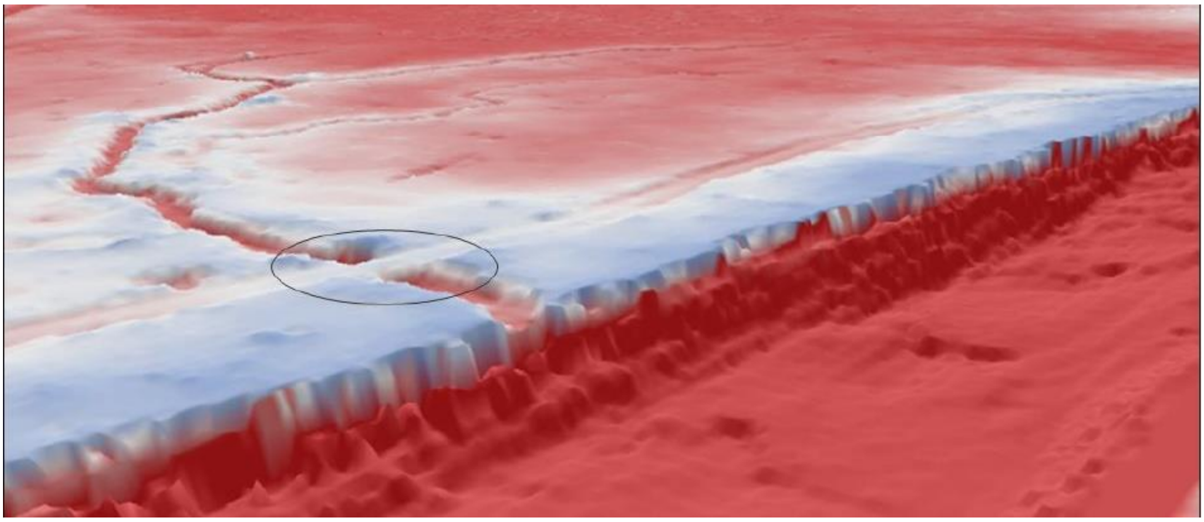

Figure 12. *Digital Elevation Model of a section River Murray in the Barmah-Millewa Reach showing the channel bank, an effluent stream and floodplain with red tones representing areas below the river water level and blue areas above the water level*[30]

When River Murray flows are high, river flow can break out over lower sections of the riverbank into effluent channels inundating the floodplain. Breakaway flows through effluent channels are a natural behaviour of distributary systems during winter floods. However, in the Barmah-Millewa Reach, they may occur during summer, as the river is regularly operated at near full capacity for much of its length during this season to meet downstream water demands.

Bank erosion that removes the natural levee and / or erosion of the effluent channel that removes an existing sill reduces the flow capacity of the reach and can result in unseasonal flooding of the Barmah-Millewa Forest.

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[29] https://www.mda.asn.au/Source/ckfinder/files/Ian%20Davidson.pdf
[30] Streamology (2022), *Condition Assessment & Works Prioritisation*

2.3 Monitoring bank erosion

Assessments of the Murray riverbanks from Yarrawonga to Torrumbarry Weir undertaken over the last two decades have documented accelerated rates of bank erosion, with some reaches exhibiting more than 40% of all banks to be undergoing erosion[31].

High-resolution bank condition surveys have been conducted across five targeted locations in the Barmah-Millewa Reach.

Surveys were first completed in February 2021 and then repeated in May 2022. These surveys found that erosion is occurring through undercutting and notching of the lower bank, after which tree roots may hold up the upper bank temporarily (see **Figure 13**). However, the weight of the bank eventually becomes overbearing, and a large block of the bank collapses into the river.

Figure 13. *Example of accelerated bank erosion in the Barmah-Millewa Reach*[32]

The survey results clearly show significant erosion occurring along the banks of the River Murray, with some banks retreating by up to 1 m across the 15-month period between surveys (**Figure 14**). Erosion is observed to be occurring through a series of block collapses, rather than as a slow, uniform, and consistent manner along the banks[33].

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[31] Cardno (2020), *Feasibility business case – Yarrawonga to Torrumbarry River Works Program*
[32] *Ibid.*
[33] Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bank Monitoring 2022 Memorandum*

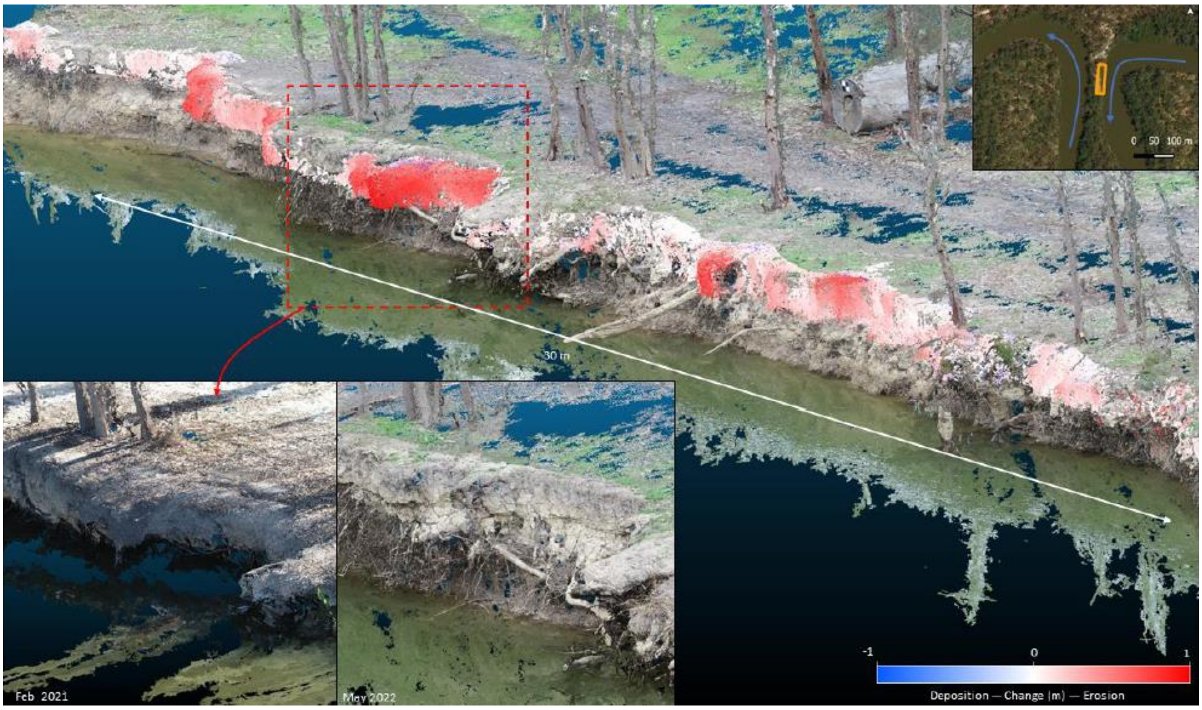

Figure 14. *Comparison of bank surveys conducted in Feb 2021 and May 2022 at Fishermans Bend Bank A. There is erosion occurring along most of the bank, with some areas retreating up to 1 m*[34].

2.4 Option description

There have been several previous assessments and action plans along this reach of the river regarding erosion management. Recent investigations which have supported the scoping of the Yarrawonga to Torrumbarry Interim River Works Program 2022 – 2027 (Y2T IRWP) primarily include a feasibility business case followed by mapping and prioritisation studies.

In 2020, the MDBA engaged Cardno to prepare a feasibility business case for a river works program from Yarrawonga to Torrumbarry Weir[35]. The business case proposed a prioritised work program based on available erosion data, which instigated the current works program under development by Water Infrastructure NSW.

In 2021, the MDBA and WI NSW engaged Streamology to complete an initial mapping and prioritisation of potential breakaway locations in the Barmah-Millewa Reach and recommend a scope for further investigation. A breakaway refers to a low point on the riverbank that allows water to flow away from the River Murray main channel, which may flow back to the channel or deliver water to the floodplain[36].

In 2022, Streamology completed the assessment of riverbank condition and prioritisation of potential breakaways. The risk-based assessment was completed to identify and prioritise sites of potential breakaway flows along the River Murray in the Barmah-Millewa Reach where works could be undertaken[37].

Risk assessment and priority works

Existing and potential breakaway locations were identified by mapping channel and floodplain features across the reach which do, or could, form breakaways resulting in the possible loss of flow capacity in the River Murray channel.

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[34] *Ibid.*
[35] Cardno (2020), *Feasibility business case – Yarrawonga to Torrumbarry River Works Program*
[36] Streamology (2022), *Condition Assessment and Works Prioritisation – Report for Water Infrastructure NSW*
[37] *Ibid.*

The risk of a potential breakaway occurring was determined through a detailed desktop review and spatial analysis combined with field verification survey. The likelihood and consequence for each breakaway location were then derived and used to evaluate risk. A total of 243 current or potential breakout sites were identified in the desktop mapping process. Field verification was completed for all sites initially considered to be of *Very High* or *High* risk rating.

Following the field verification, 4 sites were confirmed as having a *Very High* risk rating, and 19 sites with a *High* risk rating. All sites considered to be *Very High* or *High* risk are located between Bullatale Creek and Barmah Sand Dunes, a river distance of around 107 km. Most of the identified sites occur on the outside of meander bends. The report recommends that:

- 4 sites classed as *Very High* risk should be a very high priority for works.
- 19 sites classed as *High* risk should be a medium to high priority for works and monitoring.
- All other sites should not be a priority for works but should be monitored.

Remedial treatments at each site depend on the several site-specific factors, including the riverbank condition, existing structures, and presence of any large trees and/or cultural sites. Works are being designed such that there is no increase in the surface elevation of the bank levee. This means that overbank flows from the River Murray onto the floodplain will continue to occur at the same flow level as they currently do[38]. A range of remedial works have been recommended, including:

- stabilisation of the riverbank (e.g., due to erosion or failed stabilisation works).
- reinforcement of the existing levee.
- reinforcement of existing vehicle tracks.
- installation of a regulator (if more cost effective than stabilisation and land manager accepts).
- removing failed or ineffective rock stabilisation, where this is found to be exacerbating bank erosion of adjacent bank areas.

An example site proposed for remedial works is shown in Figure 15. At this site, the works include stabilisation of the riverbank and reinforcement of the levee or widening of the levee to provide greater protection.

Figure 15. *A site identified as 'High' risk of potential breakaway within the Barmah-Millewa Reach*

[38] *Ibid.*

Works program

The proposed works target sites identified as *Very High* or *High* risk of breakaway to mitigate the potential for reduced channel capacity and potential unseasonal watering of the surrounding forest. The works are not intended to address wide-scale bank erosion through the entire reach. There may be a need to expand this program in future to expand the objective of the works, such as to specifically protect sites of environmental or cultural significance. Such an expansion in the scope and focus of the program would require close collaboration with stakeholders (such as Traditional Owners for protection of cultural sites) and additional funding.

A detailed works program is being developed for each of the priority breakaway sites based on the prioritised locations for works to address erosion and prevent further loss of channel capacity. Due to the complexities of this reach of the river, each site will require site specific design, followed by a detailed options assessment. Each assessment includes a 'do nothing' option, followed by a range of options to treat the issues at the site.

The on-ground works program will endeavour to prevent further loss of water delivery capacity by targeting sections of bank that are of high risk of erosion. However, with the sediment accumulating on the riverbed, bank protection works is not considered a sustainable or long-term solution. The works will not reinstate channel capacity but aim to minimise further loss in channel capacity, by targeting sites at risk of bank failure that could result in increased loss of water in the adjoining forests. In the process, this will also address both loss of consumptive water to the forest and the undesirable summer inundation of low-lying areas of the forest. The works also have the potential to prevent the potential loss of cultural material located on the riverbank.

2.5 Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- The scope of the river works program is limited only to bank works in areas identified at high risk of leading to new breakaways into the forest. This is more limited than some stakeholders may appreciate or desire, as the works are a targeted erosion protection program (rather than broad scale) and focussed on specific locations to avoid breakaway (rather than protecting specific environmental and cultural sites). This could lead to a perception that this program is not achieving its objective from the perspective of some stakeholders.
- Continual identification and the appropriate management of environmental, planning, cultural and social sensitivities at each of the sites selected for remedial works.
- Ongoing stakeholder consultation and consideration of feedback in the design, development and implementation of the monitoring and works program.
- Approval from the joint venture Governments (Victoria, New South Wales, South Australia and Commonwealth Governments) to allow the program to proceed.

2.6 Policy considerations

The MDBA's Capacity Policy Working Group has advised that the River Works option is an extension of the riparian program that has operated for several decades. As such minimal water resource policy implications are expected from the adoption of this option.

2.7 Further work planned

The detailed works program and site-specific designs are currently under development. WI NSW plans to approach BOC for approval and funding to proceed with on-ground works later in 2022. If approved, the works program would be expected to commence from 2023 for a five-year period.

Preliminary stakeholder engagement with the Yarrawonga to Torrumbarry River Reach Stakeholder Group (YTRRSG) commenced from the second half of 2021. The group comprises government agencies, local community/council representatives, and Traditional Owners. The YTRRSG continues to meet and forms an important part of planning this works program.

2.8 Reference reports

The following is a list of the key reference reports supporting this option:

- Cardno (2020), *Feasibility business case – Yarrawonga to Torrumbarry River Works Program. Prepared for Murray-Darling Basin Authority.*
- Streamology (2021), *River Murray Mapping and Prioritisation Barmah-Millewa Forest. Report for NSW Soil Conservation Service.*
- Streamology (2022), *Condition Assessment & Works Prioritisation. Report for Water Infrastructure NSW.*
- Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bank Monitoring 2022 Memorandum*

3 Option 2 – Sediment management

3.1 Option overview

This option proposes the targeted removal of sand from the bed of the River Murray within the Barmah-Millewa Reach, with the objective of maintaining or restoring flow capacity of the river through the reach. Investigations to date suggest that targeted sand removal is the preferred method of sand management. This would involve transporting sand from the riverbed to sites for dewatering, storage, and possible reuse.

3.2 Background

Preliminary investigations

The MDBA has completed a range of preliminary investigations into the causes and consequences of declining channel capacity on the Barmah-Millewa Reach. Cumulatively, these investigations have concluded that:

- **Historic land use practices have caused an influx of sand into the River Murray between Yarrawonga and Picnic Point:** between Yarrawonga and Picnic Point, there is more than 20,000,000 m^3 of coarse sand in the bed of the river, including more than 8,000,000 m^3 in the Barmah-Millewa Reach. The main sources of the sand sediment are believed to be upstream goldmining and land clearance which was transported into the river below Yarrawonga Weir prior to the construction of the weir in the 1930s. Recent bank erosion within the reach is making a relatively minor contribution to the sand load[39].

- **Sand is spread throughout the reach and is worst in the narrowest section of the river**: for almost the entire 260 km from Yarrawonga to Echuca, there is a substantial layer of bedload material, on average from 1 to 2 metres thick. The thickness of sand varies from 40cm to more than 7.0m[40]. Downstream of the Edward-Kolety River diffluence, there is a significant increase in the average depth of the sand and variability. This includes in the narrowest section of the river where the flow capacity is at its lowest[41]. In-channel surveys between 2019 to 2022 have shown that the greatest increase in sand thickness is occurring upstream of Picnic Point, with around 10,000 m^3 being deposited in this area per year[42].

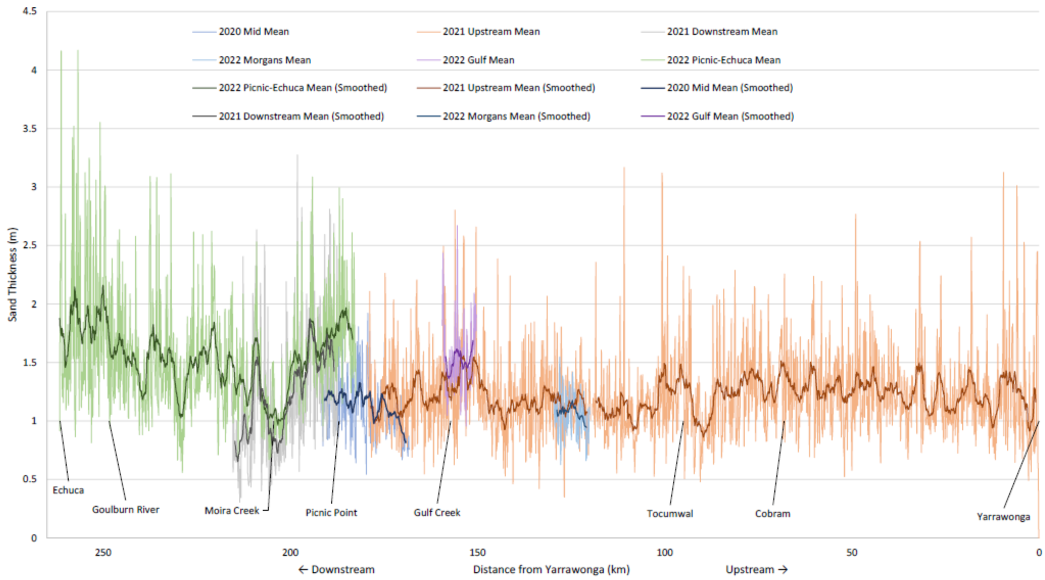

Figure 16. *Plot showing sand thickness from sub-bottom surveys, averaged into 100 metre lengths of channel[43].*

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[39] Grove (2021), *A fluvial geomorphic investigation into channel capacity changes at the Barmah Choke using multiple lines of evidence*
[40] Acoustic Imaging (2022), *Murray River SBP Survey (Victoria / NSW Border: Picnic Point to Echuca Section) for SA Water.*
[41] Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bedload Transport and Thickness Investigation Memorandum*
[42] Port & Coastal Solutions (2022), *Barmah-Millewa Reach Sand Management Options Study, Stage 2 – Bathymetric Analysis (P048R01v02)*
[43] *Ibid.*

- **The Picnic Point stretch of the reach has a lower sediment transport rate than upstream:** there is a clear decrease in energy and sediment transport rates downstream through the Barmah-Millewa Reach[44]. The constrained channel capacity acts a fundamental control, reducing sediment transport, even under high flow scenarios[45]. Investigations are currently identifying key areas within the reach where transport rates are lowest, and the most significant deposition of sand is occurring.

- **The accumulation of sand on the riverbed extends all the way to Echuca:** downstream of the Barmah-Millewa Forest, the peak and average thickness of the sand has been observed to be relatively high, including some sections which are more than 4m deep[46].

- **The sand accumulating on the riverbed is reducing the already limited flow capacity of the river:** the layer of sand in the bed reduces the depth of the river and its cross-sectional area, which decreases the flow capacity of the river. Across the entire reach, bedload sand reduces the channel capacity by an average of 24%, and within the narrow section of the river downstream of the Edward-Kolety River confluence, the bedload sand reduces capacity by 30 to 35%[47].

- **The riverbed is continuing to fill up with sand over time:** sand is continuing to move downstream in the Barmah-Millewa Reach from upstream near Yarrawonga Weir with approximately 240,000 m^3/annum of sand entering the Barmah-Millewa Reach per year and approximately 80,000 m^3/annum leaving the reach. Because of the decrease in channel dimensions within the reach and reduction in transport capacity, more sand is moving in than is being transported out of the reach[48].

- **The flow capacity of the reach will continue to decline:** if nothing is done to manage the excess sand in the Barmah-Millewa Reach, there will be an ongoing loss of capacity due to sand build-up in the channel. Preliminary modelling has indicated that the flow capacity would decline by a further 1,000 ML/day over the next ten years if no intervention works are undertaken[49].
- **The reduction in channel capacity is negatively impacting on other values within the reach:** concerns regarding capacity through the reach cannot be separated from other adverse impacts such as the loss of instream habitat and diversity, increased potential for out of season forest watering, impacts on cultural values, and an increased risk of the River Murray changing its course (an avulsion).
- **Targeted removal of sand could avoid further decline and reinstate flow capacity and help to mitigate further impacts on values within the reach:** hydraulic modelling has shown that targeted sand removal would have a significant impact on flow capacity and water level in the Barmah-Millewa Reach[50].
- **Sampling has been undertaken to better understand the material to be removed**: samples taken from the riverbed are predominantly made up of coarse sand. The concentration of heavy metals are well below thresholds of relevant guidelines. Testing of the material indicates that it may be suitable for commercial use as a concrete aggregate[51].

Overall, investigations have found that sand will continue to accumulate and the capacity in the Barmah-Millewa Reach will continue to decline unless intervention works are taken. An options analysis for managing the sand determined that a 'do nothing' scenario will have considerable negative outcomes to environmental, social, cultural, and economic values throughout the reach. The flow capacity would be expected to continue to decline as sedimentation increases, resulting in the ongoing loss of habitat, bank erosion, and unseasonal flooding of the Barmah-Millewa Forest. The analysis recommended that work be done to further investigate the sand movement and accumulation within the reach and develop options for managing this issue[52].

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[44] *Ibid.*
[45] Streamology (2021), *Options for Managing Sediment in the Barmah-Millewa Reach of the River Murray*
[46] Streamology (2022), *Op. Cit.*
[47] Streamology (2021), *Op. Cit.*
[48] *Ibid.*
[49] MDBA (2022), *Preliminary investigation into Murray River at Gulpa (409006) capacity changes resulting from sand removal/aggradation*
[50] *Ibid.*
[51] Streamology (2022), *Technical Memorandum – Sediment sampling pilot program – data results and analysis*
[52] Streamology (2021), *Op. Cit.*

3.3 Sand management options

In light of the findings that doing nothing to manage the build-up of sand in the reach was unacceptable, the MDBA engaged expert consultants to assess options for managing sand to stop further losses of channel capacity and possibly reinstate the channel capacity. The options considered included:

- **Option 1:** Flushing the sand through the reach.
- **Option 2:** Trapping the sand.
- **Option 3:** Controlling the input of sand.
- **Option 4:** Physically removing the sand.

An assessment of the options was completed by Streamology and is summarised in **Table 1**.

Table 1. Summary of the sand management options assessment[53]

Option	Description	Effectiveness	Conclusion
Option 1 Flushing the sand through the reach	Implementing changes to the flow regime in the Barmah-Millewa Reach to enhance sediment transport through the reach and/or increasing overbank flows to move coarse sediment onto the floodplain for storage	Investigations found that high flows result in higher rates of sediment build-up as more sand can be delivered to the reach, but the rate of transport of sand out of the reach does not increase. The investigations also established that if all supply of sediment into the reach could be stopped upstream of the reach, it could take > 100 years to flush the existing excess sediment through the reach. An increase in flows would not be effective in moving coarse sediment onto the floodplain due to the energy required.	Flushing the sediment through is not effective in addressing sedimentation, and therefore flow capacity.
Option 2 Trapping the sand:	Trapping the excess sediment in the channel, which protects downstream reaches from high sediment loads. This intervention involves use of in-channel structures to stabilise and trap sediment in the reach or upstream of the reach and limit further transport downstream	The volumes of sand are large and there is excess material from throughout the reach. Trapping sand in specific locations will exacerbate the current sediment accumulation in flow issues. Any revegetation of bars on channel bends will have the same effect. It is also not possible to revegetate instream bars as the flow regime with high summer flows does not allow in-stream vegetation to establish.	Storing the sediment is not effective in addressing the main issues of flow capacity. Trapping sand by revegetating bars on channel bands is not technically feasible.
Option 3 Controlling the input of sand	Preventing new sources of sand entering the Barmah-Millewa Reach	Most of the sand in the reach is derived from historic sources and is already in the river below the Yarrawonga Weir. However, smaller amounts of sediment are entering the reach from bank erosion in the reach Bank protection works are a proven feasible means of controlling bank erosion. Bypassing flows around the Barmah-Millewa Reach and thereby avoiding sustained high flow rates would also be effective in reducing bank erosion. However, the additional volumes that could be avoided through bank protection works are low in comparison to what is already in the channel.	Preventing new sand entering the river through bank erosion will not limit the continued movement of sediment into the Barmah-Millewa Reach from the upstream reaches and the associated loss of capacity. However, bank protection works could mitigate against accelerating bank erosion and the risk of new flow connections forming from the river to the floodplain, leading to unseasonal flooding. Bank protection works could also improve habitat features.

[53] *Ibid.*

Option	Description	Effectiveness	Conclusion
Option 4 Physically removing the sand:	Physically removal of some or all the sand from the bed of the channel in the Barmah-Millewa Reach.	This option is likely to be effective in maintaining or increasing the channel capacity, reducing sedimentation, and improving or maintaining habitat and diversity of the channel form. There could be negative impacts on values associated with extraction of sediment from the riverbed such as closure of areas of the river for recreation while works are underway, or the removal of vegetation to install pipes and pumps to move the sand. Impacts to cultural, environmental, economic and social values will all be considered in the assessment of feasible options. Due to the large volumes and extent of the sand, any extraction is likely to be ongoing and not a one-off.	Technically this option is feasible, with several techniques that may be applicable.

From this options analysis, Streamology concluded that controlling sediment inputs through targeted bank protection and physically removing sand (combined with works options to deliver water by bypassing the Barmah-Millewa Reach in the autumn and summer months) were the preferred options for managing the risks of the declining flow capacity and reducing environmental, social, cultural, and economic impacts[54].

3.4 Preferred option - sand removal

Objectives

The objective of the sediment removal project is to maintain or restore the river flow capacity in the Barmah-Millewa Reach by removing sand from the reach. Further studies are currently underway to better understand how sediment removal can be practically applied in the reach and to assess the effectiveness and impacts of different levels of sediment removal on channel capacity. This work will define the:

- Volume, timing, and location of extraction required to maintain and/or increase channel capacity.
- Nature and feasibility of infrastructure for extraction activities.
- Expected change in channel capacity from different extraction scenarios.
- Potential impacts to cultural, social, environmental and economics values of the Barmah-Millewa reach.

Basis of design

The potential scope of the sediment removal works has been informed by a range of field studies and the modelling of different scenarios. Initial investigations have suggested that[55]:

- Removing the sand accumulating in the reach (around 160,000 m^3/year) is realistic. By way of comparison, sand is already being removed at a rate of around 1,000,000 m^3/year from the Murray mouth in South Australia.
- due to the large volumes and extent of the sand (8,000,000 m^3 in the Barmah-Millewa Reach and 12,000,000 m^3 upstream of the reach), any extraction will be ongoing and over multiple years.

The works program is expected to target removing sand from upstream to reduce the volume of sand moving into the reach and around the Edward-Kolety River confluence (in the vicinity of Picnic Point), which has the greatest bed thickness of sediment, with 33% of the channel capacity filled with sand. This approach is conceptually depicted in **Figure 17** below.

[54] *Ibid.*
[55] Grove James R (2021), *op cit.*

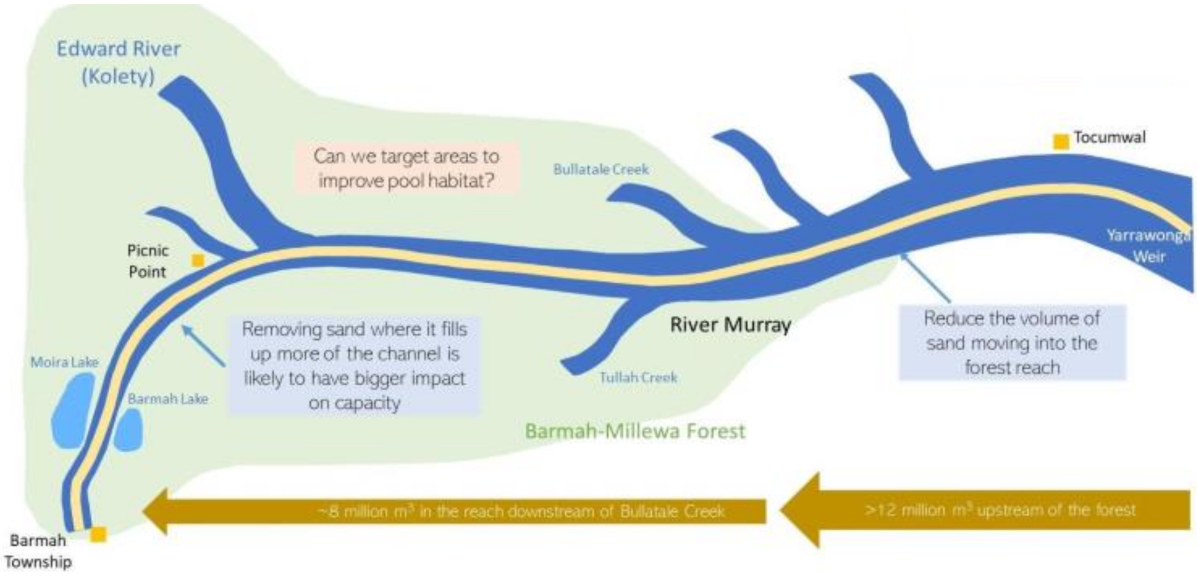

Figure 17. *Conceptual illustration of approach to sediment removal in the Barmah-Millewa Reach*[56]

Method for targeting sand removal and expected time for trenches to re-fill with sand

Preliminary modelling has been undertaken to estimate how long trenches would take to re-fill with sand and to inform the best strategy for the sand removal[57]. This analysis considered four different strategies as summarised in **Table 2** below. Additional sampling and surveys have been recommended to inform more detailed modelling and to allow the preferred extraction strategy to be selected.

Table 2. Potential strategies for the targeted removal of sand which have been modelled

Strategy	Description of sand removal strategy	Expected time to re-fill
1	Continuous 3km long trenches along the centre of the river channel	6 – 20 years
2	A series of 100m long x 20m wide trenches along the centre of the river channel (with a 100m gap between trenches).	3 years
3	A series of 100m long x 40m wide trenches along the centre of the river channel (with a 100m gap between trenches).	5 years
4	Targeted removal of sand from river bend meanders	3 to 20 years

Method of removal

In principle, there are four stages involved in the extraction of sand from the riverbed[58]:

- **Stage 1: Loosening of the materials**. This process involves loosening or cutting materials on the riverbed hydraulically using a suction dredge or cutting blades or mechanically using a bucket or grab.
- **Stage 2: Vertical transport of the materials.** This process involves raising the materials from the riverbed up to the water surface. This can be done by vacuum using a pump or mechanically using a bucket or grab.
- **Stage 3: Horizontal transport of the materials.** This process involves transporting the materials from the river to a location for treatment and disposal. This is usually done by pumping the material as a slurry through a pipeline or transporting the material in barges.
- **Stage 4: Placement of the material.** This process involves treating and placing the material in its final disposal location.

[56] Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach (proposal)*
[57] Port & Coastal Solutions (2022), *Barmah-Millewa Reach Sand Management Options Study – Stage 2: Hydrodynamic and Sediment Transport Modelling (P048R02v01)*
[58] Streamology (2022), *Barmah-Millewa Reach – Sand Management Options Report*

There are a range of significant challenges involved in loosening, transporting, and disposing sand from the Barmah-Millewa Reach. These challenges include obstructions such as woody debris, the meandering nature of the river, and securing a suitable disposal site in the vicinity nearby the reach.

To assist in defining the scope of works and method of removal, Streamology engaged Swash Project Delivery to undertake an opportunities and constraints review into sand removal options in the Barmah-Millewa Reach.

Loosening and transport of materials

Swash investigated a range of various equipment solutions to determine the method most suitable for extracting sand from the Barmah-Millewa Reach. This included consideration of cutter suction dredges, backhoe dredges, submersible dredge pumps, and hybrid solutions involving a slurryfication unit.

A hybrid solution was identified as the preferred method which can best overcome the difficulties and challenges of this project[59]. This method involves a large excavator on a pontoon used to excavate the sand (referred to as a backhoe dredge), with the excavated materials then placed into a slurryification unit, where water is then added before being pumped into a pipeline for transporting to a disposal site. This hybrid solution has been successfully used at other locations internationally.

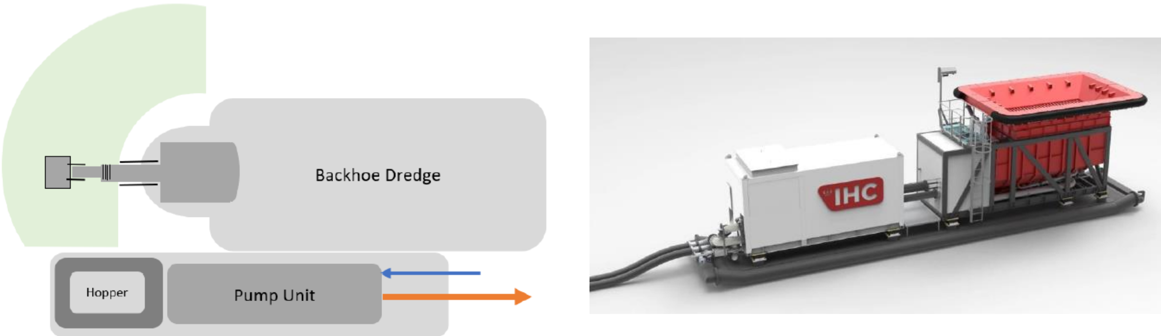

Figure 18. *Concept layout of the preferred 'hybrid solution', with a visual representation of the hopper and pump unit on the right. The blue line indicates the water intake and the orange line the discharge pipeline[60].*

Transporting removed sediment

The sand slurry removed from the riverbed needs to be transferred from the river to an appropriate onshore stockpiling facility[61]. Swash suggested that the most realistic option would be for the slurry to be transferred through pipelines to a stockpiling facility. This would require three pipeline sections to be constructed[62]:

- **The marine pipeline**, to transport the slurry from the backhoe to onshore. This likely involves a flexible section of floating pipe made from rubber, and a submerged section leading to the shoreline. The marine pipeline would generally be no longer than 2.5km to avoid excessive pumping.
- **The shore pipeline**, to transport the slurry from the shoreline to the disposal area. This pipeline would be around 300-350mm in diameter and would likely follow existing tracks and roads through the Barmah-Millewa Forest. The shore pipeline would generally be laid above-ground, allowing the pipe to be turned periodically to avoid the cumulative build-up of sediment from degrading the pipe materials. The shore pipeline is expected to be around 10km long, with booster pumps every 1.5 to 2 km.
- **The discharge area pipeline**, to discharge the slurry into the bunded area at the disposal site. The discharge pipeline is generally easily accessible and able to be readily modified. This allows the slurry to be discharged to different areas at the disposal site as required.

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59 *Ibid.*
60 *Ibid.*
61 Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach (proposal)*
62 Streamology (2022), *Barmah-Millewa Reach – Sand Management Options Report*

Figure 19. *Example of a shore pipeline.*

Dewatering, storage, and reuse of sediment

Onshore disposal areas require an area where the materials can be received as a slurry and dewatered, with the sand material separated and the water appropriately disposed. This area would be surrounded by an engineered bund to contain the materials, improve the stability of the fill, and control the flow of water.

Following dewatering, sand can be stored permanently at the site or screened, treated, and stockpiled for beneficial reuse offsite (i.e., for commercial purposes). Other treatment may be required depending on the sediment chemical properties. Note that, by way of comparison, the materials from the Murray Mouth are disposed of back to the ocean.

Once the sediment has settled out of suspension, the tailwater would be treated, then can either be returned to the River Murray through another above-ground pipeline or discharged into local watercourses. Generally, it is expected that the volume of water would be 5-6 times the quantity of the excavated materials[63].

Several potential discharge locations have been identified based on their vicinity to the areas targeted for sand removal, land area available for bunding, and existing track and road networks connecting to the river. Further studies and consultation are required to select preferred site/s.

Work methodology

The potential scale of the operation has been derived by considering a sediment removal program targeted in the reach of the river between Cutting Creek and Boals Creek, where the river is around 50m wide, and the sand in the bed of the river is around 0.8 to 2.2m thick.

The works would be expected to require 15 – 22 full time contracting resources to operate, removing around 8,000 to 18,000 m^3 (double shifts) per week. Assuming that the operation is active for 9-months of the year, it is expected that 300,000 – 700,000 m^3 could be removed each year. This is more than the rate of aggregation currently occurring each year.

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[63] *Ibid.*

The volume of water needing to be disposed of (assumed in this study as being discharged into local creeks) would be around 30 – 120 ML per week, depending on the scale of operation[64]. This operation would be expected to cost from $31/m^3 to $43/m^3 (including fuel), with the cost per unit increasing depending on the annual quantity removed. This equates to around $8 million per year if the sediment removal works were scaled to match the quantity of sand accumulating in the reach per year. Analysis of the sand material has indicated that it could have a re-sale value as a commercial product[65], which could partially offset this cost.

3.5 Pilot program

The next stage in the development of this this option is a pilot program. The pilot program would provide an insight into the workability and practicality of the sand removal program.

The pilot program aims to remove sand from the bed of the river on a scale which is small enough such that it has no adverse impacts on environmental, cultural, or historical matters. Two locations were investigated as potential pilot sites. Picnic Point has been identified as a preferred location for the pilot program, with around 4,000 m^3 of material (15m wide x 175m long x 1.5m deep area) planned to be removed with the works taking around four weeks. The pilot program would use much smaller plant and equipment than recommended for the main works[66].

For the pilot program, the preferred method for removing sand involves a submersible pump attached to an excavator on a barge[67]. This selected method reflects the preferred method of Traditional Owners. During consultation with the MDBA, Traditional Owners expressed a preference for suction removal over mechanical excavation. The removed sediment is then to be transported to a near onshore disposal site via a pipeline to be drained and stored for further transport in geofabric bags.

The design for ongoing sand removal programs, including onshore disposal methods, will be informed by the pilot program outcomes.

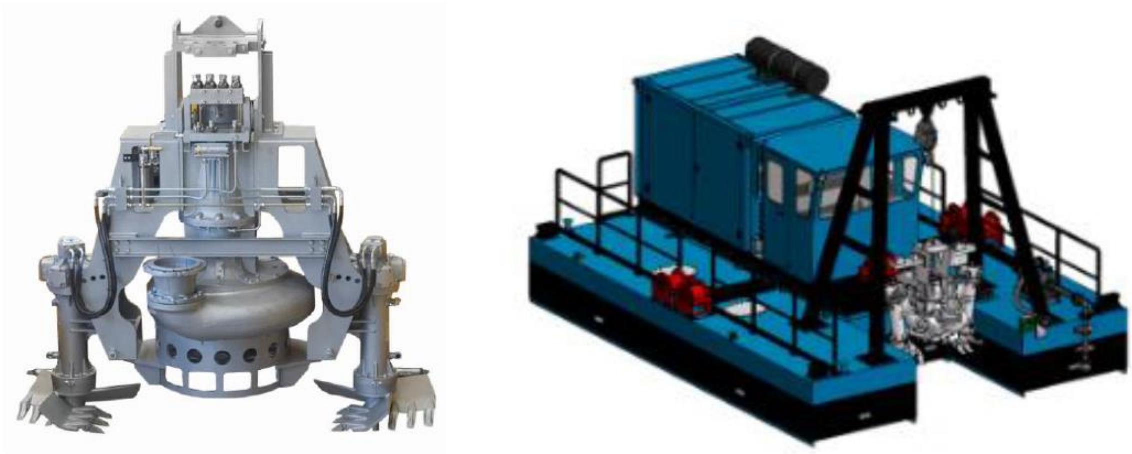

Figure 20. *A submersible pump and barge arrangement, as proposed to be used for the pilot program*

[64] *Ibid.*
[65] Streamology (2022), *Technical Memorandum – Sediment sampling pilot program – data results and analysis*
[66] Streamology (2022), *Barmah-Millewa Reach - Sand management options report*
[67] *Ibid.*

3.6 Option limitations

The following infrastructure limitations have been identified when considering the removal of sediment in the Barmah-Millewa Reach:

- limited or restricted access for deployment of the sand removal and ancillary equipment such as fuel storage within the Barmah-Millewa Forest and adjacent to the river.
- long lengths of transfer pipelines and booster pumping through the Barmah-Millewa Forest, with associated access and fuelling requirements. Multiple creek crossings are likely to be required for the pipeline alignment.
- multiple dewatering and stockpile sites, with associated access power and infrastructure. Lack of suitable sites in the vicinity of the river at several locations.
- snags and woody debris impacting on sand removal efficiency and requirement to identify how snags and woody debris will be disposed of if they require removal for sand removal to take place.

Streamology identified a range of non-infrastructure risks arising from potential sand removal, including:

- loss of access for recreation within areas where sand removal works are being undertaken.
- removal of vegetation to install sand slurry transfer pipes and pumps.
- significant regulatory requirements due to potential impacts on national listed viral species and the likely requirement for an Environmental Impact Statement under the Environmental Planning and Assessment Act 1979 (NSW) (or Victorian equivalent).

3.7 Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Ongoing consultation with Traditional Owners and incorporation of their views to the design and management of the cultural, environmental, and social impacts being caused by the sand accumulation and the response measures to be taken.
- Ongoing consultation with other stakeholders around the need for the option, including the planned design and implementation of mitigation works.
- Development and implementation of the pilot program in such a manner to understand the real-world practicalities and effectiveness of removing sand from the riverbed and to inform the design and development of the long-term mitigation works.
- Further investigation of the sand accumulating and modelling of the expected adverse environmental, cultural, social, and economic impacts under a range of potential responses.
- Further refinement of the proposed method for removing and disposing of the sand, considering the outcomes of the pilot program and the views of Traditional Owners and other stakeholders.
- Defining the scale and form of the works, further investigating the potential adverse environmental, social, cultural, and planning effects, and development of mitigation measures as appropriate. Applying to secure the regulatory approvals required to undertake the works, including ongoing consultation with regulatory authorities.
- Further refinement of the capital and operational costs to implement the program and securing of program funding.
- Staged development and implementation of the option, noting the sensitivities and complexities, to ensure that stakeholders and funders are appropriately engaged and involved in the issue at hand and the design of the mitigation solution.

3.8 Policy considerations

The MDBA's Capacity Policy Working Group has advised that the sediment removal option is focussed on retaining the current channel capacity. As such there are minimal water resource policy implications expected.

3.9 Further work planned

Studies are currently underway to further investigate and scope the works for a sediment management program. This includes additional sampling, modelling, and analysis, assessing the technical feasibility of sand removal and scoping the preferred technique, identifying the impacts of such works and requisite approvals, and communicating with stakeholders and the community.

Initial consultation and cultural heritage studies are underway to understand the ethnohistory and archaeological context of the region and Traditional Owner perspectives. These studies all recognise the rich cultural history and values of the area and the need for ongoing and more detailed consultation with Traditional Owners to inform the proposed work[68].

The outcomes from these studies will be collated into a final study report, which will then be considered by the MDBA and the joint venture Governments to determine whether a business case should be developed. If a decision is made to proceed, the next stages of investigation would be expected to commence in 2023.

A staged approach to the development of the project is being recommended. There would be several stages of work development, consideration, and approval, with community and Traditional Owner consultation extending for the entire time. Such a program may generally include:

- **Step 1**: Deep core sampling to complete heavy metal concentration analysis at selected locations at Picnic Point and at the top of the Barmah-Millewa Reach (circa 2023).
- **Step 2**: Small scale temporary operation (i.e., the pilot program) at Picnic Point to assess effectiveness of equipment, environmental impacts and benefits, and measure the sand infill rate within extraction zones (circa 2024).
- **Step 3**: Business case development and implementation of an ongoing sand removal program at Picnic Point (circa 2025-2027).
- **Step 4**: Business case development and implementation of an ongoing sand removal program at the top of the Barmah-Millewa Forest Reach (2027-2029).

Each of the steps are dependent on further technical assessment, stakeholder consultation, securing of statutory approvals, and the approval and funding for the works being granted by Ministerial Council.

[68] Cultural Heritage Connections (2022), *Barmah-Millewa Reach – Sediment Options Preliminary Aboriginal Archaeological & Cultural Heritage Study DRAFT, report prepared for Streamology.*

3.10 Reference reports

The following is a list of the key reference reports supporting this option:

- Water Technology (2020), *Barmah Choke Channel Capacity and Geomorphic Investigation*
- Streamology (2020), *Barmah Choke Sediment Transport Investigation*
- Grove (2021), *A fluvial geomorphic investigation into channel capacity changes at the Barmah Choke using multiple lines of evidence*
- Streamology (2021), *Options for Managing Sediment in the Barmah-Millewa Reach of the River Murray*
- Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach (proposal)*
- Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bank Monitoring 2022 Memorandum*
- Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment - Bedload Transport and Thickness Investigation Memorandum*
- MDBA (2022), *Preliminary Investigation into Murray River at Gulpa (409006) Capacity Changes Resulting from Sand Removal/Aggradation.*
- Streamology (2022), *Barmah-Millewa Reach - Sand management options report.*
- Port & Coastal Solutions (2022), *Barmah-Millewa Reach Sand Management Options Study, Stage 2 – Bathymetric Analysis (P048R01v02)*
- Port & Coastal Solutions (2022), *Barmah-Millewa Reach Sand Management Options Study, Stage 2 – Hydrodynamic and Sediment Transport Modelling (P048R02v01)*
- Port & Coastal Solutions (2022), *Barmah-Millewa Reach Sand Management Options Study, Stage 2 – Sediment Plume Modelling (P048R03v02)*
- Streamology (2022), *Managing sediment in the Barmah-Millewa Reach of the River Murray: scoping for environmental approvals*
- Streamology (2022), *Technical Memorandum – Sediment sampling pilot program – Data results and analysis*
- Streamology (2022), *Stage 3 Barmah Sand Management Pilot Study – Cost Estimates.*
- Cultural Heritage Connections (2022), *Barmah-Millewa Reach – Sediment Options Preliminary Aboriginal Archaeological & Cultural Heritage Study DRAFT, Report prepared for Streamology.*
- Heritage Insight (2022), *Barmah Forest and River Murray – Preliminary Cultural Heritage Study DRAFT, Report prepared for Streamology.*
- Fifteen 50 (2022), *Barmah Sand Management – Options Assessment for provision of onshore infrastructure.*

4 Option 3 – Tar-Ru (Lake Victoria) transfers

This option proposes further development of risk-based and probabilistic planning practices for making decisions on the timing and volume of transfers from Lake Hume to Tar-Ru (Lake Victoria), to balance the risks of River Murray System shortfalls and the potential for water resource losses.

4.1 Background

Tar-Ru (Lake Victoria)

Tar-Ru (Lake Victoria) is a naturally occurring shallow freshwater lake with a capacity of approximately 677 GL. It is located approximately 60 km downstream of the Murray–Darling Junction in south-western New South Wales, close to the South Australian and Victoria borders (**Figure 21**).

Since 1928, the lake has been operated by the MDBA (and its predecessors) as a regulated, off-river storage as part of the River Murray system.

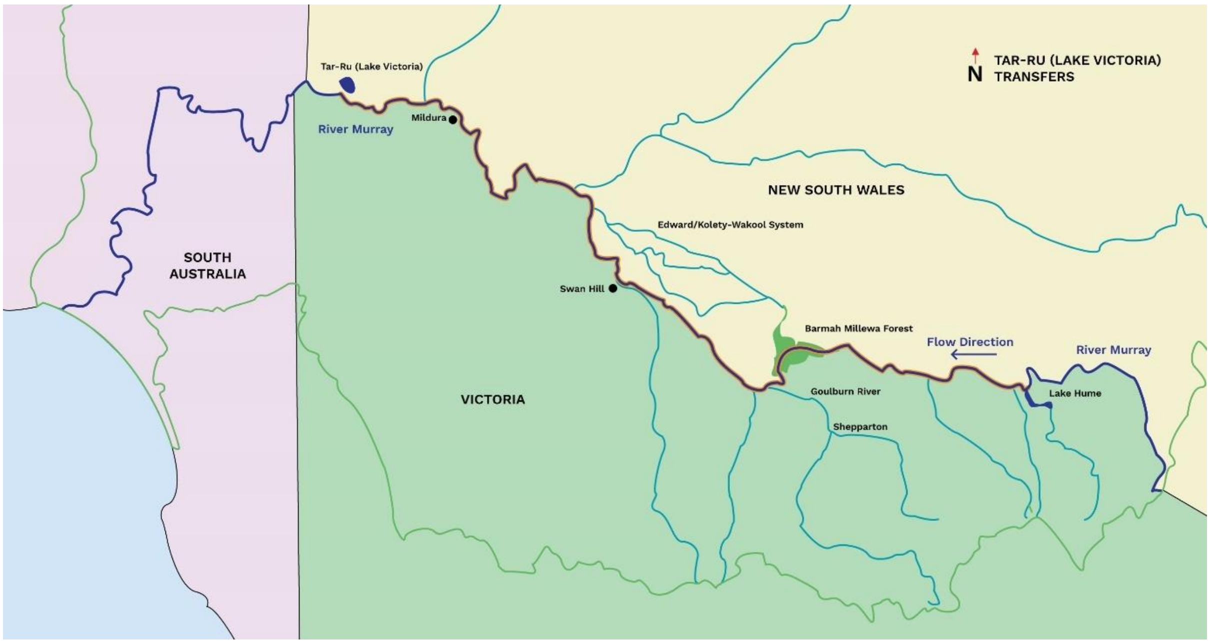

Figure 21. *Tar-Ru (Lake Victoria) location map*

South Australia's Entitlement flow

Water in the River Murray system is shared between New South Wales, South Australia, and Victoria according to arrangements defined in the Murray–Darling Basin Agreement. South Australia receives a fixed amount of water (1,850 GL), called its entitlement, that is supplied 50:50 by the upstream states New South Wales and Victoria from their shares. The South Australian entitlement varies monthly, peaking in summer.

Tar-Ru (Lake Victoria) plays a vital role in managing Victoria and New South Wales shares of the water resources of the River Murray system. The lake is used to capture and store water for later use including water sourced from spills of upstream storages and surplus from tributaries downstream of the Barmah-Millewa Reach.

The location of the lake is particularly significant because it is located downstream of the Barmah-Millewa Reach, and hence has a crucial role in enabling Victoria and New South Wales to supply South Australia's entitlements, during periods of high water demand.

Tar-Ru (Lake Victoria) is also critical to the efficient management of water for Victoria, New South Wales, and South Australia, as it is located immediately upstream of the South Australia border, and inflows and discharges can be managed to accurately meet minimum required flows downstream[69].

Tar-Ru (Lake Victoria) filling

Tar-Ru (Lake Victoria) is operated in accordance with formal operating rules designed to minimise shoreline erosion. It is filled during winter and spring so that the active storage is near or at full supply to meet peak summer flows to South Australia. The lake is then drawn down over summer and autumn to supply South Australia (and meet other downstream demands) before filling recommences from the start of June each year.

Tar-Ru (Lake Victoria) can be filled from either unregulated River Murray tributary flows, which are high in winter and spring, or by transferring water from Hume Dam to Tar-Ru (Lake Victoria). The preferred approach is to maximise the use of winter/spring unregulated tributary flows to fill Tar-Ru (Lake Victoria) rather than by transferring water from Hume Dam early in the season.

The practice of waiting for tributary unregulated flows to fill Tar-Ru (Lake Victoria) in preference to filling the storage early in the season with Hume transfers is to reduce the risk of resource loss to the upstream states arising from:

- **Surplus water flowing into South Australia**: if Tar-Ru (Lake Victoria) is filled early in the season with Hume transfers, there is a risk that subsequent unregulated flows that would otherwise be diverted into Tar-Ru could exceed the South Australian entitlements flows and not contribute to the Victorian and NSW obligations.
- **Internal spills from Tar-Ru (Lake Victoria)**: similarly, if Tar-Ru (Lake Victoria) is filled early in the season with Hume transfers, there is an increased risk of unregulated flows diverted later in the season into Tar-Ru (Lake Victoria) 'spilling' internally with a potential for a loss of water resource from one State to another. Internal spills occur when one State's share of the storage is full and inflows are internally 'spilled', becoming resources for the State which has capacity to store the inflow. For example, in 2019–20, there was 188,200 ML of internal 'spill' from Victoria to New South Wales in Tar-Ru (Lake Victoria)[70].
- **Conveyance losses**: when transfers are made from Hume to Tar-Ru (Lake Victoria), some water is lost en route (e.g. to evapotranspiration and seepage). The significance of conveyance loss considerations depends on the rate at which transfers are made and other flows being delivered.

4.2 Scoping study

Impact of current Tar-Ru (Lake Victoria) filling practices

In 2021, the MDBA on behalf of its joint venture partners commissioned a scoping study by Hydrology and Risk Consulting (HARC) to examine the key water resource impacts of current practices in the filling of Tar-Ru (Lake Victoria).

The scoping study found that waiting for tributary inflows during winter and spring to fill Tar-Ru (Lake Victoria) in order to minimise resource loss was a sound tactic based on historic records. However, under recent climate conditions winter/spring tributary inflows in the River Murray have fallen short of historic averages. As a result, since 2010, the filling of Tar-Ru (Lake Victoria) to its target level by summer and meeting the end of May target has been more difficult to achieve (see **Figure 22**)[71].

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[69] https://www.mdba.gov.au/sites/default/files/archived/mdbc-SW-reports/2145_Lake_Victoria_operating_strategy.pdf
[70] https://accounts.water.vic.gov.au/wp-content/uploads/2021/05/Murray_2019-20_1.pdf
[71] HARC (2021), *Review of impacts of system-wide drivers on Tar-Ru – Scoping report - Stage 1*

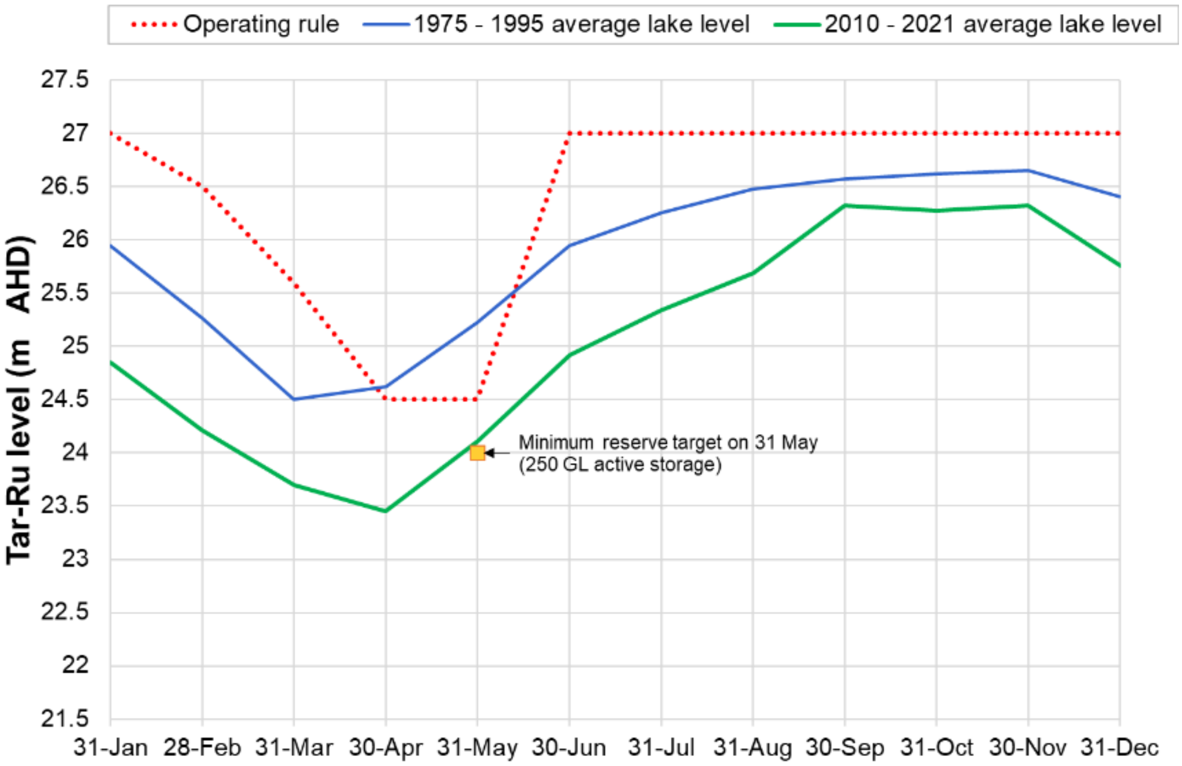

Figure 22. *Comparison of average monthly water levels at Tar-Ru comparing Lake Victoria Operating Strategy operating rules, the 1975–1995 period (blue line) and 2010-2021 period (green line)*[72]

Transfers from Lake Hume in summer to fill Tar-Ru (Lake Victoria) are limited by the constrained capacity of the Barmah-Millewa Reach[73].

HARC found that reduced tributary inflows to the River Murray system in the recent historic record meant that more transfers of water from Lake Hume had been needed to fill Tar-Ru (Lake Victoria). The water years of 2018/19 and 2019/20 are prime examples of less-than-optimal Tar-Ru (Lake Victoria) filling as a result of waiting for unregulated flows to fill the storage that subsequently did not materialise. In these years, the volume stored in Tar-Ru (Lake Victoria) peaked at 550 - 560 GL, 120 GL below the Tar-Ru (Lake Victoria) full supply level filling target, and large volumes of Hume Dam transfers were made in the peak January – April period (**Figure 23**).

[72] HARC (2021) *Historical flows in the southern connected Murray Darling Basin*
[73] *Ibid*.

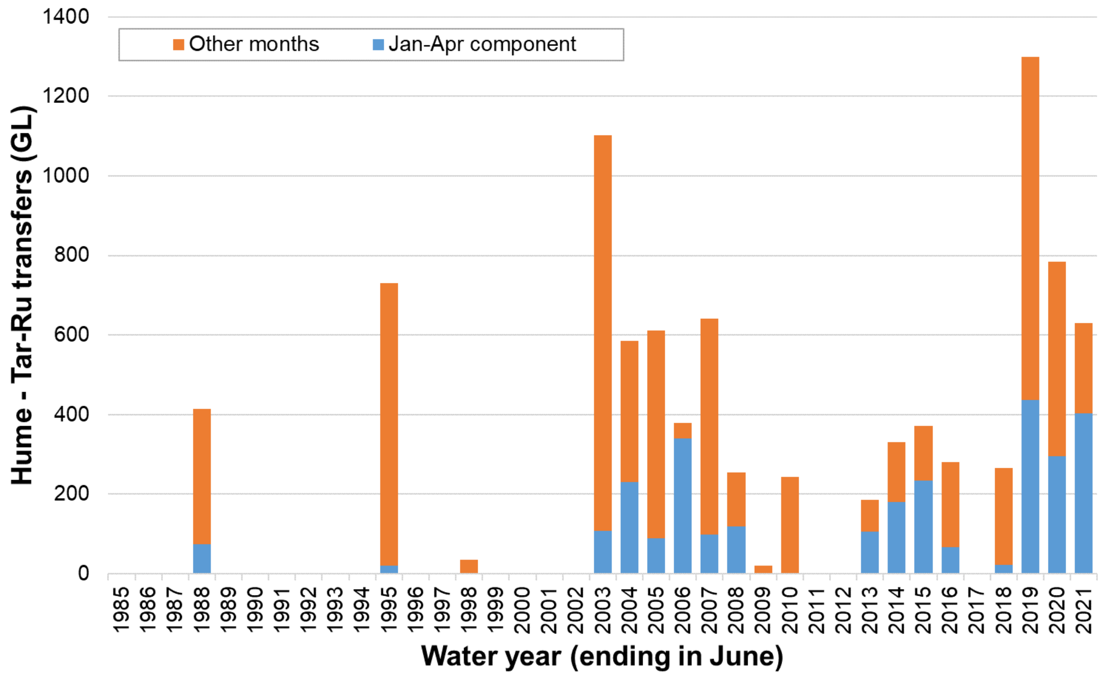

Figure 23. *Releases from Lake Hume to transfer water to Tar-Ru (Lake Victoria) in water years from the mid-1980s to date*[74]

Potential contribution to the BMFS objectives

The scoping study identified four broad drivers that have affected the filling frequency of Tar-Ru:

- reduced tributary inflows.
- operational constraints and efficiencies, including changes to the Barmah-Millewa channel capacity.
- demands for water.
- limits on Tar-Ru water level changes needed to meet cultural and environmental obligations and objectives.

Whilst the study did not consider the BMFS or the objectives of this project, it does provide an insight into whether there could be an opportunity for changed operational practices to support both the filling of Tar-Ru and to take pressure off the Barmah-Millewa Reach during the summer period. This opportunity may arise if some Hume – Tar-Ru transfer volumes could be delivered in late spring to support the filling target, rather than occurring over the summer months. This would support the BMFS objectives by either increasing the system capacity or by allowing reduced flows to be delivered through the reach during the summer months.

The risk in making early transfers is that there may be missed opportunities for harvesting unregulated flows. There is a potential opportunity to coordinate environmental water deliveries during the winter/spring period on top of early transfers. In this circumstance, the risk of foregone harvesting opportunities may be underwritten by the environmental water holders to reduce the risk of third-party impacts on state water shares. This opportunity should be further considered as part of any further development of this option.

Increased Hume – Tar-Ru (Lake Victoria) transfers outside of the summer period is an option that, if progressed, would require a significant amount of additional work coordinated between the MDBA and Basin states. This would be supported by the risk-based framework for making future decisions about the timing and volumes of Hume – Tar-Ru (Lake Victoria) transfers.

Based on the report findings, over the past 20 years, there were three water years in which bringing forward Hume – Tar-Ru transfers could have reduced the need for January – April transfers. In these years, earlier

[74] *Ibid.*

transfers would have reduced summer deliveries through the reach by approximately 50 GL to 120 GL, which is an average of approximately 420 ML/d to 1,000 ML/d over a 120-day period.

Decision-making framework

The scoping study included a concept-level plan of the tasks required to develop a framework for making decisions about the timing and volume of Hume – Tar-Ru (Lake Victoria) transfers. The concept-level plan was presented to the River Murray Operations Committee (RMOC) in late 2021 and the MDBA plan to begin implementation in 2022/2024 (Kris Kleeman, pers. comm., June 2022).

This planned future work will be important for assessing whether Hume – Tar-Ru (Lake Victoria) transfers can be brought forward earlier into the water year and potentially contribute to the objectives of the BMFS. These proposed tasks have been grouped into four sets:

- **Develop a fit-for-purpose model for future investigations**: the Source Murray Model (SMM) will be the key tool needed for forming a risk-based decision framework for Hume – Tar-Ru (Lake Victoria) transfers. For the SMM to be of most use for an investigation of Hume – Tar-Ru (Lake Victoria) transfer rules, it would need to represent River Murray and tributary inflows under current or potential future climate conditions, rather than historic conditions.
- **Confirm or re-visit water resource management policies and procedures that influence the operation of Tar-Ru (Lake Victoria)**: a range of water resource management considerations will need to be discussed, and either confirmed as rules or aspects of system operations that could be refined
- **Develop a risk-based framework for Hume – Tar-Ru (Lake Victoria) transfers using 'what if' scenario testing**: appropriate metrics will need to be selected to assess how Hume – Ta-Ru (Lake Victoria) transfers contribute to risks of resource losses, supply shortfalls for water users and deliverability constraints on water orders, whether transfer rules can be modified to balance and minimise these risks, and risk appointment.
- **Report and communicate the task outcomes**: work to develop an agreed risk-based framework for making decisions about Hume – Tar-Ru (Lake Victoria) transfers will require significant stakeholder engagement including with First Nations.

It is noted that existing Goulburn and Murrumbidgee inter-valley trade (IVT), as a Murray resource, can be used to support Tar-Ru filling targets. There is the potential under this option to consider further use of existing IVTs (in accordance with Goulburn operating rules) to support the early filling of the storage.

4.3 Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Consultation between the MDBA, States and environmental water holders regarding the risk of foregone harvesting opportunities and changes to internal spills because of early Tar-Ru transfers. This consultation should include exploring the potential opportunity for the environmental water holders to underwrite the risk of any impacts on State entitlements.
- Continued and ongoing consultation with Traditional Owners around the operational management of Tar-Ru, and in the context of this option, how any changes to the timing of Tar-Ru transfers would be managed at the storage.

4.4 Policy considerations

The MDBA's Capacity Policy Working Group has advised the following:

- The Hume to Tar-Ru transfers option is fundamentally about defining the risk balance for the River Murray system between the risk of spill of water transferred to Tar-Ru and the risk of shortfall. This represents a new area of practical policy development.
- The Hume to Tar-Ru transfers option could be extended to investigate options for environmental water holders to underwrite some / all of the risk of spill of water transferred to Tar-Ru. This option is

predicated on the assumption that a spill of Tar-Ru will be ecologically beneficial. Such an arrangement is a new area and thus will require practical policy development.

The CPWG has advised that development of the Hume to Tar-Ru Option has significant potential and is at **low risk from water policy implications**.

4.5 Further work planned

The scoping study suggests that a 2–4-year timeline is needed to complete the tasks set out above.

Earlier seasonal transfers to Tar-Ru would create a potential opportunity for environmental water deliveries to be enhanced during the winter/spring period. In this circumstance, the risk of foregone harvesting opportunities may be underwritten by the environmental water holders to reduce the risk of third-party impacts on state water shares. This opportunity should be further considered and explored as part of any further development of this option.

4.6 Reference reports

The following is a list of the key reference reports supporting this option:

- HARC (2021), *Review of impacts of system-wide drivers on Tar-Ru – Scoping report – Stage 1*
- HARC (2021), *Historical flows in the southern connected Murray Darling Basin*

5 Option 4 – MIL system optimisation

This option proposes use of the irrigation infrastructure within the Murray Irrigation Limited (MIL) channel network to increase the delivery of bypass flows around the Barmah-Millewa Reach. There are numerous different options within the MIL system which could be used. Preliminary studies have been completed to identify potential options, determine a shortlist of those which may be viable, and investigate the likely scope, scale, and key considerations for these shortlisted options. Further detail on these investigations and scoping is provided in the Technical Report: MIL Options Investigation[75].

5.1 Background

MIL channel system

Murray Irrigation Limited (MIL) is an irrigator-owned company that operates an extensive open channel irrigation district in southern NSW. MIL irrigation water is diverted from Lake Mulwala upstream of the Barmah-Millewa Reach and is conveyed to irrigators across the southern Riverina and Edward-Kolety – Wakool floodplain. At multiple points, the channel system can deliver flows via channel escapes to rivers and waterways in the Edward-Kolety, Wakool, Niemur and Billabong Creek systems downstream of the Barmah-Millewa Reach (**Figure 24**). By utilising the channel network, the escapes and natural waterways, regulated flows can be diverted around the Barmah-Millewa Reach and returned to the River Murray.

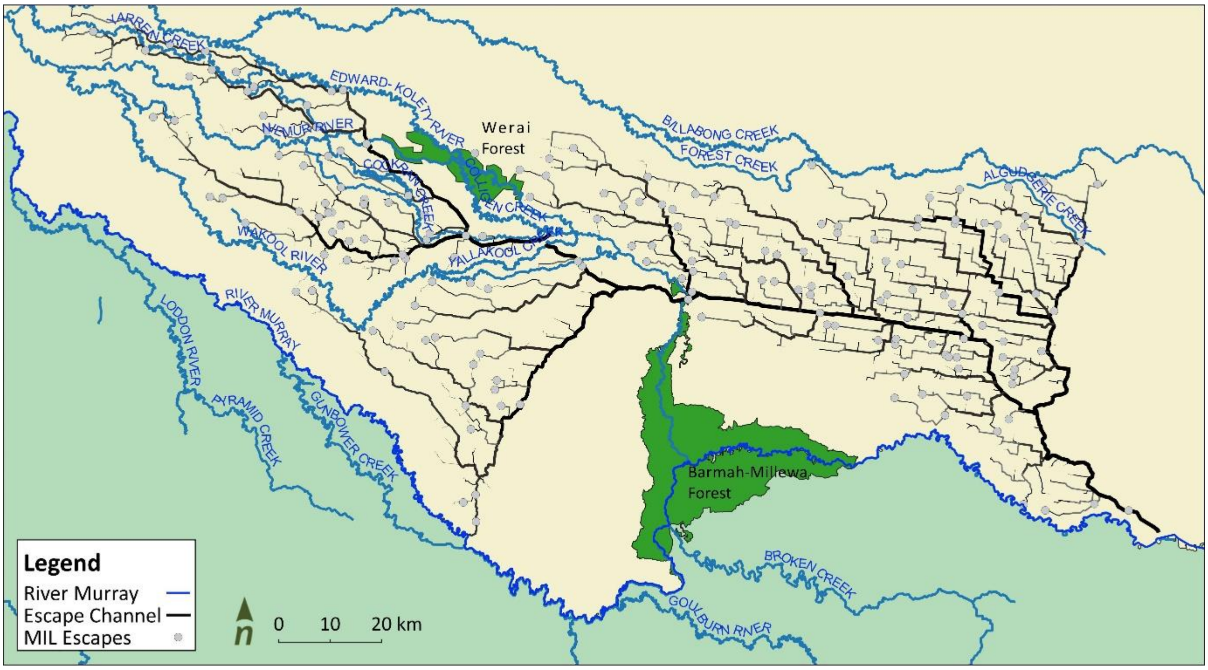

Figure 24. *Location of the MIL channel system relative to the Barmah-Millewa Forest with escapes as grey dots*

Use of the MIL system for bypass flows

Using MIL infrastructure to transfer water around the Barmah-Millewa Reach is a well-established practice. An "Escape Flow Agreement" between MIL and WaterNSW sets out the terms on which WaterNSW may make an Escapes Delivery Request for MIL to convey water to certain locations. The agreement applies to four accredited escapes including the Edward River Escape, Finley Escape, Perricoota Escape, and Wakool River Escape.

When the MDBA would like to transfer water through the MIL system, MDBA requests WaterNSW to target specific flows downstream of the escapes. When only small transfers are required, the Edward River Escape is usually used, but when larger transfers are required, a combination of different escapes can be used depending on available capacity (including in the receiving waterway).

[75] Alluvium (2022), *BMFS Technical Report: MIL Options Investigation*

Opportunity to enhance the use of the MIL system
A project has been established to investigate opportunities to expand the use of the MIL infrastructure to bypass water around the Barmah-Millewa Reach. These opportunities involve accessing spare capacity within the channel network and through targeted works to upgrade infrastructure capacity.

MIL has initiated discussions with the MDBA around progressing these opportunities. The irrigation corporation expects to see the following benefits arise from upgrading its channel network:

- **Increased utilisation of spare capacity in the channel network:** as a result of outward water trade from the irrigation area there is spare capacity within sections of the channel network or at specific times that could be utilised for the conveyance of bypass water. Similar to current arrangements for utilising channel capacity, any increase capacity would be made available on a cost recovery basis, providing a contribution to long-term asset renewal costs.
- **Enhanced environmental watering actions in the Edward-Kolety – Wakool system**: MIL supports the use of its channel infrastructure to efficiently deliver environmental water to the waterways and floodplain of the ecologically important Edward-Kolety – Wakool system. MIL sees an opportunity to increase the capacity of its infrastructure to provide both Barmah-Millewa Reach bypass flows and to deliver environmental watering actions within the Edward-Kolety – Wakool system.

5.2 Scope of feasibility study assessment

This option is being explored by the MDBA in collaboration with MIL as part of the BMFS study. Engineering assessments were undertaken to determine the capacity and outfall options within the MIL channel network. Ecological assessments were undertaken to determine the tolerable flows of the receiving natural waterways, including consideration of the cumulative flows downstream from the use of several outfalls across the system. The overall potential to increase bypass transfers via the MIL network was considered with regard to both the engineering works and the ecological tolerances of the waterways.

These feasibility study investigations are detailed in the Technical Report: MIL Options Investigation[76].

5.3 Long-list of potential options (MIL)

There are several options which could conceptually be used to increase bypass flows through the MIL network. A long list of potential options was collated as the first step in the MIL feasibility study investigations. This long list was based on engagement with MIL and the MDBA, as well as researching previous investigations. The long list was considered exhaustive. Not all options were expected to be viable; however, all were included for completeness. A summary of the long-listed options is provided below.

Increasing the use of the MIL escapes. This option was further categorised as:

- **Accredited escapes**: increasing the use of the four large escapes that are accredited by WaterNSW. These escapes are currently utilised for the delivery of bypass water.
- **Murray Reconnected Floodplains Project**: using escapes which deliver water to ephemeral waterways. These escapes have been identified as part of a separate project, the Murray Reconnected Floodplains Project. This project prioritises the use of the MIL system to deliver environmental outcomes in the receiving waterways. There may be an opportunity for these escapes to contribute to the objectives of the BMFS project. The Murray Reconnected Floodplains Project has separately received tentative funding approval from the Commonwealth.
- **MIL System Optimisation Project:** using any other escapes in the MIL channel network which could contribute to the objectives of the BMFS project.

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[76] *Ibid.*

Major capacity expansion by undertaking capital works. This option included:

- **Perricoota Escape expansion:** undertaking works to increase capacity of the Perricoota Escape and the Deniboota Canal, which outfalls to the River Murray. This option would allow the bypass capacity to be increased from 100 ML/day (current) to 300 ML/day (nominal).
- **Mulwala Canal extension:** undertaking works to extend the Mulwala Canal from its current termination point to provide an alternate route for delivering water to the Wakool Main Channel canal and the Yallakool Creek. This option would allow increased bypass flows either increasing deliveries through the Edward-Kolety River or the Yallakool Creek.
- **Upgrade of Edward-Kolety River escape:** upgrading regulators on the Mulwala Canal to increase the capacity of the Edward-Kolety escape from 2,400 ML/day to 3,500 ML/day.

Using other infrastructure in NSW (outside of the MIL channel network). This option included:

- **Moira Bypass:** a conceptual idea originally raised by the Moira Private Irrigation District (MPID). The concept was further detailed as part of the long list as a pressurised pipeline bypass that is 47 km in length constructed from Picnic Point extending to Barmah Lakes.

Each of the long-listed options were assessed against the project objectives and a range of key criteria. **Table 3** summarises the outcomes of this assessment, with three options progressing for further investigation. Detail for each of the shortlisted options is provided in the next section.

Table 3. Summary of the MIL long-list options assessment

Assessment Category	MIL escapes optimised	Perricoota Escape Expansion	Mulwala Canal Extension	Upgrade of the Edward-Kolety River Escape	Moira Bypass
Operational shortfall					
System shortfall					
Technical feasibility					
Reliability and flexibility					
Environmental					
Social					
Economic					
Regulatory requirements					
Capital investment					
O&M costs					
Proposed capacity ML/day	300 – 900	300	1,000 – 1,500	1100	200
Shortlist for further investigation	✓	✓	✓	✗	✗
Primary rationale for shortlisting decision	Effective in reducing shortfall risks using existing infrastructure with low capital costs	Effective in meeting shortfall risks and is environmentally tolerable	Effective in meeting shortfall risks and takes regulated water out of the Edward-Kolety River	Is not environmentally tolerable (refer note 1)	Is not environmentally tolerable

5.4 Shortlisted options (MIL)

Three of the long list options were shortlisted for more detailed assessment. The first of these options, the optimisation of the MIL escapes, comprises two sub -options, an option without works and a more expansive option that includes works to increase the capacity and utility of the existing escapes.

Option 4A: MIL optimised escapes

This option involves increasing the use of the MIL escapes for the purpose of providing bypass flows around the Barmah-Millewa Reach.

The MIL channel system network contains approximately 70 escape structures that can outfall water to natural waterways and flow back to the River Murray System downstream of the Barmah-Millewa Reach. Through engagement with MIL, WaterNSW and NSW Department of Planning and Environment (DPE), 20 of these escapes were identified as priority sites which could be used for this purpose. These escapes were selected primarily based on expected capacity, transmission losses, and impact on the environment. There are two sub-options being considered:

- **Option 4A.1 – No works**: accessing the available capacity at escapes which are already automated and metered and would require no upgrade works. There are eight escapes which meet this criterion and can be considered for delivering additional flows.
- **Option 4A.2 – Works required**: undertaking targeted works to increase the capacity and install automation and metering. The works involve replacing manually operated escapes with automated (metered) regulators, maximising the available channel capacity.

Figure 25 shows the location of the MIL channel network relative to the Barmah-Millewa Reach.

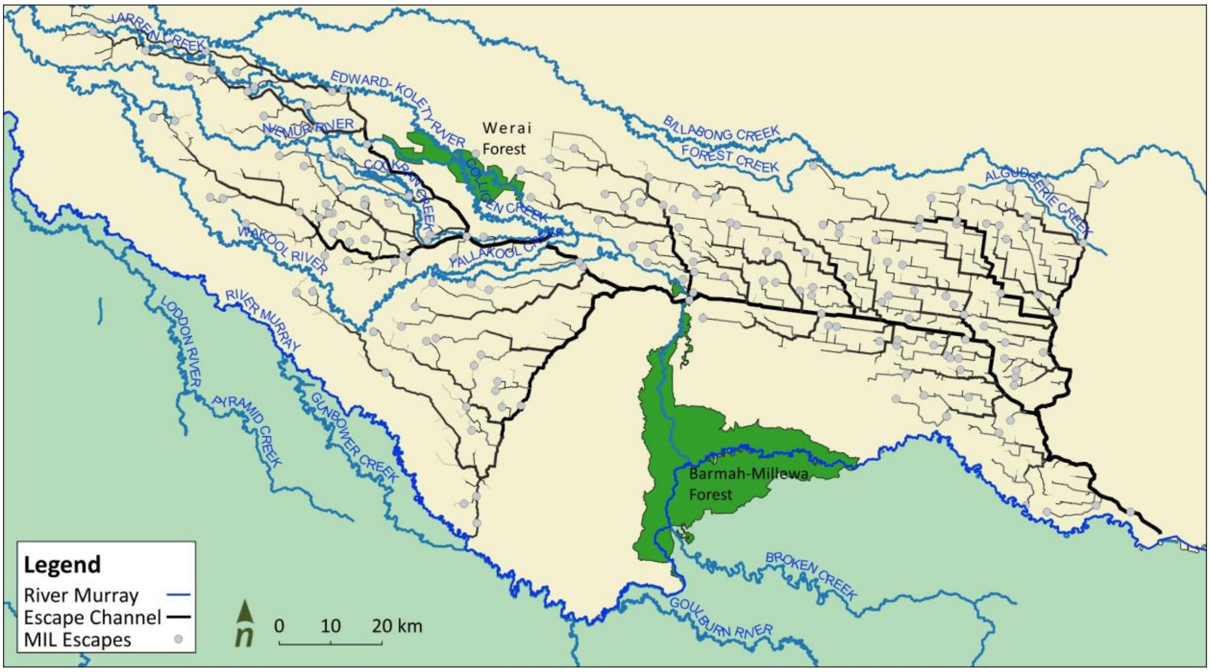

Figure 25. *Map of the MIL channel escapes and receiving waterways*

Option 4A.1: MIL optimised escapes (no works)

The *No Works* option requires no capital works to be performed. The option includes eight escapes which are all currently automated and are used for the delivery of environmental water or operational water on behalf of DPE or WaterNSW respectively. The use of the escapes for environmental watering events tends to currently occur during the spring months.

The engineering assessment determined that the MIL channel network and eight escapes have the capacity to deliver an additional 1,605 ML/day during summer. These flows would be in addition to existing system commitments.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the outfalls. This assessment considered tolerable baseflow and fresh deliveries across the summer and winter/spring seasons. Over the summer period, the average daily flow was determined as 665 ML/day.

Table 4. The escapes which could be used for bypass flows with no works required

There	MIL channel & escape available capacity (no works required)	Receiving waterway	Ecologically tolerable release – seasonal average in summer (ML/day)
Wakool Main Escape	500	Wakool River	108
Southern Escape	70	Neimur / Wakool Rivers	70
Mallan W221/4 Escape	15	Niemur River	-
Mallan W149 Escape	70	Niemur River	-
Northern Niemur Escape	300	Niemur River	288
Mascotte Escape	300	Niemur River	-
Billabong Escape	250	Billabong Creek	96
Perricoota Escape	100	River Murray	100
TOTAL	1,605 ML/day		662 ML/day Adopt 665 ML/day

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- The engineering assessment determined that the MIL system could provide around 1,600 ML/day of additional capacity at eight outfalls. The ecological assessment determined that a seasonal average flow of 665 ML/day could be tolerable over summer, delivered from five outfalls. These flows would be delivered through a combination of baseflow and freshes over summer.
- This option could be implemented on a very short timeframe and with no capital investment required.
- These outfalls could also be used during winter/spring to deliver around 1,400 ML/day of additional capacity. This could be used to support the filling of Tar-Ru and to support environmental outcomes.
- The change in flow regime in the receiving waterways has been assessed to be ecologically tolerable and will require further refinement in terms of operational requirements to achieve such prescribed variability. The releases would need to be provided to the natural waterways as 'pulses' across the summer period. A range of escapes could be operated to form a mosaic of waterways across the Edward-Kolety – Wakool system supplied with base flows and freshes.
- Delivering flows through the MIL channel system and natural waterways as a means of bypassing the Barmah-Millewa Reach would result in higher conveyance losses. If the average additional flow was delivered for 100-days over summer, the additional losses would be in the range of 7 – 14 GL per year.
- There will be a delivery charge for the transfer of water through the MIL network. It is likely that this would be a volumetric charge based on the volume of total water delivered. This charge would be

subject to negotiation between MIL and MDBA. However, based on other similar agreements, it is expected that the charge may range from $4-5 per megalitre delivered.

Option 4A.2: MIL Escapes optimised

The *Works Required* option investigates whether there is an opportunity to undertake upgrade works at the 20 priority MIL escapes to deliver higher bypass flows. The upgrade works generally involve automating the escape regulators and increasing the capacity of receiving channels and waterways.

The engineering assessment determined that the MIL channel network and escapes could be upgraded to deliver an additional 3,355 ML/day during summer. These flows would be in addition to existing system commitments.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the outfalls. This assessment considered tolerable baseflow and fresh deliveries across the summer and winter/spring seasons. Over the summer period, the average daily flow was determined as 960 ML/day.

Table 5. The escapes which could be used for bypass flows, with works required

Escape name	Existing capacity (ML/day)	Upgraded capacity (ML/day)	Receiving waterway	Ecologically tolerable release – seasonal average in summer (ML/day)	Works required on escape based on ecologically tolerable flows
Wakool Main Escape	500	700	Wakool River	136	Upgrade works
Southern Town Escape	50	250	Wakool River	183	Upgrade works
Southern 27 Escape	15	50	Wakool River	-	Upgrade works
Southern Escape	70	70	Niemur / Wakool Rivers	24	No works required
Mallan Escape Frasers	50	330	Niemur River	-	No capacity in waterways
Mallan W149	70	70	Niemur River	-	No capacity in waterways
Mallan W186A	15	100	Niemur River	-	No capacity in waterways
Northern Escape W190	20	160	Niemur River	-	No capacity in waterways
Mallan W211 Escape	15	125	Niemur River	-	No capacity in waterways
Mallan W221/4 Escape	15	90	Niemur River	-	No capacity in waterways
Niemur Escape	300	300	Niemur River	280	No works required
Mascotte Escape	300	300	Niemur River	-	No works required
Northern 4 Escape	15	20	Niemur River	15	Upgrade works
Jimaringle 1 Escape	15	40	Niemur River	40	Upgrade works
Jimaringle 3 Escape	10	20	Niemur River	-	Upgrade works
Jimaringle 11 Escape	20	20	Niemur River	20	No works required
Jimaringle Escape	20	60	Edward-Kolety River	-	Upgrade works
Northern Branch Channel	30	300	Niemur River	60	Upgrade works
Billabong Escape	250	250	Billabong River	96	No works required
Perricoota Escape	100	100	River Murray	100	No works required
TOTAL	1,880 ML/day	3,355 ML/day		954 ML/day (Adopt 960)	

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- The engineering assessment determined that the MIL system could provide around 3,355 ML/day of additional capacity through the 20 priority outfalls. The ecological assessment determined that a seasonal average flow of 960 ML/day could be tolerable over summer, delivered from 14 outfalls. These flows would be delivered through a combination of baseflow and freshes over summer.
- Eight outfalls would need to be upgraded and six outfalls could provide additional flows with no additional works required. There is no capacity in downstream waterways from six of the outfalls and thus no works would be undertaken on these outfalls.
- Upgrading the eight outfalls would require a capital investment of around $18.5 million and take two years to complete.
- These outfalls could also be used during winter/spring to deliver around 2,000 ML/day of additional capacity. This could be used to support the filling of Tar-Ru and to support environmental outcomes.
- Similar to option 4A.1,
    - the releases would need to be provided as 'pulses' across the summer period. A range of escapes could be operated to form a mosaic of waterways across the Edward-Kolety – Wakool system supplied with base flows and freshes.
    - delivering flows through the MIL system would result in higher conveyance losses. If the average additional flow was delivered for 100-days over summer, the additional losses would be in the range of 11 – 22 GL per year.
    - there will be a delivery charge for the transfer of water through the MIL network, expected to be around $4 – 5/ML delivered.

Option 4B: MIL major capacity expansion

The Perricoota Escape outfalls water from the Deniboota Canal to the River Murray via a 10km escape channel (**Figure 26**). The existing design capacity of the Perricoota Escape is 150 ML/day. During the summer months, around 100 ML/day of this capacity is currently available for delivering bypass flows. This option explores undertaking upgrade works to the Deniboota Canal and the Perricoota Escape to support bypass flows of up to 300 ML/day (i.e., an increase of 200 ML/day from the current available capacity).

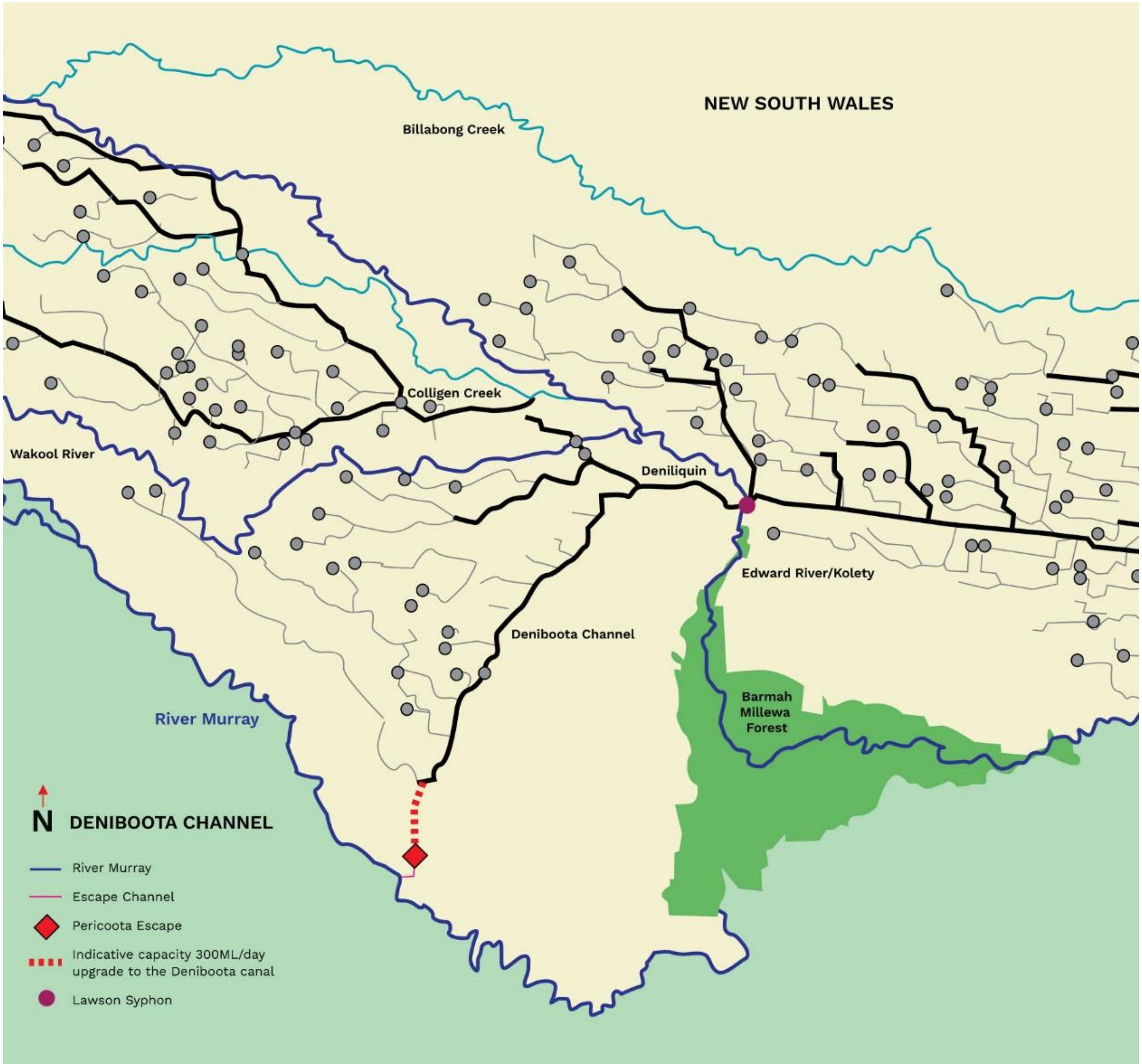

Figure 26. *Location of the Perricoota Escape capacity expansion*

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Preliminary engineering assessments and advice from MIL operational staff have indicated that the Deniboota Canal would struggle to deliver increased flows to the River Murray under gravity due to limited hydraulic head difference between the canal and the operational levels of the river.
- If the hydraulic head difference were available, this option would still provide a relatively limited increase in capacity to address system shortfall risk compared to other options under investigation.
- The capital works would likely cost around $25 million. Contributions to increased operations and maintenance costs would need to be paid to MIL, in addition to volumetric delivery charges.
- MIL stakeholders are generally concerned that the construction of new infrastructure for the purpose of bypassing water could facilitate the further trade of water to downstream areas in the system.

Option 4C: MIL Mulwala Canal Extension

This option involves an extension of the Mulwala Canal from its current termination point at the Wakool Escape on the Wakool River to allow additional bypass flows to be delivered downstream (**Figure 27**). The preferred option involves the construction of a pipeline discharging to the Yallakool Creek.

The Mulwala Canal upstream of its current termination point has an existing surplus capacity of around 1,000 ML/day. The Mulwala Canal could be extended by around 7km to allow flows to be delivered into the Yallakool Creek.

The Yallakool Creek flows into the Wakool River. Flows on the Wakool River are managed to be avoid overbank flows which could impede access for private landholders.

The engineering assessment determined that sufficient capacity was available in the system to install a 200 ML/day pipeline to deliver flows into the Yarrakool Creek system. This would require the installation of dual concrete pipes 1500mm in diameter for a length of 6.3km.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the pipeline extension. The ecological assessment confirmed that the ecologically tolerable flow should be restricted to an average of around 185 ML/day due to capacity constraints in the Wakool River. However, expecting that some of this available capacity in taken by optimising the current escapes (Option 4A), the additional capacity available for this option reduces to around 38 ML/day.

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- This option would provide a relatively limited increase in capacity to address system shortfall risk compared to other options under investigation.
- As the Yallakool Creek and Wakool River are natural watercourses, it would be preferential for flows to be delivered as 'pulses' across the summer period.
- The Yallakool Creek has a large channel and spare capacity, meaning it could accommodate additional flows without increasing environmental risks. However, the Wakool River downstream of the Yallakool has a constraint on the ecological flows that can be delivered. The ecological assessment reduces the total delivery flow rate to 185 ML/day on average.
- When done in conjunction with delivery of water via either of the 'escapes optimised' options, there is a greater reduction in average deliverable flows – to 38 ML/day.
- The capital works would likely cost around $38.5 million. The works would take around two years to design and construct.
- Delivering flows through the MIL system would result in higher conveyance losses. If the average additional flow was delivered for 100-days over summer, the additional losses would be in the range of 0.5 – 1 GL per year.

Figure 27. *Map of the Mulwala Canal and Yallakool Creek location relative to the Barmah-Millewa Forest*

5.5 Policy considerations

The MDBA's Capacity Policy Working Group has advised the following:

- The key policy area for investigation associated with use of the MIL infrastructure to transfer water into the Wakool-Niemur system is how conveyance losses are accounted for. This is both the conveyance loss charged by MIL for use of their channel system and any increase in conveyance loss in the Wakool-Niemur River system as a result of the increased regulated flow volumes. Under current accounting rules the conveyance loss in the Wakool-Niemur River system is accounted to NSW, however if operational water is to be directed through this system losses would be expected to be shared.
- There is also an issue in how the MIL capacity is secured when needed for river operations for this option to be viable/useful i.e. can priority of access MIL infrastructure capacity be guaranteed?

The CPWG has advised that the **key challenge** with the use of the MIL infrastructure **is negotiating an agreement (cost and conveyance loss) with MIL** in a way that all jurisdictions have confidence in the process.

There are business risks associated with making long-term arrangements with commercially focussed enterprises (e.g. MIL and Snowy Hydro Limited). Contract arrangements will need to be negotiated in a transparent manner to all partner governments, clearly documented, and enforceable.

5.6 Further work planned

The MIL feasibility study investigations confirmed that there is a real opportunity for enhancing the use of the MIL channel network for supporting the Barmah-Millewa project objectives.

The increased use of the MIL channel escapes to deliver bypass flows has potential to substantially support system operators with managing system shortfall risks and allows operators to deliver flexible and variable flows to the Barmah-Millewa Reach and natural watercourses, providing environmental outcomes.

Further work to develop this option may involve:

- Further development of Option 4A, involving the increased delivery of bypass water using the MIL channel escapes.
- Development of a daily timestep water balance hydrologic model for the Edward-Kolety – Wakool waterways for the analysis and verification of flow rates and available capacities.
- Detailed conveyance loss assessments for each of the proposed delivery routes. This may include making actual deliveries with temporary gauging to record flows through the system and confirm losses.
- Engineering designs for the proposed asset upgrade works, including the escapes and channels which may be upgraded. This would also include an engineering assessment on the receiving natural waterways to identify any potentially affected assets which may need to have works undertaken to support the higher flow deliveries and manage potential impacts.
- Further ecological assessments to better understand the opportunities to offset reductions in floodplain vegetation distribution through delivery of environmental flows through the region.
- Further analysis and discussions between stakeholders in regard to the acceptance and availability to use the surplus summer capacity within the Edward-Kolety River below Stevens Weir as a bypass opportunity.
- Engagement with key stakeholders on the process of selecting a final option or a series of options.
- Negotiation with MIL on the terms and conditions for increased access to the MIL channel network, including contributions for increased operations and maintenance costs associated with any upgrades, the volumetric delivery charge, and the form of agreement.

5.7 Reference reports

The following is a list of the key reference reports supporting this option:

- Alluvium (2022), *Technical Report: MIL Options Investigation*

6 Option 5 – Victorian options

This option proposes works to enhance existing or construct new Victorian infrastructure to convey water from upstream to downstream of the Barmah-Millewa Reach, or to store water to meet peak downstream demands. There are numerous different options in Victoria which could be used. Preliminary studies have been completed to identify potential options, determine a shortlist of those which may be viable, and investigate the likely scope, scale, and key considerations for these shortlisted options. Further detail on the investigation and scoping of this is provided in the Technical Report: Victorian Options Investigation[77].

6.1 Background

Victorian tributaries and rural water infrastructure are already used to bypass flows around the Barmah-Millewa Reach and to provide capacity to mitigate shortfall risks. Scope exists to enhance the use of existing infrastructure or to develop new infrastructure to increase the bypass capacity. The range of potential options include:

- **Storage options**, which involve using existing or new storages downstream of the Barmah-Millewa Reach to assist with managing delivery shortfall risks.
- **Bypass options**, which involve transferring water from above to below the Barmah-Millewa Reach by using existing or new infrastructure.
- **Goulburn-system options,** which involve supplying Goulburn commitments to the Murray system through constructing alternative and ecologically sustainable options. These options would then be used to deliver concentrated volumes of IVT commitment to the Murray during summer, which would supplement water otherwise required to be passed through the Barmah-Millewa Reach.

6.2 Scope of feasibility study assessment

This option is being explored by the MDBA in collaboration with Goulburn Murray Water (GMW), Department of Environment, Land, Water and Planning (DELWP), and catchment management authorities. Potential options were identified drawing on existing studies, including options that have previously been ruled out, and through consultation with key government agencies. Further detail on the investigation and scoping of this is provided in the Technical Report: Victorian Options Investigation[78].

6.3 Long-list of potential options (Victoria)

There are several options which could conceptually be used to increase bypass flows through Victorian infrastructure. A long list of potential options was collated as the first step in the Victorian options feasibility study investigations. This long list was based on engagement with Victorian Government agencies, as well as researching previous investigations. Some of the Victorian interventions have been considered in previous studies at a feasibility or pre-feasibility level of investigation. Other interventions are new proposals with very limited prior investigation. A summary of the long-listed options is provided below.

Storage options

- **Victorian mid-Murray storage (VMMS) enhancements**: increased utilisation of the VMMS to meet downstream demands in the River Murray.
- **Construct a new purpose-built mid-Murray storage**: construction of a new, purpose-built offstream storage in the mid-Murray to store water to meet short-term peak demands in the lower Murray.
- **Floodplain storages**: utilisation of floodplain storages (such as Hattah Lakes) as an offstream storage to meet downstream demands.

[77] Alluvium (2022) *BMFS Technical Report: Victorian Options Investigation*
[78] *Ibid.*

Bypass options

- **Murray Goulburn Interconnector channel**: construction of a new, purpose-built channel from the River Murray upstream of the Barmah-Millewa Reach, outfalling to the Goulburn River near Shepparton. The water would then return to the River Murray downstream of the Reach via the lower Goulburn River. A similar concept has previously been investigated, commonly known as the Bunna Walsh Canal.
- **Murray Valley Irrigation Area (MVIA) outfalls**: increasing the use of GMW channels and outfalls to deliver bypass flows via the lower Broken Creek.
- **Barmah Forest natural waterways**: increasing the delivery of bypass flows via natural waterways in the Barmah Forest.
- **Barmah bypass pumped pipeline**: construction of a new, purpose-built pump station and pipeline, with an offtake upstream of the Barmah Forest and outlet at the River Murray near Barmah. The pipeline would be constructed around the periphery of the Barmah Forest.
- **Barmah bypass gravity channel**: construction of a new, purpose-built gravity channel, extending from Lake Mulwala and outfalling into the River Murray near Barmah.
- **Lake Buffalo to Lake Nillahcootie pipeline:** construction of a new, purpose-built pipeline to connect Lake Buffalo and Lake Nillahcootie. The pipeline would be used to transfer River Murray upper tributary flows around the Barmah-Millewa Reach via the Broken River and Goulburn River.

Goulburn system options:

- **RO14 bypass channel:** enlargement and extension of the Rochester No 14 (RO14) channel to the River Murray. This option would allow the concentrated delivery of Goulburn inter-valley transfer commitments to the Murray system to be made over summer.

Each of the long-listed options were assessed against the project objectives and a range of key criteria. Table 6 summarises the outcomes of this assessment, with three options progressing for further investigation. Detail for each of the shortlisted options is provided in the next section.

Table 6. Summary of the Victorian long-list options assessment

Assessment Category	Proposed capacity ML/day	Shortlist for further investigation	Primary rationale for shortlisting decision
VMMS	300	✓	Effective in reducing shortfall risks with low capital cost
Off-stream storage	100	✗	Very poor value-for-money. Substantial land acquisition.
Floodplain storage	-	✗	Ecologically not tolerable. High losses.
Murray-Goulburn interconnector	400	✗	Very poor value-for-money. Ecologically not tolerable in receiving waterways.
Enhanced use of the MVIA outfalls	100	✓	Effective in reducing shortfall risks. Opportunity to expand on concept.
Barmah Forest natural waterways	200	✗	Ecologically not tolerable. High losses.
Barmah bypass pipeline	500	✗	Prohibitive capital and operational costs. Very poor value-for-money.
Barmah bypass gravity channel	1,000+	✓	Effective in reducing shortfall risk and high-capacity volume.
Lake Buffalo to Lake Nillahcootie	500	✗	Ecologically not tolerable. Very poor value-for-money.
RO14 bypass channel	500	✓	Effective in reducing shortfall risks with moderate capital cost

6.4 Shortlisted options (Victoria)

Option 5A: Enhanced use of the Victorian mid-Murray storages

The Victorian Mid-Murray Storages (VMMS) consist of four storages: Lake Boga, Lake Charm, Kangaroo Lake and Ghow Swamp. The VMMS are located in north central Victoria, approximately 100 km downstream of the Barmah-Millewa Reach.

The storages can supply Victorian entitlement holders in the Torrumbarry Irrigation Area and in the lower Murray downstream of the storages. For the purposes of this study, Ghow Swamp has not been included, recognising its existing role in supplying Victorian entitlements and local irrigator demands, and ongoing efforts to improve outcomes for social, cultural, and environmental values at the site.

While the VMMS already contribute to the objectives of the BMFS, maximising the use of the storages is currently limited by several factors, including restrictions on discharge capacity, operational management practices, salinity management, social use conflicts, cultural heritage, constraints during re-filling, and irrigation channel demands. Enhancing the use of the VMMS would involve works and operational changes needed to use the storages more actively for managing demands and shortfall risks in the lower Murray.

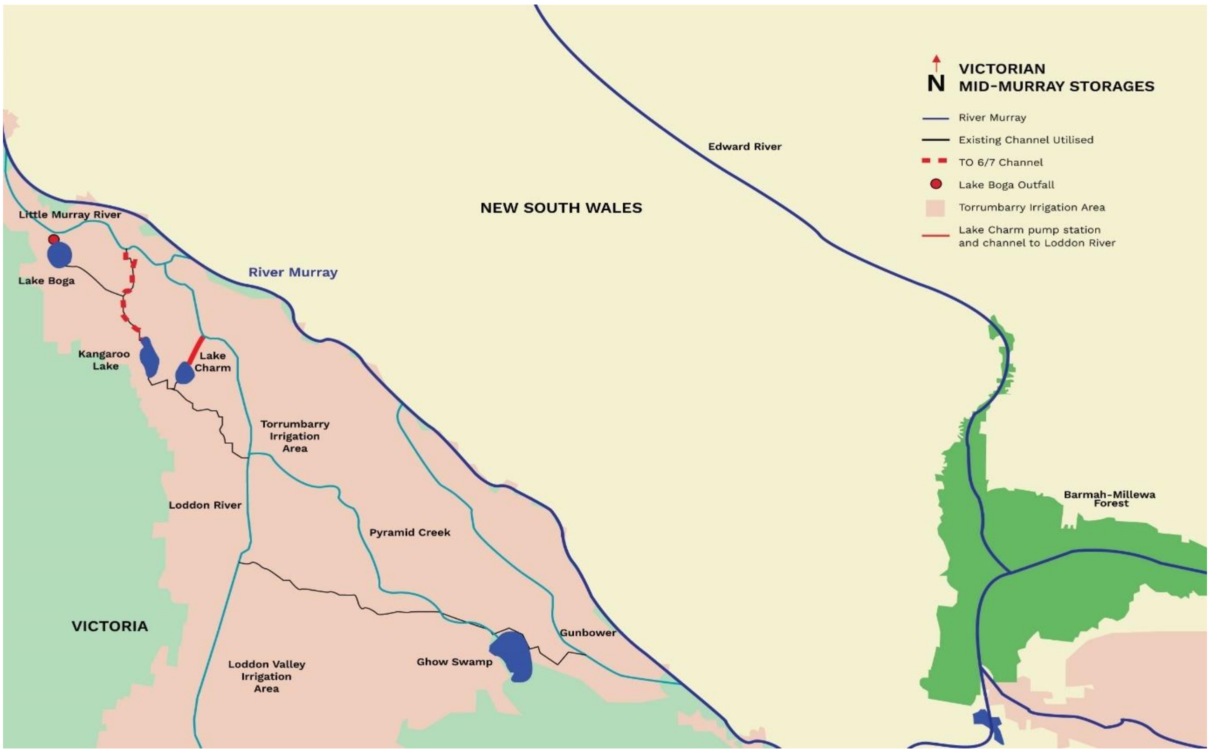

Figure 28. *Victorian mid-Murray storages under consideration – Lake Charm, Kangaroo Lake, and Lake Boga*

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Enhancing the use of the storages requires relatively minor capital works and operational changes to be implemented. This could be achieved within 1 – 2 years of funding being allocated.
- The combined discharge capacity of the storages could be increased to around 1,000 ML/day, which could be sustained over a 10-day period, delivering around 10 GL over a short time.
- An enhanced, more flexible storage option relatively close to major horticultural developments in the Sunraysia region would provide greater flexibility to quickly respond to changes in demand. This recognises that the travel time from the VMMS to Mildura Weir is around 7 days.
- This is likely to be of increased benefit under climate change, where increasingly frequent extreme weather conditions are forecast to occur.
- The capital cost to enhance the discharge capacity is around $6 million. Funding would need to be provided to GMW for the increase in operations and maintenance costs.

Option 5B: Enhanced use of the Murray Valley Irrigation Area outfalls

The channel system of the Murray Valley Irrigation Area (MVIA) diverts water from the River Murray at Lake Mulwala via the Yarrawonga Main Channel (YMC) to supply irrigators within the district. A number of the channels in the MVIA connect to the lower Broken Creek via outfall structures. The lower Broken Creek flows into the River Murray just below the Barmah-Millewa Reach. As a result, the MVIA channels can be used to bypass the Barmah-Millewa Reach (refer **Figure 29**).

There are seven existing outfalls which can be used to deliver bypass flows. These outfalls have a combined capacity of 180 ML/day. The outfalls have been fully utilised over summer in recent years, meaning that any enhanced use of the outfalls would require upgrade works.

Of the seven existing outfalls, four discharge directly into the highly regulated reaches of the lower Broken Creek (reaches 3 and 4), where operational flow capacity is highest over summer. Engineering investigations confirmed that the capacity of the outfalls could be upgraded by around 110 ML/day, providing a total capacity of 290 ML/day.

Ecological investigations have confirmed that any increase in summer flows in the lower Broken Creek would be detrimental to the health of the river, including the potential to exacerbate issues with erosion. Accordingly, increasing bypass flows via the lower Broken Creek would only be feasible if there was an equivalent reduction in other flow deliveries in the creek.

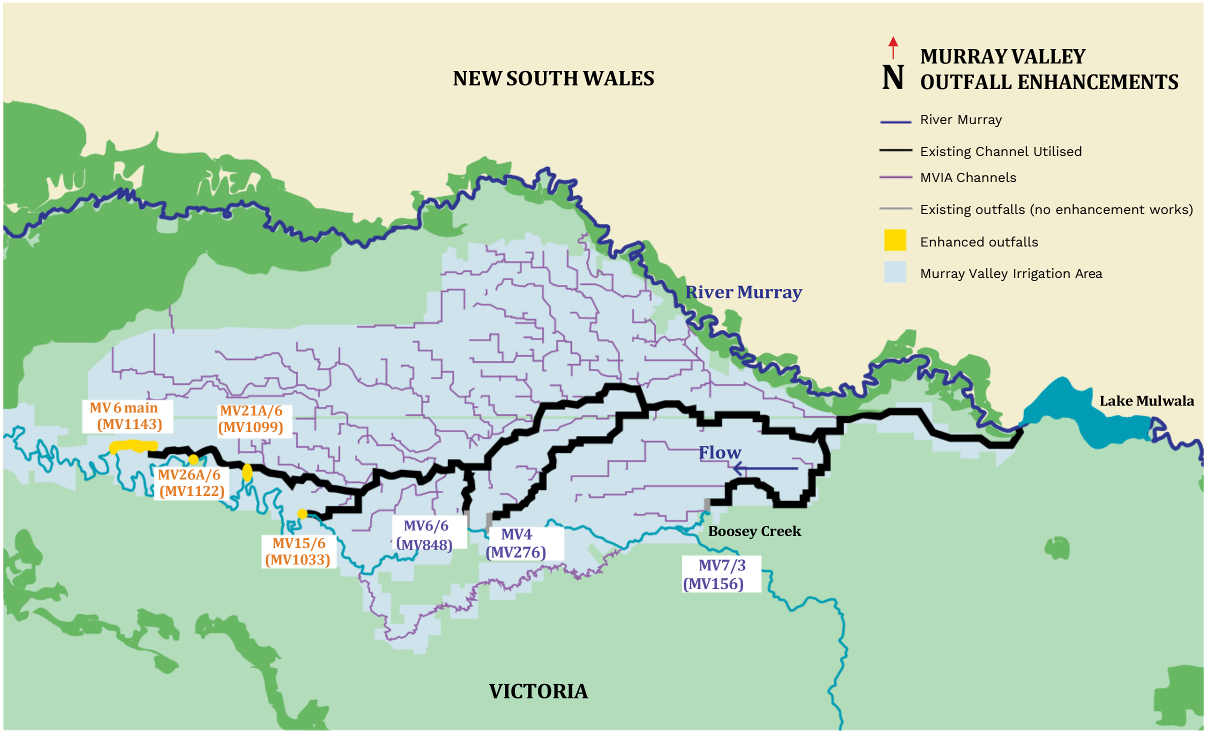

Figure 29. *Murray Valley Irrigation Area outfalls*

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Increasing summer flows into the lower Broken Creek would not be ecologically tolerable. Any increase in the bypass flows would require an equivalent reduction in other demands currently delivered by the creek. In practice, this would require some of the Goulburn to Murray IVT commitments to be delivered elsewhere, such as via the RO14 bypass option under consideration.
- While upgrading the channel infrastructure to deliver an additional 110 ML/day of bypass flows requires a relatively low capital investment (around $2 million) and can be delivered in a short timeframe (1 – 2 years), the need for an equivalent reduction in IVT flows in the lower Broken Creek will require more substantive investment and timeframe to deliver.

Option 5C: Barmah bypass gravity channel

This option proposes the construction of a channel extending from Lake Mulwala to the River Murray near the township of Barmah. The channel would be used to gravitate water around the Barmah-Millewa Reach.

There are several existing channels in this area which are used by GMW to supply customers in the Murray Valley Irrigation Area (MVIA). Constructing a large channel along the alignment of an existing channel would likely be more practical than a new alignment. For the purposes of feasibility investigation, an indicative alignment was selected to follow the Murray Valley (MV) 5 channel, which is supplied from Lake Mulwala via the Yarrawonga Main Channel (YMC) and MV 2 channel (**Figure 30**).

Initial investigations and consultation with Goulburn-Murray Water (GMW) indicated that, based on demand in recent years and long-term trends in the GMID, there is significant under-utilisation and therefore available capacity in the YMC and MV 2 channels. These are large channels with significant infrastructure. Accordingly, for the purpose of this feasibility study, the flow rate for this bypass option was determined by utilising this available spare capacity, which is around 1,000 ML/day.

Preliminary engineering investigations determined this option would require replacement of around 70km of channel with a significantly increased capacity, as well as the construction of approximately 20km of new large channel. This would require almost every asset on the existing channel to be replaced or relocated, including approximately 155 irrigation outlets, 94 domestic and stock services, 72 regulators and 111 bridges and other structures.

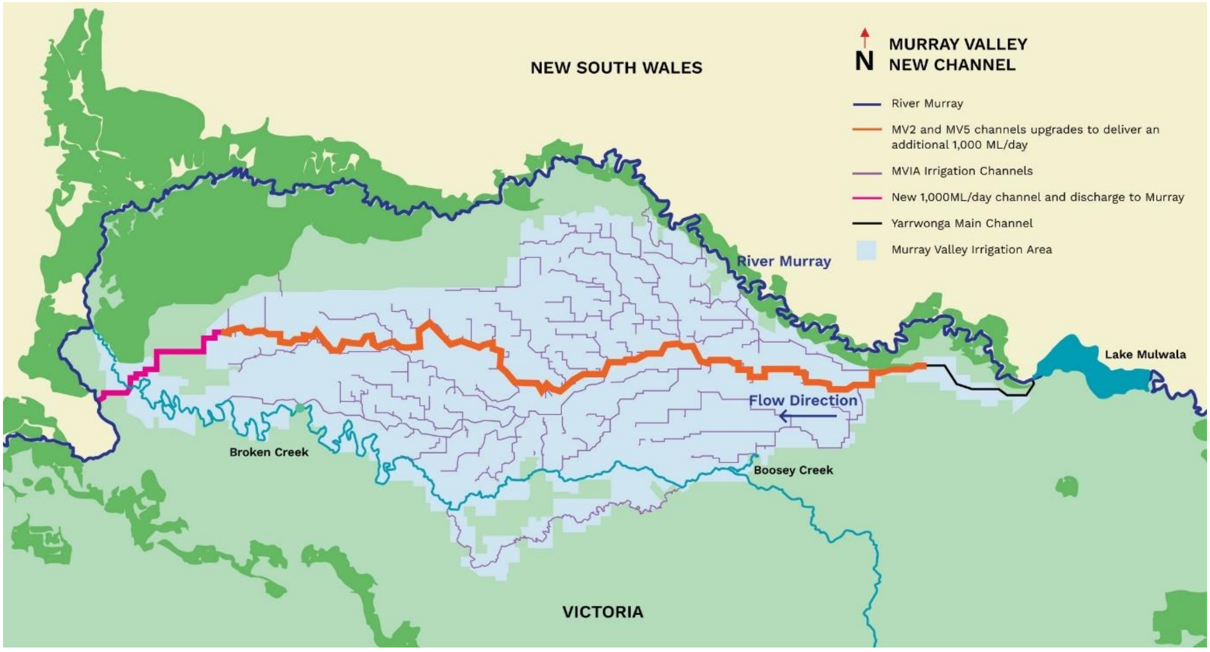

Figure 30. *An indicative alignment for a channel to be constructed from Lake Mulwala to the River Murray*

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- This option would require substantial construction works, with a capital investment of around $630 million and a timeline to deliver of around 5 – 8 years. Significant funding would also need to be provided to GMW for the increase in operations and maintenance costs. GMW may also charge a delivery charge for using their channel system.
- The option could deliver bypass flows without the use of any natural waterways. As such, the option would be reliably available and could sustainably deliver flows throughout the entire season.
- The option would significantly improve the flexibility for river operators to manage deliveries on the River Murray through the Barmah-Millewa Reach and in other natural waterways, allowing for more variable flows to be provided and to better align with environmental objectives.

Option 5D: RO 14 bypass channel

This option considers creating an alternate pathway for delivering Goulburn commitments to the River Murray in the form of a bypass channel. This bypass could be used during times when pressure on the Barmah-Millewa Reach is greatest and there is the highest risk of delivery shortfalls in the lower Murray (i.e., over summer).

Each year, there is water held in the Goulburn system that is 'owed' to the Murray system. These volumes vary year-to-year depending on allocation and uptake of trade opportunities, from at least 100 GL in most years to more than 300 GL in some years. This water is delivered from the Goulburn system to the Murray primarily via natural waterways. These waterways have ecological tolerances which limit the rates of delivery, particularly over summer, as flows in the waterways would have naturally been at their lowest.

There is an opportunity to create an alternate delivery pathway from the Goulburn system with the construction of a large channel between the WWC and the River Murray, such as along the alignment of the RO 14 channel. Preliminary engineering investigations determined this option would require the replacement of around 28km of channel with an increased capacity channel and the replacement of a 12km pipeline with a channel. This would also require almost every asset on the existing channel and pipeline to be replaced or relocated, including approximately 114 irrigation outlets, 129 domestic and stock services, 42 regulators, and 43 bridges and other structures.

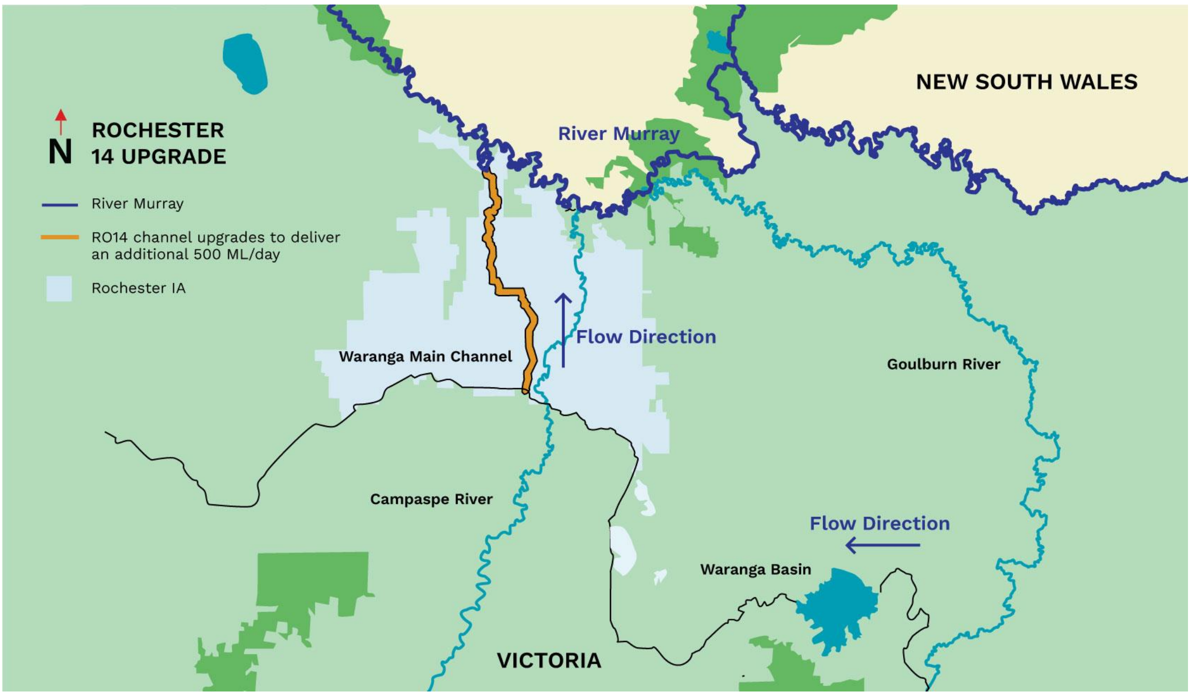

Figure 31. *The location of the Rochester 14 channel and indicative extension to the River Murray*

Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- This option would require substantial construction works, with a capital investment of around $165 million and a timeline to deliver of around 5 years. Significant funding would also need to be provided to GMW for the increase in operations and maintenance costs. GMW may also charge a delivery charge for using their channel system.
- The option could deliver bypass flows without the use of any natural waterways. As such, the option would be reliably available and could sustainably deliver flows throughout the entire season.
- This option would provide an opportunity for significant environmental outcomes by providing system operators an alternate (and ecologically sustainable) route for delivering Goulburn IVT commitments to the River Murray. Currently, these IVT volumes are delivered via the lower Goulburn River, lower Broken Creek, and Campaspe River. The construction of this option would allow operators to have greater flexibility and variability in the volumes and timing supplied through these natural waterways.

6.5 Policy considerations

The MDBA's Capacity Policy Working Group has advised the following:

Option 5A: Mid-Murray Storages

- The Victorian Mid-Murray storages are currently assumed to provide 30GL of regulated water to support Victorian Murray Entitlements. As such the option should have minimal water resource policy implications at the River Murray system level as it is about altering the timing of supply rather than the volume.
- Implementation of the 'at call' volume will require practical arrangements between the MDBA river operators and the GMW operators. These will require agreement and may uncover small scale policy issues.
- The option will require the development of a practical operating regime where the trade-off between operational flexibility and ecological objectives in the Little Murray will need to be resolved.

The CPWG has advised that use of the Victorian Mid-Murray storages has a **low risk from water policy implications**.

Option 5B: Murray Valley Irrigation Area outfalls and **Option 5D: RO14 bypass channel**

- The Rochester channel option is predicated on the volume of IVT to be delivered from the Goulburn system remaining fixed, with the channel providing flexibility about the timing of supply.
- Victoria has very recently worked through the policy and practical issues of limiting the volume of IVT supplied from the Goulburn system. This has been a major task and altering it to provide the additional flexibility in timing of supply may be seen as 'moving the goal posts'.
- The current rules for IVT supply from the Goulburn effectively define a maximum volume in a water year, not a fixed volume, with the supply broadly matching the expected demand (at a monthly time step). The possible use of the Rochester channel to transfer some of the IVT water to the Murray at a different time will require significant policy consideration prior to investment.

The CPWG has advised that use of the Rochester (RO14) channel (incorporating the MVIA outfalls to the Broken Creek) **will require resolution of the policy implications of the changed timing of supply of the Victorian IVT.**

Option 5C: Barmah bypass gravity channel

The extension of the Yarrawonga Main Channel (YMC) to deliver water to the River Murray is effectively the same (from a water resource perspective) as using the irrigation network and Broken Creek to transfer water around the Barmah-Millewa reach. As such **minimal water resource policy implications are anticipated**.

6.6 Further work planned

The Victorian feasibility study investigations confirmed that there are potentially viable options available for supporting the Barmah-Millewa project objectives.

There is a real opportunity to enhance the use of the Victorian Mid-Murray Storages. The location and discharge capacity of the storages means that operators could rapidly respond to a potential delivery shortfall event in the Sunraysia district, allowing them to manage releases more efficiently from Hume Dam. This is of particular importance in years when Menindee Lakes is unavailable as a shared resource.

There are opportunities for providing major system capacity and environmental flow improvements through construction of major channel infrastructure. These options would require very significant investment and consideration of local social impact for surrounding landholders and irrigators.

Further work to develop this option may involve:

- Further development of Option 5A, involving the enhanced use of the VMMS. This would involve detailed engineering and site investigations to confirm why the current discharge capacity is being limited from the storages and design the works to be undertaken.

- If the bypass channel options were to be progressed, an options investigation should be completed to analyse potential flows, alignments, and work requirements. This would support the development of a business case for investment consideration.
- Negotiation with GMW on the terms and conditions for increased access to their channel network, including contributions for increased operations and maintenance costs associated with any upgrades, any delivery charge for use of their infrastructure, and the form of agreement.

6.7 Reference reports

The following is a list of the key reference reports supporting this option:

- Alluvium (2022), *Technical Report: Victorian Options Investigation*

7 Option 6 – Snowy Scheme inter-valley transfers

This option proposes the use of the Snowy Hydro system to transfer some releases that would normally be delivered to the River Murray upstream of Hume Dam instead via the Murrumbidgee River for delivery to the River Murray near Euston. Using this option would reduce the need to supply regulated water through the capacity restricted Barmah-Millewa Reach.

Murrumbidgee releases from the Snowy Hydro system can either be made via the Tumut River or the Upper Murrumbidgee River, as shown in **Figure 32**.

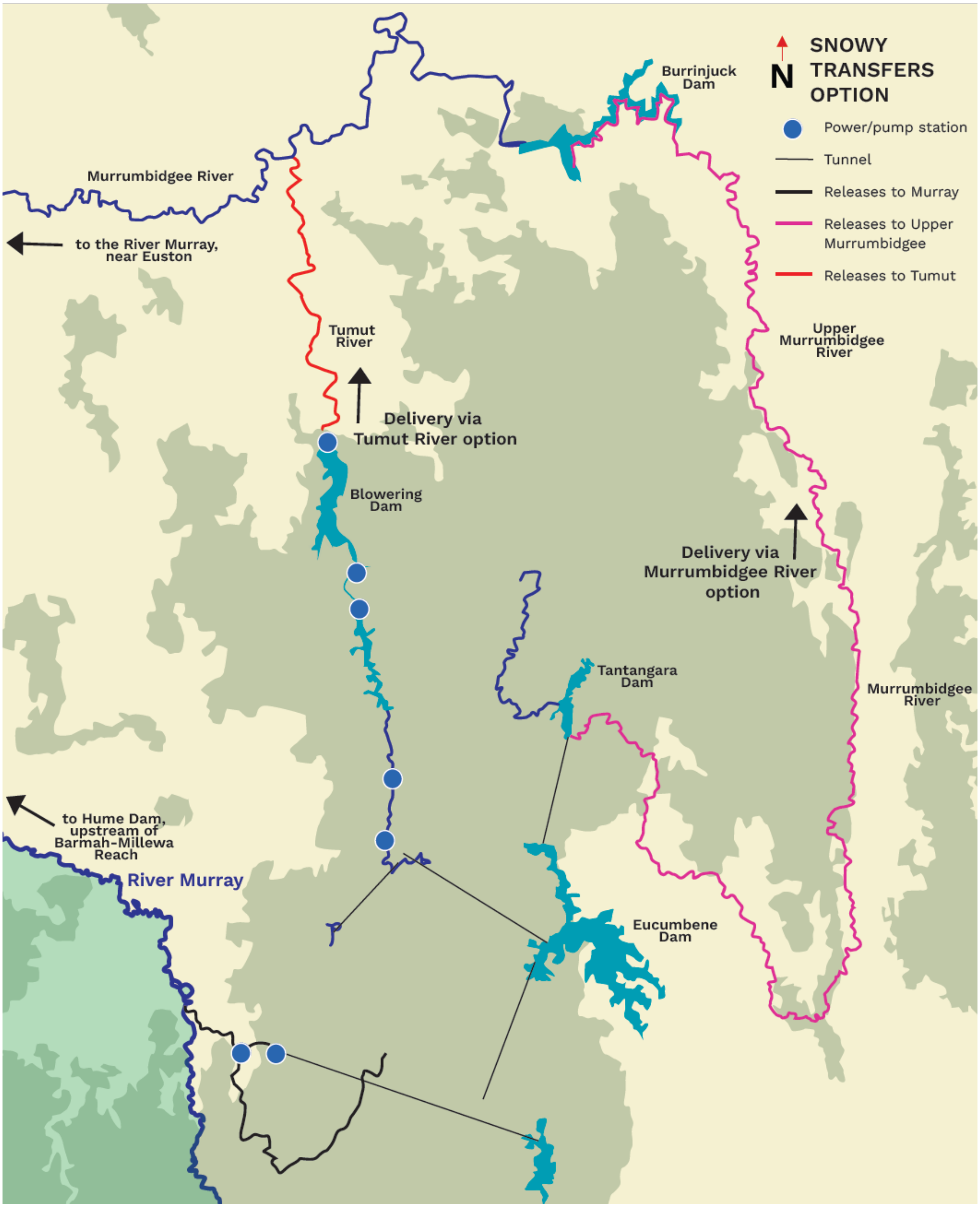

Figure 32. *Key features and flow paths of the Snowy Scheme*

7.1 Background

The MDBA contracted Paul Simpson Consulting (PSC) to undertake a desktop assessment of the scope and feasibility of this option. PSC's feasibility study identified the key decision options and changes to existing management arrangements that would be required to implement inter-valley transfers through the Snowy Scheme and assessed the impacts of the proposed changes[79].

7.2 Description of the option

Snowy Scheme

The Snowy Scheme is a hydroelectric generation scheme located in the upper catchments of the Murray, Murrumbidgee, and Snowy Rivers. The scheme harvests water from the upper catchments into dams and generates electricity by releasing water through power turbines into the Murray and Murrumbidgee Rivers or tributaries of these rivers. The scheme is divided into two power generation systems:

- **Snowy-Murray Development**, which generates power from flows released into the Murray catchment.
- **Snowy-Tumut Development**, which generates power from flows released into the Murrumbidgee catchment.

It is possible to release water from the Snowy Scheme directly from Tantangara Dam into the upper Murrumbidgee River, where water could be re-regulated in Burrinjuck Dam. However, Tantangara Dam has no power generation capability, and therefore making releases from the storage directly into the Murrumbidgee River would reduce power generation from the scheme.

Snowy Water Licence

The Snowy Scheme is operated by Snowy Hydro Limited (SHL). Snowy Hydro is a Commonwealth government business enterprise under the Corporations Act and operates on a strictly commercial basis[80].

The Corporation is subject to NSW state legislation including the Snowy Hydro Corporatisation Act and the Snowy Water Licence. The Snowy Water Licence sets out the rights and obligations on Snowy Hydro Limited for the collection, storage, and release of water within the Snowy Scheme's area of operation.

Required Annual Releases

Flow releases to the catchments from the Snowy Scheme are governed by the Snowy Water Licence issued to SHL by the NSW Government.

The licence obliges SHL to supply annual water release targets, known as Required Annual Releases (RAR), for each of the Murray and Murrumbidgee catchments. RARs are nominally set at 1,062 GL per year in the River Murray and 1,026 GL in the Murrumbidgee.

Inter-valley connections within the Snowy Scheme

Lake Eucumbene and Tantangara Reservoir store water for both the Snowy-Murray and Snowy-Tumut Developments and are connected through tunnels, as illustrated in **Figure 32**

This connection allows Snowy Scheme RARs to be varied by increasing the annual RAR to one catchment (or valley) and undertaking a corresponding reduction in the RAR to the other valley, thus facilitating inter-valley transfers between the Murray and Murrumbidgee. These inter-valley transfers are possible in either direction.

Inter-valley transfers

A mechanism exists in the Snowy Water Licence to undertake inter-valley transfers between the Murray and Murrumbidgee systems. Clause 9 of Schedule 4 to the Snowy Water Licence sets out a process for inter-valley water transfers including:

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[79] Paul Simpson Consulting (2022), *Barmah-Millewa Feasibility Study: Using the Snowy scheme and Murrumbidgee River System to augment Murray River flows*
[80] https://www.snowyhydro.com.au/about/our-company

- **Cl 9.2** – the NSW Minister may request the Water Consultation and Liaison Committee[81] to consider a transfer.
- **Cl 9.3** – the Water Consultation and Liaison Committee must be given reasonable opportunity to consider a proposal.
- **Cl 9.4** – Snowy Hydro Limited must operate the scheme to effect the transfer, unless it cannot be done for operational or practical reasons.

The Snowy Water Licence requires that variations to the water release requirements can only be made without the agreement of Snowy Hydro Limited following determinations by separate independent experts on the "water management and resource impacts", and the financial impact upon Snowy Hydro Limited, and payment of any compensation to Snowy Hydro Limited for the financial impact.

This mechanism is infrequently used, and it was not envisaged that there would be standing arrangements in one direction (Murray to Murrumbidgee for this feasibility investigation) applying each year.

Snowy Scheme Annual Water Operating Plan

Snowy Hydro prepares an annual water operating plan for the scheme before the commencement of each year which provides certainty for SHL in terms of its obligations to release water. The operating plan sets out:

- the target RAR for the coming water year and the range of forecast water releases on a quarterly basis. SHL operates to ensure the RAR is met by 30 April each year.
- the volumes of inter-valley transfers. This means the volume of inter-valley transfer for the upcoming water year in the River Murray (June -May) would be expected to be set in February and remain unchanged during the course of the year.

Aside from the quarterly forecasts of water releases, SHL does not have specific requirements regarding the pattern or timing of RAR releases during the water year. The corporation operates the to maximise electricity generation opportunities while meeting its water release obligations.

Murray-Darling Basin Agreement

The Murray-Darling Basin Agreement (the Agreement) between the basin states and the Commonwealth government includes:

- provisions for accounting of inflows from tributary rivers (including the Murrumbidgee River) to the River Murray, and
- a schedule (Schedule F) that sets out agreed arrangements for sharing water from the Snowy Scheme.

The Agreement requires flows from the Murrumbidgee River into the River Murray to be accounted as a NSW resource. An inter-valley transfer from the Murray to Murrumbidgee with delivery back into the Murray would need to be accounted as a shared resource, similarly to inflows into the River Murray from the Snowy Scheme.

Regulated Murrumbidgee Water Sharing Plan

Murray releases transferred to the Murrumbidgee would come under the jurisdiction of the NSW Water Management Act, Regulated Murrumbidgee Water Sharing Plan. The water sharing plan for the Murrumbidgee regulated river water source (the regulated WSP) includes Burrinjuck and Blowering Dams, and the Murrumbidgee and Tumut Rivers below the dams, and sets requirements for the management of the water captured and released by the dams.

There is currently no provision in the regulated WSP to recognise additional water released from the Snowy-Tumut development as a result of a transfer from the Murray development, and current arrangements would result in Murray inter-valley transfers being allocated to water access licences as set out in the regulated WSP.

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[81] Constituted under the Snowy Water Inquiry Outcomes Implementation Deed, this is the primary forum for operational consultation between Snowy Hydro Limited and NSW, Victoria, and the MDBA.

7.3 Option description

PSC identified the decision options and key management arrangements that would need to be considered to implement inter-valley transfers through the Snowy Scheme to bypass the Barmah-Millewa Reach.

Murrumbidgee transfer pathway

There are two physical flow routes that could be used to supply the Murray inter-valley transfer into the regulated Murrumbidgee River system.

- **Snowy-Tumut hydro power development into Blowering Dam:** This is the standard route used by SHL to generate power through water supplied into the Murrumbidgee system. The Snowy-Tumut development releases water directly into Blowering Dam on the Tumut River, which is the largest of the two main storages supplying the Murrumbidgee regulated river system.

  The major constraint in using this route is channel capacity constraints on the Tumut River downstream of Blowering Dam where there is an upper limit on the volume of water that can be delivered during any given period.

- **Direct releases from Tantangara Dam into the upper Murrumbidgee River**: to be re-regulated in Burrinjuck Dam. Releases via this route are not currently contemplated under the Snowy Water Licence and arrangements would need to be made via a separate legal deed and inter-governmental agreement.

  A key issue for this route is that Tantangara Dam has no power generation capability and therefore making releases from the storage directly into the Murrumbidgee River would reduce power generation from the scheme. A positive aspect of this option is that any additional releases will benefit environmental outcomes due to the current diminished flows in the upper Murrumbidgee.

Tumut River impacts

The Snowy-Tumut development releases water into Blowering Dam which is the largest of the two main storages supplying the Murrumbidgee regulated river system. Blowering Dam releases flows into the Tumut River, a tributary of the Murrumbidgee River (see **Figure 32** for reference).

A factor to be considered in using the Tumut route to deliver Murray to Murrumbidgee inter-valley transfers is deliverability constraints in the Tumut River downstream of Blowering Dam. When most of the available water in the Murrumbidgee regulated river system is held in Blowering Dam (including assured releases from the Snowy Scheme), there can be difficulties delivering a high enough proportion of the available water through the Tumut River before the end of the summer irrigation season. This deliverability issue has, at times, required restrictions on the proportion of the water available that can be delivered by the end of the summer irrigation season.

Existing regulated flow releases from Blowering to the Tumut River also impact on the environmental values of the river and there has been landholder and community concern over the impacts of river regulation on public amenity, flooding, and recreation. Long periods of operating at channel capacity have caused erosion and water logging of nearby land, affected flow paths over time, and the rock-lining and other management measures have decreased the aesthetic value of the Tumut River.

Additional flows from Snowy Hydro inter-valley transfers delivered during the summer irrigation period would likely exacerbate capacity issues and Tumut River unless the delivery of transferred water was delayed or limited to avoid impacts to water delivery in the Murrumbidgee Valley. Whilst transfers may not increase flow-related impacts to the Tumut River back to past levels, it is likely to raise concerns from the local community.

Lower Murrumbidgee River impacts

As with other regulated rivers in the MurrayDarling Basin, flow regulation has altered the natural flow regime in the Murrumbidgee River, increasing summer and autumn flows and decreasing average flows in winter and spring. The lower Murrumbidgee River floodplain, below Maude Weir to the confluence of the River Murray, is a key environmental asset within the Murray–Darling Basin

Murray to Murrumbidgee inter-valley transfers will increase flows in the regulated Murrumbidgee River system, leading to higher-than-normal flows in the lower reaches. Environmentally damaging unseasonal summer flows in the lower reaches would potentially occur more often, and in conjunction with inter-valley transfers for water trade.

The potential impact of a long-term increase in summer flows in the lower Murrumbidgee River would need to be considered further. At present, it is not clear whether an increase in flows in the lower Murrumbidgee River of 500 ML/day (as proposed above) would result in increased environmental impacts, and whether these would be within tolerable limits.

Annual inter-valley transfer volume

The volume of inter-valley Murray to Murrumbidgee transfer required would vary from year to year, based on several inter-linked factors that include water availability, climatic conditions, tributary inflows downstream of the Barmah-Millewa Reach, and specific operational requirements such as transfers to Tar-Ru (Lake Victoria).

Initial investigations suggest that an annual inter-valley transfer of 50 GL/yr (nominally 500 ML/day delivered over 100 days) would provide River Murray system river operators with a useful buffer to manage potential system shortfalls.

The following factors will likely influence the assessment of the overall feasibility and relative benefits and costs of different levels of inter-valley transfer:

- Increased risks of Tumut River flooding, community, and environmental impacts.
- Increased risks of lower Murrumbidgee River environmental impacts.
- Snowy Hydro costs from foregone or changed electricity generation.

Snowy Hydro cost impacts

The Snowy Water Licence requires that variations to the water release requirements can only be made without the agreement of Snowy Hydro Limited following determinations by separate independent experts on the "water management and resource impacts", and the financial impact upon Snowy Hydro Limited, and payment of any compensation to Snowy Hydro Limited for the financial impact.

The primary financial impact of inter-valley transfers on Snowy Hydro arise from the location, timing and volume of releases, and the resultant opportunities that Snowy Hydro gains or losses in terms of revenue from electricity generation. The scale of potential costs from inter-valley transfers is difficult to assess, noting the variables above. The involvement of Snowy Hydro Limited would be required to quantify the costs under a range of potential supply and volume scenarios.

From publicly available data it is known that:

- the Snowy Scheme generates a similar amount of energy per gigalitre via either the Snowy-Murray or Snowy-Tumut developments;
- hydroelectric plants like the Snowy Scheme typically operate as flexible or peaking plants, which tend to increase their output when market prices are high and reduce output when prices are low. Snowy Hydro has considerable discretion around the pattern and timing of RAR releases during the water year and if this flexibility was reduced by inter-valley transfer obligations, it could impact the opportunity cost of the transfer;
- the Snowy-Murray development generates energy into the Victorian sector of the National Electricity Market (NEM), and the Snowy-Tumut development generates energy into the NSW sector of the NEM. Price differentials in the markets could impact on the opportunity costs of inter-valley transfers; and
- if Murray to Murrumbidgee inter-valley water were to be released from Tantangara Dam to the Upper Murrumbidgee River, Snowy Hydro would completely forgo power generation for the water released, impacting the cost of the transfer.

From first principles, it would be reasonable to presume that higher volumes of inter-valley transfer and higher degrees of flexibility required around the timing of releases would impact the revenue of SHL.

Arrangements to alter the long-term balance of releases from the Snowy-Murray to the Snowy-Tumut development may potentially also result in some internal transition costs relating to forward contracts, and other operational and maintenance arrangements over time.

Fixed or variable (at call) volume of inter-valley transfer within a year

To provide certainty for SHL operations, RAR volumes for each valley for the forthcoming water year including inter-valley transfers are generally fixed at the beginning of the water year at the time of the preparation of the Annual Operating Plan. Providing certainty around the release volumes enables SHL to optimise its water release and energy generation planning for the coming year.

In contrast, the MDBA is unlikely to know the volume of Murray transfer it would require for bypass operations at the commencement of the water year. The volume of water required could increase and decrease through the year in response to the factors include water availability, climatic conditions, and tributary inflows downstream of the Barmah-Millewa Reach. Accordingly, for bypass purposes, it would be preferable if the volume of inter-valley transfer could be varied at call to match River Murray system requirements

If the impacts to SHL arising from varying the Murray transfers within a water year are prohibitive, it may be possible to proceed with a fixed Murray transfer and hold that water in Blowering or Burrinjuck Dam until the following water year when it can be called on if needed. However, this approach would, create an issue for the management of bypass flows if either:

- dry conditions occur: holding the previous years transfers of water in storages for release in the following year does not provide the flexibility to increase transfers in response to dry conditions.
- wet conditions occur: wet conditions occurring following an agreement on the volume of inter-valley water to be transferred could result in Blowering or Burrinjuck dam spilling or pre-releasing water before the inter-valley transfer can be delivered to the Murray in the following water year. The spilled water would then not be available to be called out to meet bypass requirements in that year.

Notice and flexibility

It is unlikely that the volume of Murray to Murrumbidgee inter-valley transfer required could be accurately estimated prior to the commencement of any water year. The volume of water required would increase and decrease through the year in response to the factors such as demand, tributary inflows, seasonal climate, etc.

The Snowy Water Licence requires that an annual water operating plan is prepared before the commencement of each year (the water year for the Snowy Scheme is May to April). To provide certainty for Snowy Hydro Limited, release requirements for each year are generally set at this time. Setting a volume of Murray to Murrumbidgee transfer at the beginning of each water year would require the MDBA to forecast the coming year's water availability. Forecasts early before the start of a water year would have significant uncertainty.

It may be possible to agree with Snowy Hydro to set an approximate volume of transfer or even to have water transferred on-demand during water year. Either of these arrangements would be more disruptive to Snowy Hydro Limited's electricity generation planning and commercial arrangements, and therefore likely to generate greater opportunity costs.

One possible arrangement that may prove practical is for the inter-valley transfer volume to be sourced from Murrumbidgee reserves and then paid back in the following year from inter-valley transfers. This arrangement would provide certainty to Snowy Hydro at beginning of the year around the volume of water to be transferred. This approach would need to be explored in more detail with WaterNSW to understand its feasibility and potential impacts on Murrumbidgee water users.

Murrumbidgee River Weirs Opportunity

The Snowy Scheme option has potential to be operated to address delivery risks in the River Murray via temporary drawdown of weirs in the lower Murrumbidgee River. The Redbank, Maude, Hay and Tombullen Weir are located on the lower Murrumbidgee River within relatively close proximity to the River Murray. The weirs are operated to re-regulate surplus flows, to deliver ordered water, and maintain flow targets at Balranald.

It may be possible to temporarily draw down these weir pools in the summer irrigation season to meet short term delivery risks in the River Murray, working in concert with Victorian mid-Murray Storage options. It is understood that the drawdown of these weir pools could provide in the order of 4 - 8GL over a 10-day period (to be confirmed in subsequent stages of investigation).

The Snowy Scheme option has some potential to augment the current procedures for short-term shortfall mitigation via Murrumbidgee IVT call-out.

MDBA operators regularly plan to reserve a proportion (typically 20GL) of the Murrumbidgee IVT account for the Murray shortfall season, rather than calling for the whole IVT balance as soon as the operations would allow earlier in the year. This provides a potential source of water, from any available water in the lower-Murrumbidgee re-regulating structures to respond to a Murray short-term shortfall in a timely manner.

The Snowy Scheme option augmentation would be to continue with this short-term shortfall operation of the lower-Murrumbidgee even when there is no available IVT, and then re-balance valley accounts via a Snowy transfer.

The opportunity and its implications and mitigation measures warrant further investigation in subsequent stages to this feasibility assessment.

7.4 Option limitations

A summary the principal impacts and limitations of the Snowy Scheme inter-valley transfer bypass option is provided below:

- Snowy Hydro impacts:
    - agreement required with SHL to enable inter-valley transfers to occur with SHL having no legal obligation to enter into an agreement and with expectation that SHL will be compensated for any costs.
    - potential costs/benefits to SHL arising from changes to the volume of flows to each of the scheme developments/valleys as a result of inter-valley transfers.
    - Inter/intra-year uncertainty costs to SHL if the Murray inter-valley transfer volume is flexible at call throughout the year (or alternatively reduced bypass benefits to the regulated Murray system and potential inter-valley transfer spill risks if the transfer volume is fixed in advance).
    - substantial foregone power generation revenues if the Tantangara/Upper Murrumbidgee route is utilised for inter-valley transfers.
    - potential transition costs for SHL.
- Tumut River impacts:
    - limited capacity in the Tumut River downstream of Blowering Dam to accommodate increased flows from inter-valley transfers.
    - impacts to environmental and amenity values in the Tumut River of increased flows from inter-valley transfers.
    - potential impact to cultural values
- Murrumbidgee River impacts:
    - arrangements required to offset within the Murrumbidgee system the increased transmission losses incurred from conveying Murray inter-valley transfers in the Murrumbidgee River.
    - more complex river operations to manage inter-valley transfers.
    - environmental risk from increasing unseasonal flows in the lower Murrumbidgee River.

- if the Tantangara/Upper Murrumbidgee route is used, then arrangements need to be put in place to protect inter-valley transfer flows from being taken by licensed diverters and Icon Water.

7.5 Development and implementation considerations

The key considerations for the next stages of developing and potentially delivering this option include:

- Confirming the practicality and encumbrances to be better defined and considered, including the quantify the likely inter-valley transfer volumes, flexibility in call out, and institutional and administrative arrangements that would be required.
- Confirming the viability and practicality of drawing down the Murrumbidgee weir pools to mitigate delivery shortfall risks on the lower Murray, in combination with the inter-valley transfers considered by this option.
- Consultation between the MDBA, joint governments, and Snowy Hydro around the practicality of implementing the option, including cost and statutory requirements.
- Consultation with Traditional Owners and other stakeholders around the cultural, environmental, social, and economic impacts associated with the proposed inter-valley transfers.

7.6 Policy considerations

The MDBA's Capacity Policy Working Group has advised the following:

- The Murrumbidgee – Snowy option is effectively a policy option as it does not propose the construction of any new works. As such all of the issues identified in the option require some level of policy development / resolution (i.e. need for new administrative arrangements and collaborative operational planning activities, uncertainty around operational costs and compensation).
- This option offers large volumes but long travel times to areas of demand in the Murray, which means it is focussed on system shortfall situations.
- However, the smaller scale option of being able to call modest (<10 GL) of water from the Maude and Redbank weir pools to mitigate a delivery shortfall risk in a timely manner has potential to be useful. Policy issues associated with this sub-option may be able to be more easily resolved as the volumes are of a scale for which there is prior experience in using the Snowy Scheme to balance end of year inter-valley trade accounts.
- Implementation of the 'at call' volume will require practical arrangements between the MDBA river operators and the Water NSW operators. These will require agreement and may uncover small scale policy issues.

The CPWG has advised that **use of the Snowy scheme for large volumes of water will be difficult**. There does appear to be merit in investigating use of the Snowy Scheme to repay a relatively small volume of water (called infrequently from the Murrumbidgee weirs) to offset a delivery shortfall.

There are business risks associated with making long-term arrangements with commercially focussed enterprises (e.g. MIL and Snowy Hydro). Contract arrangements will need to be negotiated in a transparent manner to all partner governments, clearly documented, and enforceable.

7.7 Further work planned

PSC has identified the following activities are required to provide further scope definition and understanding of impacts and benefits of this option.

Hydrologic modelling

Hydrologic modelling is required to better understand the benefits in the Murray regulated river system that could be achieved through inter-valley transfers. This modelling could leverage the recently completed integration of Source Murray Model, the newly developed Murrumbidgee Source Model, and SHL's Snowy Scheme Model. This integrated modelling to better understand timing and volumes of:

- Murray transfers to better meet demands and reduce impacts on the Murray and Edward-Kolety – Wakool rivers.
- additional releases from the Snowy-Tumut development, and Blowering Dam to better assess impacts to Tumut River.
- inter-valley delivery back to the River Murray to confirm supply benefits in the Murray regulated river system.

Assessment of costs to SHL

While the general presence or absence of cost impacts to SHL of the proposed inter-valley transfers is relatively clear, the quantification of these impacts requires further work that considers the potential costs in relation to the operation of the National Electricity Market. This would require consultation with SHL, and potentially a third-party review to quantify financial impacts on the operation of the Snowy Scheme and generation revenue.

Environmental impact assessment

An assessment is required of the potential environmental impacts in the lower Murrumbidgee River from increased volumes of inter-valley transfer water delivery to the River Murray. Some quantification of changes to flow regimes via the hydrologic modelling work above would also be an important input to this work.

The investigation of potential impacts that could arise from inter-valley delivery of Murray transfers may also need to consider current and future inter-valley delivery of water to support water trade across the southern connected Murray-Darling Basin.

Maude and Redbank weir opportunity

In addition to the above, the opportunity to temporarily drawdown the Maude and Redbank Weirs warrants further investigations. These investigations should also explore any links to the Balranald Weir SDLAM project.

7.8 Reference reports

The following is a list of the key reference reports supporting this option:

- Paul Simpson Consulting (2022), *Barmah-Millewa Feasibility Study: Using the Snowy scheme and Murrumbidgee River System to augment Murray River flows*