



Australian Government

Commonwealth Environmental Water Office

Commonwealth Environmental Water Office

# Water Management Plan

Chapter 3.12 – River Murray Valley

2020–21



This document represents a sub-chapter of 'Commonwealth Environmental Water Office Water Management Plan 2020-21, Commonwealth of Australia, 2020'.

Please visit: <https://www.environment.gov.au/water/cewo/publications/water-management-plan-2020-21> for links to the main document.

#### Acknowledgement of the Traditional Owners of the Murray–Darling Basin

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## 3.12 River Murray Valley

### 3.12.1 Region overview

#### (a) *River valley*

The River Murray is Australia's longest river, running a course of 2,500 km from near Mount Kosciuszko in the Australian Alps to the Southern Ocean at Goolwa, in South Australia. A mountain stream in its upper reaches, the river turns into a meandering river lined with magnificent river red gum forests and woodlands, before ending its journey flowing through the vast Lower Lakes and northern edges of the Coorong, and out through the small Murray Mouth. Many creeks and anabranches flow in and out of the River Murray, the largest being the Edward/Kooley-Wakool River system.

Water for the environment, managed by the Commonwealth can be ordered for delivery to sites downstream of Hume Dam, near Albury, with water also supplied from Lake Victoria (west of Wentworth) and from its various tributaries, including from the Goulburn, Ovens, Kiewa, Loddon and Campaspe rivers in Victoria, and by the Murrumbidgee and Darling rivers in NSW. (Figures 1 and 2). The Ovens and Kiewa Rivers are particularly valuable to the ecology of the River Murray given their limited regulation, which means they provide natural inflows into the River Murray.

#### (b) *Traditional Owners*

The River Murray flows through the traditional land of many First Nations and the river and its floodplains have long been important for sustenance and spirituality (MDBA 2020).

The upper Murray catchment includes the traditional land of the Dhudhuroa, Djilamatang, Ngarigo, Walgalu and Yaitmathang Aboriginal Nations.

The Aboriginal Nations associated with the mid-Murray planning area include the Wiradjuri, extending from the River Murray to the Macquarie River in the north, and west to Balranald. The east, from the Murray and south into the Great Dividing Range, is the traditional land of the Dhudhuroa and Waywurru Nations. The region centred on Echuca, is the traditional land of the Barapa Barapa/Perepa Perepa, Wamba Wamba/Wemba Wemba and Yorta Yorta Nations. The lower stretch of the central Murray catchment includes the traditional land of the Barkindji, Maraura, Muthi Muthi, Nyeri Nyeri, Tati Tati, Wadi Wadi and Weki Weki Nations.

The Aboriginal Nations associated with land around the confluence of the Darling and Murray rivers include the Barkindji, Maraura, Muthi Muthi and Nyeri Nyeri. Upstream of the confluence of the Darling and Murray includes the land of the Barkindji and Maraura nations. Along the River Murray, from about Mildura and into South Australia is also the traditional land of the Ngintait Nation. The land of the lower reaches of the Murray, the Lakes and the Coorong is the traditional land of the Ngarrindjeri nation. The land west of the river and including the Mount Lofty Ranges, includes the country of the Kaurna and Peramanok Nations.

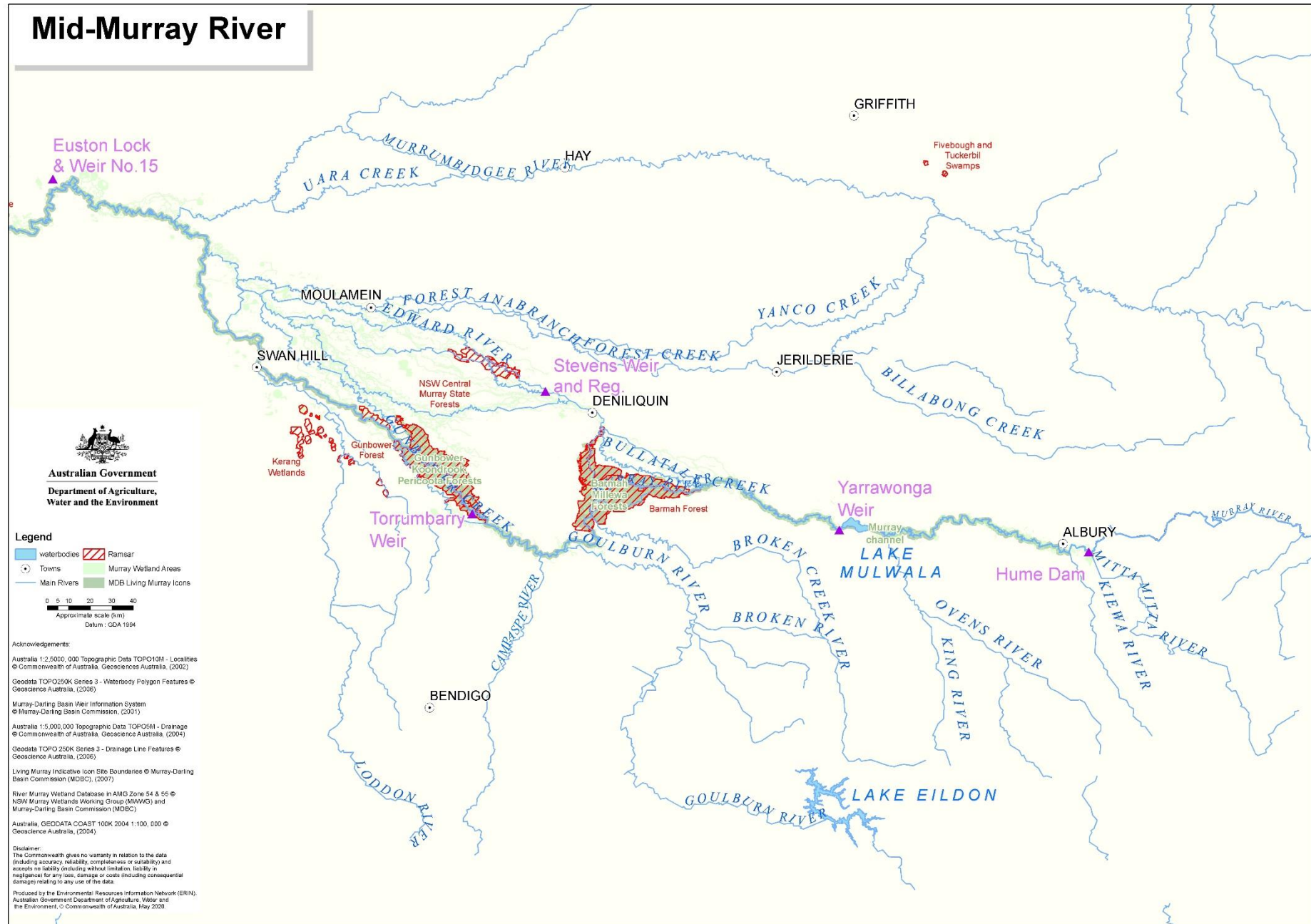


Figure 1: Map of the mid-Murray River valley, including the Edward/Kolety-Wakool river system.

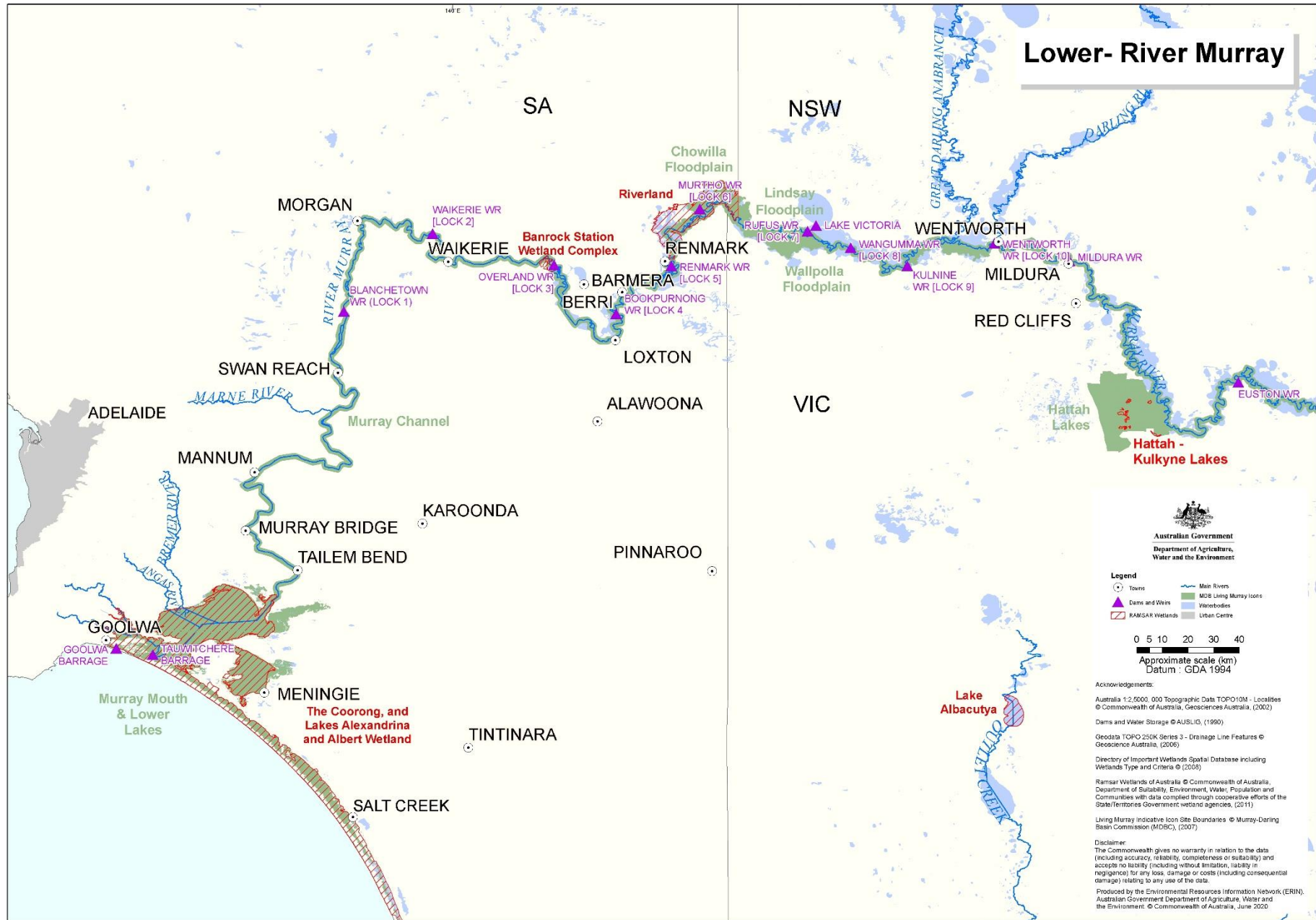


Figure 2: Map of the Lower-River Murray valley



### (c) *Important sites and values*

The River Murray valley supports a range of environmental values of local, regional, national and international significance. Examples include:

#### *Vegetation*

Over 90 000 ha of river red gum and over 40 000 ha of black box and extensive lignum shrublands, including the vast river red gum forests of the Mid-Murray (Barmah-Millewa, Gunbower, Koondrook-Perricoota and Werai Forests). Together these comprise the largest complex of tree dominated floodplain wetlands in southern Australia and Australia's largest parcel of river red gum forests). The mid-Murray also comprises the woodlands of the Lower Murray (Hattah-Kulkyne Lakes, Lindsay-Mulcra-Chowilla Floodplain) and lignum shrublands. There are also important non-woody vegetation communities including the Moira grasslands in the Barmah-Millewa Forest and *Ruppia tuberosa* in the Coorong.

#### *Native Fish*

The River Murray, along with its anabranches, creeks and wetlands, provide habitat for a suite of native fish, including nationally listed threatened species, such as Murray cod, trout cod, silver perch and Murray hardyhead. The creeks through Barmah-Millewa Forest, the Edward/Kolety-Wakool system and Gunbower Creek (in the Mid-Murray) and the Lindsay-Mullaroo Creek system, Chowilla floodplain, Katarapko and Pike creeks and anabranches (in the Lower Murray) are also important habitat for native fish. Several small wetlands in the Lower Murray, along with the Lower Lakes, support some of the last remaining wild populations of threatened small-bodied native fish, such as Southern purple-spotted gudgeon, Southern pygmy perch and Murray hardyhead.

The connection between the Murray Mouth, the Coorong and the Lower Lakes is a hot spot for native fish diversity, supporting marine, estuarine, freshwater and diadromous (live in both salt and freshwater) fish. This includes a range of recreational and commercial fish species such as black bream, greenback flounder, yellow-eye mullet, golden perch, and mulloway. Species like sandy sprat and small-mouthed hardyhead are also essential food sources for predatory fish and waterbirds in the region.

#### *Birds*

Floodplain ecosystems of the Murray-Darling Basin support a high diversity of migratory shore birds and waterbirds, as well as 108 species of floodplain dependent woodland birds. There are several wetlands for waterbirds recognised as having Basin-wide significance importance for waterbirds. These include the River Murray, Barmah-Millewa Forest (which includes wetlands that are significant to the nationally endangered Australasian Bittern), Gunbower-Koondrook-Pericoota Forest, Hattah Lakes, Chowilla-Lindsay-Wallpolla, Noora evaporation Basin, Pyap Lagoon, and the Lower Lakes and Coorong. The Coorong and Lakes Albert and Alexandrina comprise the most important site in the Basin for shorebirds and the seventh most important site in Australia. They also support the greatest waterbird species richness of the Murray-Darling Basin. In addition to waterbirds, the River Murray floodplain between Robinvale and Swan Reach has also been identified as highly important to the nationally vulnerable regent parrot.

#### *Ramsar Wetlands*

The River Murray region contains several internationally important Ramsar listed wetlands: Barmah Forest, Gunbower Forest, New South Wales Central Murray Forests (consisting of Millewa, Koondrook-Pericoota and Werai forests), Hattah-Kulkyne Lakes, the Riverland (including Chowilla floodplain), Banrock Station Wetland Complex and The Coorong, Lakes Alexandrina and Albert Wetland. These sites are recognised for their unique and diverse wetlands, support of species of conservation significance and biological diversity, their role in providing refuge during adverse conditions, and regularly supporting large numbers of waterbirds. This includes those listed under international migratory agreements. The significance of these sites is documented in the ecological character descriptions (<http://www.environment.gov.au/cgi-bin/wetlands/alphablist.pl>).

## *(d) Partners and Stakeholder engagement*

### *Delivery Partners*

The planning, management and delivery of Commonwealth water for the environment throughout the Murray valley is undertaken in collaboration with a range of partners and stakeholder groups.

All Commonwealth environmental water is coordinated with other government environmental water holders: NSW Department of Planning, Industry and Environment - Environment, Energy and Science (DPIE-EES), the Victorian Environmental Water Holder (VEWH), the South Australian Department of Environment and Water (SA DEW), and the Murray Darling Basin Authority (MDBA) in its role in coordinating The Living Murray programs. In most cases, the Commonwealth environmental water is transferred to these agencies, who are responsible for ordering this water for delivery. The primary coordination body is the Southern Connected Basin Environmental Watering Committee (SCBEWC), which includes representatives from each of the federal and state government environmental water holders, as well as representatives from the Murray Lower Darling Rivers Indigenous Nations. Managers of The Living Murray (TLM) icon sites provide annual watering proposals that are considered by the committee in planning and delivering water for the environment. As part of this process, the Indigenous Partnerships Program supports First Nations contribution to the planning and management of key sites and environmental watering activities.

In addition to the above organisations, the delivery of environmental water is also supported by and coordinated with:

- river operators (MDBA, WaterNSW, Goulburn-Murray Water, SA Water)
- irrigation corporations (Murray Irrigation Limited, Renmark Irrigation Trust)
- regional natural resource management agencies (North Central Catchment Management Authority, Goulburn-Broken Catchment Management Authority, North East Catchment Management Authority, Mallee Catchment Management Authority, NSW Murray Local Land Services, South Australian Murray-Darling Basin Natural Resource Management Board), NSW DPI Fisheries
- land managers (such as Parks Victoria, NSW National Parks and Wildlife Service and Forestry Corporation NSW)
- private organisations (Nature Foundation SA, Murray-Darling Wetlands Working Group, Banrock Station/Accolade Wines, Calperum Station/Australian Landscape Trust).

### *Stakeholder engagement*

The Commonwealth Environmental Water Office (CEWO) plans for the use of water with input from and/or consultation from many partners. These include the delivery partners listed above, scientists engaged in monitoring the outcomes of Commonwealth environmental water use and various community groups and individuals.

There are several advisory groups that draw on the expertise and experience of community members to help inform our work. Advisory groups may include water managers, recreational fishers, landholders, First Nations groups, independent scientists, local government representatives and a variety of partner agencies. Key stakeholder advisory groups include:

- The CEWO's Edward-Wakool Environmental Water Reference Group
- The New South Wales Murray-Lower Darling Environmental Water Advisory Group
- Victorian Environmental Water Advisory Groups
- The Coorong, Lower Lakes and Murray Mouth Community Advisory Panel.

### 3.12.2 Environmental objectives

Table 1 sets out the objectives for environmental watering in the River Murray valley, based on long-term environmental objectives in the Basin Plan, draft state long-term watering plans, site management plans (including Ramsar site ecological character descriptions), and best available knowledge.

The objectives targeted in a particular year may vary depending on available water, catchment conditions, operational feasibility and demand for environmental water. These objectives will continue to be revised as part of the Commonwealth Environmental Water Office's commitment to adaptive management.

**Table 1.** Summary of objectives for environmental watering in the River Murray valley.

Basin-wide Matters	In-Channel Assets	Off-Channel Assets	End of System
<b>Vegetation</b>	<ul style="list-style-type: none"> <li>Maintain riparian and in channel vegetation condition.</li> <li>Increase periods of growth for nonwoody vegetation communities that closely fringe or occur within river corridors.</li> </ul>	<ul style="list-style-type: none"> <li>Maintain the current extent of floodplain vegetation near river channels and on low-lying areas of the floodplain, including Moira grass.</li> <li>Improve condition of black box, river red gum and lignum shrublands.</li> <li>Improve recruitment of trees within black box and river red gum communities.</li> <li>Maintain and improve condition of wetland vegetation.</li> </ul>	<ul style="list-style-type: none"> <li>Ensure survival and promote growth and recruitment of <i>Ruppia tuberosa</i> in the south lagoon of the Coorong.</li> <li>Maintain or improve the diversity, condition and extent of aquatic and littoral vegetation at the Lower Lakes.</li> </ul>
<b>Waterbirds</b>	<ul style="list-style-type: none"> <li>Provide habitat and food resources to support waterbird survival and recruitment and maintain condition and current species diversity.</li> </ul>	<ul style="list-style-type: none"> <li>Provide habitat and food resources to support waterbird survival and recruitment and maintain condition and current species diversity.</li> <li>Complete seasonally appropriate bird breeding events that are in danger of failing due to drying.</li> <li>Support naturally triggered bird breeding events.</li> <li>Provide habitat for migratory birds.</li> </ul>	<ul style="list-style-type: none"> <li>Maintain habitat and food sources to support waterbird condition and populations within the Lower Lakes and Coorong lagoons (including curlew sandpiper, greenshank, red-necked stint and sharptailed sandpiper).</li> <li>Complete seasonally appropriate colonial bird breeding events that are in danger of failing due to drying.</li> </ul>



Basin-wide Matters	In-Channel Assets	Off-Channel Assets	End of System
<b>Native Fish</b>	<ul style="list-style-type: none"> <li>Provide flows to support habitat and food sources and promote increased movement, recruitment and survival/condition of native fish.</li> </ul>	<ul style="list-style-type: none"> <li>Provide flow cues to promote increased movement, recruitment and survival/condition of native fish (particularly for floodplain specialists).</li> </ul>	<ul style="list-style-type: none"> <li>Maintain or improve diversity, condition and population for fish populations (including estuarine-dependent and diadromous fish) through providing suitable habitat conditions within the Coorong lagoons and maintaining migration pathways that supports species recruitment and survival/condition.</li> <li>Provide flow cues to promote increased movement, recruitment and survival/condition of native fish.</li> </ul>
<b>Invertebrates</b>	<ul style="list-style-type: none"> <li>Provide habitat to support increased microinvertebrate and macroinvertebrate survival, diversity, abundance and condition.</li> </ul>		
<b>Other vertebrates</b>	<ul style="list-style-type: none"> <li>Provide habitat to support survival, maintain condition and provide recruitment opportunities for frogs and turtles.</li> </ul>		
<b>Connectivity</b>	<ul style="list-style-type: none"> <li>Maintain baseflows and increase overall flows in the River Murray.</li> <li>Maintain longitudinal &amp; lateral connectivity through contributing to an increase in the frequency of freshes, bankfull and lowland floodplain flows.</li> </ul>	<ul style="list-style-type: none"> <li>Maintain latitudinal connectivity (within constraints) to wetlands, floodplains, creeks and anabranches by contributing an increase in the frequency of lowland floodplain flows.</li> </ul>	<ul style="list-style-type: none"> <li>Improve the connection of the River Murray to the Coorong and the sea, through supporting increased barrage flows and Murray Mouth openness.</li> </ul>
<b>Processes</b> <b>Water quality</b> <b>Resilience</b>	<ul style="list-style-type: none"> <li>Increase primary productivity, nutrient and carbon cycling, biotic dispersal and movement. Increase transport of organic matter, salt and nutrients downstream.</li> <li>Maintain water quality and provide refuge habitat from adverse water quality events. Increase mobilisation and export of salt from the River Murray system.</li> <li>Provide drought refuge habitat and maintenance/condition of native biota.</li> </ul>		

Information sourced from: MDBA (2019); Department of the Environment (2011a and b); MDBA (2012a-i); DELWP (2015); Department of Environment, Water and Natural Resources (2015)

### 3.12.3 First Nations Environmental Objectives

Advice on environmental water objectives in the Murray River valley has been provided by the Murray Lower Darling Rivers Indigenous Nations (MLDRIN) through the First Nations Environmental Water Guidance project. Table 22 includes just some of the common objectives for the Murray River valley, selected as they were raised by 2 or more participating Nations for the region. It is important to note these objectives do not represent the detail, depth and complexity of Nations' localised water-related objectives.

Some of these objectives sit outside the scope of water for the environment to influence, while for others, the link between water for the environment and the site or issues is not well understood. Environmental flows will aim to contribute to identified objectives, where possible. The Commonwealth Environmental Water Holder is committed to continuing to strengthen engagement with all Southern Basin First Nations to support those Nations to articulate objectives for water management.

**Table 2:** First Nations environmental water objectives for the River Murray valley for 2020-21 (MLDRIN, 2020)

<b>Waterways and Places in Need of watering</b>
Wetlands, Billabongs, Floodplains, Other places - parks, forests, islands, Creeks, Major rivers, Tributaries, Baaka (Darling), Reedy Creek, Wera Forest, Billabong Creek, Edward River, Murray, Wakool River, Billabongs, Floodplains, Ramsar-listed wetlands.
<b>River Flows and Connectivity</b>
Improve water quality, Improve timing and seasonality of flows, Improve flows and quantity, Restore wetland hydrology, Remove barriers and constraints, Improve tributary flows, Restore flows in degraded rivers, Improve river and or floodplain connectivity.
<b>Vegetation</b>
Old Man Weed, Cumbungi, Lignum, Black Box, Grasses, Medicinal plants <sup>i</sup> , Reeds and Rushes, Nardoo, River Red Gum.
<b>Fish</b>
Murray Cod, Catfish, Yellowbelly, Native fish (general)
<b>Waterbirds</b>
Pelican, Swan, Birds, Ducks, Sea eagle <sup>i</sup> , Darters.
<b>Other species</b>
Turtles, Yabbies, Frogs, Shrimp, Platypus, Mussels, Water Rat, Murray Cray, Kangaroo <sup>i</sup> , Emu <sup>i</sup> , Macroinvertebrates.

<sup>i</sup> Water for the environment targeting other environmental outcomes may influence this species or objective

### 3.12.4 Recent conditions and seasonal outlook

#### (a) Recent conditions and environmental water use

The health of rivers, wetlands and floodplains, and the plants and animals they support, can be influenced by flows and conditions in the past. In some cases, this can date back many years, with parts of the environment still showing the effects of the Millennium Drought along with the more recent 2017–2020 drought.

#### Flows

Since the large-scale flooding of 2016-17, the River Murray has experienced three consecutive years of well-below average inflows. In 2019-20, River Murray inflows were less than half the long-term average of 8 870 gigalitres and within the driest 12 per cent of years since 1891. Without water for the environment, several critical off-channel waterways would have otherwise remained dry over this three-year period. Water

for the environment has supported variable flows in the River Murray, particularly in winter and spring, which are of critical importance to native fish populations. End-of-system flows have been solely dependent on water for the environment, which has accounted for 100 per cent of flows through the barrages since January 2018, and prevented the Lower Lakes dropping below the critical threshold of 0.4 m (a trigger for the planning phase of the Drought Emergency Framework).

The dry conditions since 2016-17 have been followed by above average rainfall over large parts of the southern Basin during early 2020. This was particularly evident during April and early May, with high rainfall in the catchments resulting in a rise in streamflow through the Mid-Murray region.

### *Vegetation*

- Floodplain forests and woodlands:
  - The condition of river red gum forests at low elevation in the Mid-Murray (e.g. Barmah-Millewa and Gunbower Forests) has largely been maintained since the 2016-17 flood. Excellent red gum (and to a lesser extent, black box) tree canopy responding positively to environmental water delivery has been recorded (GB CMA 2020b, North Central CMA 2020). Due to dry conditions, woodlands at higher elevation and throughout Koondrook-Perricoota Forest, have shown declining health since the 2016-17 floods (New South Wales Forests 2020).
  - The internationally important Moira grass plains of Barmah-Millewa Forest have seen excellent growth during periods where water has been delivered and grazing pressure has been managed. Overall, the Moira grass plains are in good condition with the extent of coverage expected to increase with the addition of four new grazing exclusion fences in February 2020 (GB CMA 2020a).
  - Aquatic vegetation in wetlands that have received sufficient water is generally in good condition throughout the length of the River Murray. Instream aquatic native plants are slowly recovering in the Edward/Kolety-Wakool system after the 2016 flood (Watts et al. 2019). Similarly, the increased variability of weir pool levels has provided benefits for vegetation fringing the main river channel, anabranches and low-lying wetlands for several reaches of the River Murray (Ye et al. 2020, Gehrig 2018). Wetland vegetation condition in other locations, such as those more exposed to drought conditions, heat stress or grazing pressure, is poorer.
  - Further downstream, the condition of river red gum and black box woodlands such as at Hattah Lakes and Chowilla Floodplain has largely been maintained in areas where infrastructure has enabled the delivery of water (Mallee CMA 2020). In higher elevation sites where water has not been delivered, particularly at Chowilla, black box is showing signs of stress following three years of dry conditions (MDBA 2019).
- Coorong and Lower Lakes:
  - Fringing vegetation in Lower Lakes has become more diverse and the abundance of key taxa has increased over the past 3 years. This represents ongoing recovery from the millennium drought as the lakeside vegetation community re-establishes. Improvements have likely been driven by seasonally appropriate water levels varying between higher levels in spring (~0.85 m) and lower levels in autumn (~0.5 m) (Nicol et al. 2019, Nicol pers. comm.).
  - While monitoring indicates there has been little to no improvement in *Ruppia* distribution and abundance in the Coorong South Lagoon, some local community members are reporting that *Ruppia* abundance and distribution has increased in the southern part of Coorong North Lagoon and in certain areas in the South Lagoon (Glen Hill pers. comm., Jarrod Eaton, pers. comm.).

### *Native Fish*

The 2016-17 flood was beneficial to wetland and floodplain vegetation and waterbird populations in many areas. However, the natural floods also generated a significant hypoxic blackwater event as organic material, accumulated by the lack of frequent, natural, flushing flows, was washed off the floodplain. While environmental flows were used to mitigate the impacts on native fish populations in some localities, the hypoxic blackwater still resulted in large-scale fish kills throughout the Mid-Murray and through parts of the

Lower Murray. There have since been mixed outcomes for fish species across the Murray system, however achieving sustained breeding success across the various key fish species remains a challenge.

- Fish species that occupy flowing river habitats and breed independently of particular flow events are perhaps the best faring native species across the Murray. Murray cod and trout cod have bred successfully in the Mid-Murray river channel during the spring and summer of most recent years (ARI, in prep., GB CMA 2020a, Raymond 2018). The Edward/Kooley-Wakool River systems continue to be a nursery area for Murray cod, with the species' population slowly recovering since the 2016 flood (Watts et al., 2018 and 2019). Similarly, in the Lower River Murray, Murray cod have successfully bred for six consecutive years following an extended period of unsuccessful breeding, considerably improving the structure of the Murray cod population in the Lower Murray (Ye et al. 2020).
- Iconic fish species that are dependent on a distinct flow 'pulse' during warmer spring or summer months for their breeding success, such as golden and silver perch, have bred in the Mid Murray (Raymond et al. in prep., GB CMA 2020a). In the Edward/Kooley-Wakool River systems, silver perch are benefitting from nursery habitat and winter flows that allow movement throughout the year (Watts et al. 2019). However, there has been a sustained lack of breeding success for golden perch in both the Edward/Kooley-Wakool and Lower River Murray areas for several years (Ye et al. 2020, Watts et al. 2019), which is a concerning trend.
- The condition of species that occupy floodplain wetland sites is variable, dependent on location. Overall this category of fish species has been heavily affected by reduced flows to floodplain wetland sites and introduced species, such as carp. For example, monitoring of the Lower Lakes in late 2018 failed to detect Yarra pygmy perch, which is now considered likely to be extinct in the Murray-Darling Basin (Wedderburn et al. 2019). However, there have been some success stories as a result of providing water for the environment.
  - Populations of the nationally endangered Murray hardyhead have been maintained at several locations, with two new populations established in recent years.
  - Increased variability in water levels in the Lower Lakes has benefited fringing and submergent vegetation (Nicol et al. 2019). In turn, small-bodied fish species have also demonstrated positive responses. Murray hardyhead have become more abundant and expanded in range after successful spawning and recruitment in the Lower Lakes in 2018-19 and 2019-20. For southern pygmy perch, high spring lake levels and improved submergent vegetation habitat have favoured spawning and some additional populations have been observed, however consecutive years with lake levels dropping to 0.5m have not supported strong recruitment or population recovery as preferred habitat is reduced at minimum (Wedderburn et al. 2019).
- Diadromous fish species spend portions of their life cycles partially in fresh water and partially in salt water. Water for the environment has been solely responsible for maintaining the connection between the River Murray and its estuary, the Coorong, for extended periods since the Millennium drought. This connection is having clear benefits for diadromous fish species.
  - For example, monitoring undertaken in the Lower Lakes in late spring 2019 recorded the native congolli as the most abundant fish species for the first time since surveys began in the mid 2000's. Congolli are a key part of the Coorong and Lower Lakes food web as a major prey item for larger predators including mullet, pelicans, cormorants and golden perch, thus the high abundance of congolli is a strong positive indicator of available food resources for other species (DEW 2020).
  - Pouched lamprey has also been detected moving upstream during winter/spring for several consecutive years, and for the last two years short-headed lamprey were detected for the first time since 2006-07, suggesting that numbers of both species are gradually recovering (Bice et al. 2020).
- Outcomes for estuarine fish species in the Coorong have been variable, influenced by both the continuous connection between the lakes and the Coorong and low flows in ongoing drought conditions. Sustained connection has supported increasing abundances of congolli and common galaxias, which need connection but are not particularly flow dependent. On the other hand, while black bream spawned and recruited in early 2018 during a small flow pulse, barrage flows in late spring/summer 2018-19 and 2019-20 were comparatively low and recruitment has not been detected. (Ye et al. 2019, Ye

pers. comm. 2020). Autumn ‘pulsing’ of flows from the barrages in line with tide and storm conditions has been linked to improvements in range and condition in commercial Coorong fish such as Coorong mullet (Glen Hill pers. comm. 2020).

### *Waterbirds*

Basin scale monitoring of waterbirds in the Murray-Darling Basin indicates waterbird numbers are declining over the long term (since the 1980s). Waterbird breeding has generally been limited across the Murray system for several consecutive years. This may be due to a lack of natural breeding cues resulting from below average rainfall conditions through most of winter and spring, as well as limited foraging and nesting habitat availability and condition. Aerial waterbird surveys indicate a significant proportion of the waterbird breeding in the past two years in the Murray valley (and more broadly) has occurred at the Coorong and Lower Lakes (Kingsford et al. 2019).

Other notable points in relation to waterbirds in the Murray valley include:

- Barmah-Millewa Forest continues to provide a haven for bitterns, a species where survival is threatened by habitat loss, drought and fire (pers comms NSW NPWS, 2019). Up to twenty five percent of the estimated remaining population are thought to rely on use of the Barmah-Millewa wetlands (Belcher et al. 2018).
- The nationally vulnerable regent parrot has experienced a 12 per cent population decline in recent years due to a decline in river red gum health. Survey results from 2019-20 have shown a further decrease in nesting, but there are some indications that birds are moving into areas that are receiving environmental water as this is helping to maintain or restore tree condition (SA Regent Parrot Recovery Team, pers. comm.).
- The annual summer census of waterbirds in the Coorong and Lower Lakes observed low numbers of shorebirds including migratory waders, with many species having abundances below their long-term medians. Birds that were present were spending up to 80 percent of their time foraging, highlighting low food abundance within the mudflats, a consistent observation in recent years (Adrienne Rumbelow pers. comm. 2020, Paton et al. 2018).

Details of previous Commonwealth environmental use in the River Murray are available at:

<http://www.environment.gov.au/water/cewo/catchment/mid-murray/history>

<http://www.environment.gov.au/water/cewo/catchment/lower-murray-darling/history>

### *(b) Seasonal outlook*

According to the Bureau of Meteorology outlook (BoM 2020), across the Murray River valley there is a 60 to 75 per cent chance of above median rainfall between July and September 2020.

While this forecast indicates that the severe dry conditions may ease somewhat, several months of above average rainfall are needed to see a recovery from the current long-term drought. Additionally, maximum temperatures are likely to remain slightly below average over the coming months.

### *(c) Water availability*

The volume of Commonwealth environmental to be carried over in the River Murray valley for use in 2020-21 is 138 ggalitres. Total carryover in the Southern-connected Basin<sup>1</sup> is 267 ggalitres.

Allocations will vary depending on conditions. In the Murray, allocations against Commonwealth entitlements in 2020-21 could range from 498 ggalitres under very dry conditions, to 1 068 ggalitres in very wet conditions.

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<sup>1</sup> Southern-connected Basin is the network of rivers that feed into the Murray River between the Hume Dam and the sea. This includes the Murray, Murrumbidgee, Lower Darling, Ovens, Goulburn-Broken, Campaspe and Loddon valleys.



#### *(d) Environmental demands*

While current and forecast conditions may signal improving conditions, years of drought conditions have had a significant impact on the environment. However, due to drought conditions in preceding years, there are several environmental demands that require water urgently in 2020-21. Without future significant rainfall and inflows to the system there is a need to avoid further damage to key assets through application of environmental water.

The environmental water demands for assets in the River Murray in 2020-21 are represented in Table 3, Table 4 and Table 5 below. Note that the capacity to contribute to many of these environmental demands is contingent on a substantial improvement in water availability in the catchment.

Looking across the demands for the Murray valley (identified in Table 4), they can be summarised as following:

- Critical environmental demand for water have been identified for ameliorating hypoxic conditions in the Edward/Kooley Wakool System, which has suffered from multiple hypoxic events in recent years.
- Critical environmental water demand for low level floodplain wetlands in South Australia that are suffering significant tree canopy cover loss and at risk of irretrievable damage.
- High environmental demands for water are generally related to sites/reaches that require frequent watering (an annual or biannual flow regime), for medium to high elevation floodplain wetlands that require larger but less often watering and end of system environments.
- Moderate environmental demands for water have been identified for both in-channel (large fresh) and floodplain wetlands that have recently had their requirements met through either natural floods or managed environmental deliveries.
- Low environmental demands for water were identified at floodplain wetlands sites that can be easily watered via environmental watering infrastructure (as these sites have been able to be watered in recent years).

**Table 3.** Environmental demands, priority for watering in 2020–21 and outlook for coming year in the Mid-Murray.

Environmental asset	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2020–21		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020–21
<b>River Murray from Hume Dam to Euston and Barmah-Millewa Forest</b>	2 000-5 000 ML/day at Yarrawonga Weir throughout the year for native fish habitat to improve recruitment and population structures, and water quality in main river channel and Barmah-Millewa creeks.	Annual	Continuous requirement, therefore the environmental demands has been assessed as High.	High	High priority for Commonwealth environmental watering (likely to receive water even under a very low water resource availability)	High
	Variable flows between 5 000 and 9 500ML/day at Yarrawonga Weir from July to November for fish condition, spawning, dispersal, in-channel non-woody vegetation and ecosystem function/productivity.	Annual	In-channel variability in 2018-19 was limited due to operational deliveries. Partially met in 2019-20.	High	High priority for Commonwealth environmental watering (likely to receive water even under a very low water resource availability)	Moderate
	Freshes 12 000-18 000 ML/day variable flow rate for at least 5 days, measured d/s Yarrawonga Weir during the period July to November for native fish habitat to improve recruitment and population structures (in-channel outcomes and anabranches) and for core wetlands, including Australasian bittern habitat. Would also provide carbon/productivity benefits to Edward/Koety-Wakool system during the cooler time of the year.	5-10 in 10 years (2 years)	Has been met in 5 of the last 7 years. Therefore, the environmental demand has been assessed as Moderate.	Moderate	Option to be considered under a low to high water resource availability.	Moderate
	Small overbank of 12 000-15 000 ML/day for a minimum of 45 days measured d/s Yarrawonga between August to November, to improve recruitment and population structures (in-channel outcomes and giant rush wetlands). Would also provide carbon/productivity benefits to Edward/Koety-Wakool system during the cooler time of the year.	4-8 in 10 years (2 years)	Has been met or partially met in 4 of the last 7 years. Therefore, the environmental demands have been assessed as Moderate.	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
	> 25 000 ML/day at Yarrawonga Weir (unregulated flow) for at least 7 days (river red gum forest) and followed by flows of up to 18 000 ML/day or greater for three to five months targeting Moira grassland.	6-8 in 10 years (2-3 years) Annual (2 years) for Moira grass.	For river red gum, the target has been met or partially met 2 in 6 years.  For Moira grass the target has been met fully 2 in 6 years.  Not met since spring 2016. Therefore, the environmental demand has been assessed as High.	High	Reliant on large, unregulated flows. Commonwealth environmental water may extend the depth and duration of natural floods within current constraints (i.e. < 15 000 ML/day), subject to ecological need, water availability and assessment of risk and potential, adverse third-party impacts.	High
<b>Gunbower Creek</b>	Winter low flow and summer ramp down to support juvenile fish and maintain habitat connectivity during off-irrigation season:  · Winter base flows (200 ML/day for 5 months).	Annually (1 year).	Met or partially met every year in the last 5 years. Watering required on an annual basis therefore the environmental demand has been assessed as High.	High	Priority for Commonwealth environmental watering (likely to receive water even under low water resource availability, subject to flow constraints)	High
	Spring pulse and stable summer flows for fish breeding: · Small fresh up to 400 ML/day in spring, reducing to 300 ML/day in summer.	Fish spawning fresh 2 in 3 years.	Met or partially met every year in the last 5 years. The environmental demand has been assessed as Moderate.	Moderate	Priority for Commonwealth environmental watering (likely to receive water even under low water resource availability, subject to flow constraints)	Moderate

Environmental asset	Indicative demand (for <u>all sources of water</u> in the system)			Watering history	2020–21		Implications for future demands
	Flow/Volume		Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020–21
Gunbower Forest	Small-moderate actions (~100-1 000 ML/day in late winter/early spring – duration dependant on inflow rate) targeting permanent and semi-permanent wetlands, or targeted infrastructure use at the sites.	Up to 2 500 ha via Gunbower Forest infrastructure.	6-9 in 10 years (2 years)	Significant watering action in 2014-15 and 2015-16 and natural flood event in 2016-17 inundated various parts of the Forest. Drying phase in 2017-18, with the exception of high value permanent wetlands. Watering action in 2018-19. Small throughflow event to targeted wetlands in 2019-20. Environmental demand has been assessed as High.	High	It is anticipated that demands in Gunbower Forest will be met by other water holders in 2020-21.	High
	Infrastructure delivery to Gunbower Forest targeting river red gum forest (~1 600 ML/day for 90 days in winter/spring)	Up to 4 700 ha via Gunbower Forest infrastructure.	6-7 in 10 years (3 years)	Met or partially met in 5 of the past 6 years. The environmental demand has been assessed as Moderate.	Moderate	It is anticipated that demands in Gunbower Forest will be met by other water holders in 2020-21.	High
Mid-Murray Off-Channel Wetlands and ephemeral creeks Hume to Euston	Infrastructure delivery targeting permanent off-channel wetlands.		Annually	Annual requirement therefore the environmental demand has been assessed as High.	High	High priority for Commonwealth environmental watering (likely to receive water even under low water resource availability)	High
	Infrastructure delivery targeting semi-permanent off-channel wetlands.		3-7 in 10 years (5 years).	Variable across sites with last natural watering event in 2016. Therefore, the environmental demand has been assessed as Moderate.	Moderate	Option to be considered under a moderate to high water resource availability.	High
	Infrastructure delivery targeting ephemeral off-channel wetlands.		1 in 5 years.	Variable across sites with last natural watering event in 2016. Therefore the environmental demand is Low overall.	Low	Option to be considered under a moderate to high water resource availability.	Moderate

## Key - potential watering in 2020-21

	High priority for Commonwealth environmental watering (likely to receive water even under low water resource availability)
	Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate - high water resource availability); or water demand likely to be met via other means
	Low priority for Commonwealth environmental watering (under high - very high water resource availability)
	Unable to provide Commonwealth water because of constraints or insufficient water

## Key - environmental demands

	Critical demand i.e. urgent need for water in that particular year to manage risk of irretrievable loss or damage
	High demand for water i.e. needed in that particular year
	Moderate demand for water i.e. water needed that particular year and/or next
	Low demand for water i.e. water generally not needed that particular year
	Very low demand for water i.e. water generally not needed that particular year or the following year

Note that demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime

## References for Table 3:

Murray and Barmah-Millewa Forest indicators adapted from Department of the Environment (2011b), MDBA (2012c).  
 Gunbower Creek indicators sourced from North Central CMA (2013; 2014b; 2015b; 2016b; 2017).  
 Gunbower-Koondrook-Perricoota Forest indicators adapted from MDBA (2012a), MDBA (2012 h and i) and Department of the Environment (2011a).  
 Mid Murray Off-Channel Wetlands and ephemeral creek indicators sourced from North Central CMA (2014a; 2015a; 2016a).

**Table 4.** Environmental demands, priority for watering in 2020–21 and outlook for coming year in the Edward/Kolety-Wakool River system. The majority of flows listed below will be synchronised with flows in the River Murray (Table 3 above).

Environmental assets	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2020-21		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020-21
<b>Yallakool - Wakool</b>  Maintenance of native fish habitat and instream aquatic vegetation Longitudinal connectivity Fish spawning, recruitment and movement Nutrient cycling Water quality	~200 ML/day base flow for ~304 days during late winter to late Autumn (~61 GL). Note: winter base flows are a separate flow component and is included below.	Annual	Has been met 5 out of the past 5 years	Low	Likely to be met by operational flows except in a <u>very dry year</u> when CEW may be used to prevent system from being cut off subject to <a href="#">NSW Extreme Events Policy</a>	Low
	~600 ML/day peak for 4 days pulse/fresh over 20 days in spring with gradual recession (~10 GL, includes ~200 ML/day base flow).	Annual	Has been met 5 out of the past 5 years	High	Priority for Commonwealth environmental water to continue ecosystem recovery	High
	~430 ML/day for 41 days to maintain minimum flow for fish nesting habitat, and inundation for aquatic vegetation growth (~17 GL in total, includes ~200 ML/day base flow)	Annual	Has been met 5 out of the past 5 years	High	Priority for Commonwealth environmental water to continue ecosystem recovery	High
	~600 ML/day peak for 4 days undertaken 1-3 times in late spring/early summer with a gradual recession at end of fish nesting period (~10.61 GL, includes ~200 ML/day base flow).	Annual	Has been met 2 out of the past 5 years	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
	~470 ML/day peak for 3 days over 25 days pulse/fresh in autumn with a gradual recession (~7.3 GL, includes ~200 ML/day base flow).	2 in 3 years (2 years)	Has been met 2 out of the past 5 years	Moderate	Option to be considered under a moderate to high water resource availability.	Moderate
	~170 ML/day winter base flow from early-May (irrigation shut down) until last week of July (system restarts) (~10 GL). Needs minimum of 4,000 ML/day at Yarrawonga to meet all Edward/Kolety system winter base flow requirements.	Annual	Has been met 2 out of the past 5 years.	High	Priority for Commonwealth environmental water to continue ecosystem recovery.	High
<b>Colligen - Niemur</b> As per Yallakool-Wakool above	The potential flow components for the Colligen-Niemur during 2020-21, and related assessment of demands & urgency of demands are like the flow components outlined for the Yallakool-Wakool above. The primary difference is that the flows planned for the Colligen-Niemur have been scaled to fit within its constraint for environmental flows of up to 450 ML/day.					
<b>Edward/Kolety River</b> downstream of Stevens Weir	Up to 2 700 ML/day (constraint downstream of Stevens Weir) spring-pulse (~15 GL). Will need to align with delivery of flows into Yallakool-Wakool and Colligen-Niemur systems.	Annual	Has been met 5 out of the past 5 years.	Low	Likely to be met by operational flows	Low
<b>Tuppall Creek</b>	Spring pulse with variability flows during the year (~3 GL of CEW + ~3 GL NSW).	Annual	Has been met 5 out of the past 5 years	Moderate	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	Moderate
<b>Merran Creek</b>	~ 460 ML/day preferably in spring and comprised of: Merran Creek at Franklins Bridge (~250 ML/day), Waddy Cutting (~150 ML/day) and St Helena Creek (~60 ML/day).	Annual	Has been met 5 out of the past 5 years	High	Priority for Commonwealth environmental water to continue ecosystem recovery.	High
<b>Jimaringle, Cochrans and Gwynnes Creeks</b>	Total flow of ~3 000 ML deliverable preferably in spring. May also require high flows in receiving Niemur system to dilute potential poor water quality outflows from these systems.	1 in 2 years (2 years)	Last significant flow was the 2016 flood event.	Moderate	Use of CEW in these systems suspended pending further advice from NSW re acid sulphate soils and salinity issues.	Moderate
<b>Werai Forest</b>	Flows greater than ~2 100 ML/day downstream of Stevens Weir (with forest regulators open) in late autumn-early spring when water temp is below 16 degrees (~15 GL). Will need to align with delivery of flows into Yallakool-Wakool and Colligen-Niemur systems.	2-3 in 5 years (2 years)	Has been met 5 out of the past 5 years	Moderate	Use of CEW, including pumping, could be considered subject to stakeholder support, operational delivery infrastructure, third party impacts and accounting being addressed.	Moderate

Environmental assets	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2020-21		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020-21
<b>Koondrook-Perricoota Forest</b>	Annual watering proposals for this site are developed by Forestry NSW and can be contributed to by a number of water holders. Flow objectives may include maintaining habitat for aquatic vegetation, stimulate wetland vegetation response and the provision of carbon (productivity) during cooler times of the year.	2-3 in 5 years (2 years)	Has been met 1 in 5 years (minimum flow provided in 2019-20, similar to 2014-15 commissioning event).	High	Commonwealth environmental water could be considered in future years, subject to stakeholder support, third party impacts and return flows being addressed.	High
<b>Pollack Swamp</b>	~2 GL per year watering proposals for pumping to this site during late spring and summer developed by Forestry NSW and DPIE. Flow objectives may include provide water to water stressed red gums, encourage the recruitment of terrestrial species (i.e. red gums and benefits to waterbirds and frogs) and aquatic flora (i.e. amphibious and mudflat).	Annual	Has been met 5 out of the past 5 years	High	Priority for Commonwealth environmental water to maintain ecosystem health - undertaken in partnership with NSW.	High
<b>Edward/Kolety Wakool System – Recession Flows</b> Maintenance of instream aquatic vegetation and native fish habitat	~15 GL within constraints to provide more natural recession flows off rain rejection and unregulated events in the system.	As required - usually triggered via advice from NSW agencies re anticipated flow rates in the system.	Has been met when required	Moderate	Commonwealth environmental water may be used to manage flow recessions associated with natural or rain-rejection events.	Moderate
<b>Edward/Kolety Wakool System - Refuge Flows</b> Habitat flows Water quality Provision of refuges for native fish	~30-120 GL a year to manage hypoxic water quality events and other critical habitat needs.	As required - usually triggered once dissolved oxygen levels reach 4.0 mg/l in line with Basin Plan water quality requirements.	Has been met when required	Critical once trigger is met	High priority for Commonwealth environmental water to abate the impact of potential fish kills if triggers are met.	Critical once trigger is met

**Key - potential watering in 2020-21**

	High priority for Commonwealth environmental watering (likely to receive water even under low water resource availability)
	Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate - high water resource availability); or water demand likely to be met via other means
	Low priority for Commonwealth environmental watering (under high - very high water resource availability)
	Unable to provide Commonwealth water because of constraints or insufficient water

**Key - environmental demands**

	Critical demand i.e. urgent need for water in that particular year to manage risk of irretrievable loss or damage
	High demand for water i.e. needed in that particular year
	Moderate demand for water i.e. water needed that particular year and/or next
	Low demand for water i.e. water generally not needed that particular year
	Very low demand for water i.e. water generally not needed that particular year or the following year

Note that demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime

**References for Table 4:**

Edward-Wakool indicators compiled from multiple sources (Hale & SKM 2011; Watts et al. 2013; Watts et al. 2014; Watts et al. 2015; Watts et al. 2016; Watts et al. 2017; Webster 2010). Previous watering actions and their outcomes have also been used for all indicators.



**Table 5.** Environmental demands, priority for watering in 2020–21 and outlook for coming year in the Lower Murray.

Environmental assets	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2020-21		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020-21
River Murray from Euston to Lower Lakes, including pool level wetlands	Elevated river baseflow of at least 10 000 ML/d at SA Border for up to 60 days in spring/summer for in-channel aquatic vegetation, fish and water quality.	9 in 10 years (2 years)	All indicators met in 2010-11, 2011-12, 2012-13 and 2016-17 (high flow years during the last decade). 2013-14 and 2017-18 also saw high baseflows and moderate freshes. The drier years (2014-15, 2015-16, 2018-19 and 2019-20) saw contributions to the baseflows and a moderate fresh in 2019–20 of 15 000 ML/day but only for a short duration  All indicators have a high demand for 2020-21	High	A very high priority for watering in 2020-21, even in low resource availability.	High
	Moderate fresh of 15 000-25 000 ML/day at SA Border for up to 90 days in spring/summer for perch spawning and survival and other ecological benefits.	2 in 3 years (2 years)		High	A very high priority for watering in 2020-21, noting that at least moderate resource availability (and potentially multiple water holder contributions) would be required and extended duration may be challenging.	High
	Large fresh of 25 000-35 000 ML/day at SA Border for up to 60 days in spring/summer for fish populations and other in-channel biota.	1 in 2 years (3 years)		High	High resource availability and tributary inflows would be required to deliver flows of this magnitude	Moderate
Hattah Lakes	Small action targeting temporary wetlands (inundation to 42-43 m AHD in winter/spring) - up to 22 000 ML via infrastructure equivalent to natural event of 40 000-50 000 ML/day at Euston for 26-60 days.	1 in 2-3 years (4 years)	All indicators met in 2016-17 (flood).  Environmental water also delivered to 44.85 m AHD in 2017-18.  No additional water has been provided since then (with the exception of a small watering event at Lake Kramen in 2019-20).	Moderate	Environmental needs likely to be met by other sources of environmental water.	Moderate
	Moderate action targeting wetlands and fringing river red gums (inundation to 43.5 m AHD for 90 days in winter/spring) - up to 40 000 ML via infrastructure equivalent to natural event of 85 000 ML/day at Euston for 7-30 days.	1 in 3 years (7 years)		Moderate	Only likely to be delivered under moderate to high water resource availability	Moderate
	Large event targeting wetland and river red gum/black box woodlands on floodplain (inundation to 45 m AHD for 90 days) - up to 120 000 ML via infrastructure equivalent to natural event of 150 000 ML/day at Euston for 7 days anytime in the year.	1 in 8 years (12 years)		Low	Only likely to be delivered after a large natural overbank flow	Low
Floodplain and wetlands from Euston to South Australian border	30 000 ML/day at Lock 8 for 30-60 days targeting low lying wetlands and anabranches, or priority areas via infrastructure.	2 in 5 years (4 years)	All indicators met in 2016-17 (flood).  Environmental water delivered to targeted wetland sites in 2017-18, 2018-19 and (to a lesser extent) 2019-20 across a range of floodplain elevation levels. However, the majority of sites have not received water since 2016-17  Therefore the environmental water demand has been assessed as high for small to medium overbank flows and moderate for larger overbank flows.	High	Commonwealth environmental water is able to contribute to overbank flows only in high resource availability years with significant tributary inflows.  Water is likely to be delivered to priority wetland sites via infrastructure.	Moderate
	50 000-60 000 ML/day at Lock 8 for 60-120 days targeting river red gum forest, lignum shrubland and associated wetlands, or priority areas via infrastructure.	1 in 5 years (5 years)		Moderate		Low

Environmental assets	Indicative demand (for <u>all sources of water</u> in the system)		Watering history	2020-21		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2021–22 if watering occurred as planned in 2020-21
Floodplain and wetlands from South Australian border to Lower Lakes	Small overbank flow of 40 000-50 000 ML/day at SA border for at least 30 days targeting river red gum forest, tea tree, lignum, river cooba and associated wetlands, or priority areas via infrastructure	1 in 2 years (3 years)	Indicators were last met in 2016-17, with small overbank flow also achieved via 2011-12 and 2012-13 natural flows. Environmental water has also been delivered to some priority wetland sites each year, across all floodplain elevation levels. The broader floodplain however is in poor condition with significant tree canopy loss. There is a critical to high demand for overbank flows in 2020-21.	Critical	Water use will be limited to delivery via infrastructure to priority wetland sites, in the absence of overbank flows. Commonwealth water can only contribute to overbank flows in high resource availability years with significant tributary inflows.	High
	Moderate overbank flow of 50 000-60 000 ML/day at SA border for at least 30 days targeting river red gum forest, tea tree, lignum, river cooba and associated wetlands, or priority areas via infrastructure	1 in 2 years (5 years)		Critical		High
	Infrastructure delivery to a priority area equivalent to 60 000-70 000 ML/day at SA border unless met by unregulated flows, targeting black box, cooba, lignum and chenopod and associated wetlands	1 in 3 years (4 years)		High	Water is likely to be delivered to priority wetland sites via infrastructure. Commonwealth environmental water can contribute to overbank flows only in high resource availability years with significant tributary inflows.	Low
Coorong, Lower Lakes and Murray Mouth	Minimum barrage flow of 650 GL/yr (and lake water levels maintained above 0.4 m AHD) to provide suitable conditions and refuge habitat in the lakes and north lagoon for native fish, plants and internationally important migratory birds.	1 in 1 year	Lower Lakes and Coorong north lagoon in generally good condition, with some signs of stress in the north lagoon due to three successive low-flow years (invertebrate deaths, localised algae outbreaks). Minimum flow (1 in 1 year) was not met in 2015-16 or 2018-19.	High	A very high priority for watering in 2020–21, even in low resource availability.	High
	Barrage flows of 2 000 GL/yr required to provide suitable conditions and refuge habitat for native fish, plants and internationally important migratory birds.	Rolling three-year average		High	A high priority for watering in 2020–21, even in low resource availability, noting that due to low outflows in 2018-19 and 2019-20, ~1000GL would be required to meet this target in 2020-21. Commonwealth water likely to contribute significantly, however target cannot be met by Commonwealth water alone.	Moderate
	Barrage flows of 6 000 GL every three to five years to maintain and improve habitat conditions within the Coorong. Lake water level range between 0.4 and 0.83 m AHD to maintain healthy lake ecology.	1 in 3 years (5 years)	Coorong south lagoon still in poor health. While Commonwealth environmental water can help to minimise further damage, strong recovery in the Coorong South Lagoon requires significant volumes of water and will likely only occur in high resource availability years. Large flow events in the last decade include 2010-11 (15,000+ GL), 2012-13 (6797 GL) and 2016-17 (6484 GL).	Moderate (met in 2016-17)	Commonwealth water will contribute to meeting this demand, however the targets cannot be met by Commonwealth water alone and will depend upon unregulated flow event(s).	Low
	Barrage flows of 10 000 GL every seven to seventeen years to improve habitat conditions within the Coorong. Lake water level range between 0.4 and 0.9 m AHD to maintain healthy lake ecology.	1 in 7 years (17 years)		Moderate (met in 2010-11)		Low

## Key - potential watering in 2020-21

	High priority for Commonwealth environmental watering (likely to receive water even under low water resource availability)
	Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate - high water resource availability); or water demand likely to be met via other means
	Low priority for Commonwealth environmental watering (under high - very high water resource availability)
	Unable to provide Commonwealth water because of constraints or insufficient water

## Key - environmental demands

	Critical demand i.e. urgent need for water in that particular year to manage risk of irretrievable loss or damage
	High demand for water i.e. needed in that particular year
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	Low demand for water i.e. water generally not needed that particular year
	Very low demand for water i.e. water generally not needed that particular year or the following year

Note that demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime

## References for Table 5

River Murray Channel indicators sourced from Wallace et al. (2014), Ecological Associates (2015), Ecological Associates (2010), DEWNR (2015) and MDBA (2012g)  
Hattah Lakes indicators sourced from MDBA (2012f), (2012g); Roberts and Marston (2011).  
Floodplain from Euston to SA indicators sourced from MDBA (2012b): 40 000 ML/day for 45-60 days or 50 000 ML/day for 26-45 days. Total duration of natural flows can include multiple discreet flow pulses above 40-50 000 ML/day with a minimum duration of individual pulses of 7 days.  
Floodplain from SA to Lower Lakes indicators sourced from MDBA (2014b), MDBA (2012d) and DEWNR (2015)  
Coorong, Lower Lakes and Murray Mouth indicators sourced from MDBA (2012e) and DEWNR (2015)

### 3.12.5 Water delivery in 2020–21

The use of water for the environment will be responsive to prevailing conditions, water availability, and any emergent opportunities or risks. As such, our plans are flexible (as opposed to being prescriptive) and we may deviate from them in order to maximise the achievement of environmental outcomes throughout the Basin.

Where possible, water for the environment will be managed to benefit multiple sites enroute and will be coordinated with other sources of water. This will include other environmental water portfolios (such as The Living Murray program), consumptive and operational deliveries, natural flows and inflows from key tributaries such as the Ovens and Kiewa Rivers.

The following summary indicates how we may manage Commonwealth environmental water deliveries under various scenarios.

#### *Very Dry (a year that is in the driest 10 per cent of years, in terms of inflows)*

- Maintain baseflows to support in-channel species (including native fish), provide drought refuge, maintain water quality and riverine functions:
  - in the main river channel in winter (4 000 ML/day at Yarrawonga), spring (8 000 ML/day at Yarrawonga) and summer (6 000 ML/day at the South Australian border)
  - through the creeks and key wetlands of Barmah-Millewa Forest over spring
  - through Gunbower Creek
  - through the Edward/Kolety-Wakool River system, including the Yallakool-Wakool and Colligen-Niemur Creek systems (subject decisions made by NSW agencies under the NSW Extreme Events Policy)
  - provide continuous connection through the Lower Lakes and into the Coorong and maintain water levels in the Lower Lakes above 0.4 m (to avoid the risk of acidification).
- Use infrastructure, pumps and/or weir pool manipulation to provide water to key wetlands throughout the valley that provide refuge habitat or are at risk of suffering irretrievable damage
- Respond to poor water quality events that may result from low flows

#### *Dry to Moderate (a year that is in the driest 25-50 per cent of years)*

As per very dry (above), with following additional events in scope:

- Provide a spring fresh down the River Murray to support a broad range of environmental outcomes.
  - The timing, size and duration will be dependent water availability. Under drier scenarios, the fresh is likely to be of lower height and delivered later in spring to early summer. With increasing water availability, the targeted flow height and duration is likely to increase and may start earlier in spring. Even under a dry scenario, this may see flows travel through Barmah-Millewa Forest (reflecting the frequency in which this forest would naturally receive low-level flows).
- Provide spring fresh to Gunbower Creek.
- In the Edward/Kolety-Wakool River system provide a spring fresh and minimum flow target during fish nesting period, followed by increase flow variability in summer and autumn and winter flows from May- August 2021.
- Target minimum end-of-system flow targets to support salt export and improve conditions in the Coorong and the Lower Lakes for native fish and waterbirds.
- Increased scope (number of sites and volumes) of infrastructure-assisted water delivery to wetlands (including autumn watering).

#### *Natural bankfull or overbank flows*

- Extend the duration and recession of natural overbank flows.

*Wet (a year that is in the wettest 25 per cent of years)*

- Extend the duration and recession of natural overbank flows, including with ‘top-up’ watering for wetlands in autumn.
- Provide refuge flows in response to hypoxic blackwater events.
- Support elevated end-of-system flows.

### 3.12.6 Monitoring and Lessons learned

#### *(a) Monitoring*

Operational monitoring is undertaken for all Commonwealth environmental watering actions. It involves collecting on-ground data on environmental water delivery such as volumes delivered, impact on the river systems hydrograph, area of inundation and river levels. It can also include observations of environmental outcomes. The Commonwealth Environmental Water Monitoring, Evaluation and Research program has the Lower Murray and Edward/Kooley-Wakool region as focus areas. It aims to understand the environmental response from Commonwealth environmental watering with respect to the targeted objectives by carrying out monitoring of site condition and ecological response over many years.

Information on the Commonwealth Environmental Water Office’s monitoring activities is available at:

<http://www.environment.gov.au/water/cewo/catchment/mid-murray/monitoring>

<https://www.environment.gov.au/water/cewo/catchment/lower-murray-darling/monitoring>

This monitoring is complemented by that undertaken through The Living Murray program, focussed on Barmah-Millewa Forest, Koondrook-Perricoota Forest, Gunbower Forest, Hattah Lakes, Chowilla-Lindsay–Wallpolla Floodplain, the Lower Lakes and Coorong, and the River Murray channel itself.

Monitoring results from The Living Murray icon sites are available at:

<https://www.mdba.gov.au/managing-water/water-for-environment/progress-outcomes>

#### *(b) Lessons learned*

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment.

Environmental water delivery is still a relatively new practice, which means trialling and learning by doing from various events and outcomes. These learnings continue to be incorporated into the way environmental water is managed. While there are many learnings relating to particular locations, types of watering actions or subsets of the Murray’s ecology (some are described in Table 6), key learnings that apply throughout the River Murray valley are summarised as follows.

#### *Environmental water coordination*

- Coordinating releases of water for the environmental across multiple river systems is complex. Factors such as delivery constraints, notification requirements and site-specific environmental demands or risks make it challenging to align releases of water in multiple tributaries to achieve coordinated flows downstream, however progress is being made. In spring 2019, the ‘Southern Spring Flow’ provided extensive environmental benefit along the River Murray, from Hume Dam to the Coorong in South Australia, enhanced by its timing aligning with a spring fresh in the Goulburn River. Full details, including environmental outcomes, are described in the ‘Southern Spring Flow Wrap-up’ (CEWO 2020a).

- The 2019 Southern Spring Flow, along with previous coordinated flow events and associated monitoring activities, has shown the benefits of flows moving through the length of the river system. However, the experience has also shown that until delivery constraints are relaxed, either natural flows or environmental releases from additional tributaries (such as the Murrumbidgee or Lower Darling Rivers) are required to achieve particular flow targets. For example:
  - At a maximum flow rate of 15 000 ML/day downstream of Yarrawonga, satellite images show that only 25 per cent of Barmah-Millewa Forest was wet as a result of the Southern Spring Flow (CEWO 2020a). Benefits from this extent of inundation are significant. For example, Moira grass growth, flowering and seed-set, river red gum condition, and generation of food for native fish in watercourses downstream of the forest as far as South Australia (CEWO 2020a, GB CMA 2020a). However, additional benefits such as to vegetation in the remaining majority of Barmah-Millewa Forest, remains unattainable with water for the environment alone.
  - The combined Murray and Goulburn releases achieved a peak flow at the South Australian border of around 15 000 ML/day. This flow threshold has been shown to be important for shifting a noticeable proportion of the Lower River Murray from still water to flowing water habitat, which benefits native plants and animals that are adapted to a riverine environment (Ye et al. 2020). This type of flow cue, along with warmth triggers, is understood to in turn trigger spawning of golden perch. However, golden perch did not breed in the Lower River Murray in spring 2019, continuing a trend that has occurred over past 7 consecutive years (Ye et al. 2020). This result is a concern for the population health of the iconic golden perch. Experience suggests that aligning environmental releases from the Murray and Goulburn Rivers alone does not provide a flow pulse large enough, or for long enough, to allow golden perch to breed in the Lower Murray. Environmental releases will need to be coordinated with additional tributaries, or added to natural flow events, in order to achieve breeding success.

#### *End of system flows*

The importance of delivering water for end of system flows is significant and remains amongst the highest priorities in the River Murray. Recent benefits of flows to the end of the River Murray, including new approaches to managing this water within the Lower Lakes and as it is released into the Coorong estuary, are as follows:

- Flows through the barrages to the Coorong have been almost continuous since the Millennium Drought (Ye et al. 2020). Without water for the environment, barrages would need to have been closed for extended periods, effectively disconnecting the River Murray from its estuary. Connection to the estuary and sea is vitally important for many fish species to move between fresh and saltwater habitats to successfully reproduce, and for providing suitable food and habitat for migratory shorebirds.
- Environmental flows substantially increased salt export out of the Basin, reduced salt import into the Coorong and reduced salinity concentrations in the Coorong. Flows have prevented 20 million tonnes of salt building up in the Coorong from 2014 to 2019, avoiding catastrophic impacts that would have been reminiscent of those experienced during the Millennium Drought (Ye et al. 2020). In some years, environmental water has contributed to over 500 000 tonnes of salt being exported from the river and out the Murray Mouth (Ye et al. 2018). This is the equivalent of 25 000 semi-trailers each carrying a full load of salt (around 20 tonnes). Reducing salinity levels has benefits for native plants and animals, as well as for stock, domestic and irrigation purposes.
- Without water for the environment water, water levels in the Lower Lakes would have dropped to levels that are ecologically devastating without water for the environment several times since the Millennium Drought. Environmental water stored temporarily in the Lower Lakes, prior to its release into the Coorong, has provided significant benefits to the health of the Lower Lakes. This is through provision of increased variability in the water levels of the Lower Lakes. Benefits have included improved diversity and extent of fringing and submergent vegetation, improved populations of some small-bodied native fish species and increased habitat for waterbirds and migratory shorebirds (SA DEW, 2020).



- While large volumes of freshwater are required to manage the health of the entire Coorong, new approaches to managing small releases of water through the barrages to the Coorong can have significant benefits. For example:
  - Strategically releasing pulses of water through Tauwitchere barrages to coincide with favourable wind, tide and swell conditions has proven effective in reducing Coorong salinity levels along the full length of the North Lagoon (CEWO 2020b).
  - Water delivered to the Coorong estuary in spring and summer 2017-18 for black bream breeding was successful, with 100 young-of-year black bream detected in autumn 2018, and good numbers of age 1+ black bream subsequently reported in autumn 2019. Recent research suggests that successful black bream cohorts are associated with low to moderate barrage flows during spring and early summer (Ye et al. 2019).
  - Lamprey have been detected migrating even under low flow conditions (e.g. 2018). As such they remain a legitimate objective in similar conditions during winter/early spring, though more moderate flows are likely to enhance attraction to barrages and passage upstream (Bice et al. 2020).

#### *The value of flows all year round*

Environmental flows have moved in scope from being solely delivered to specific sites at specific times (during drought times and when environmental water holdings were relatively small). Water for the environment is now also being delivered in a manner that aims to provide benefits through the length of the river system, as discussed above. Recent experience has also demonstrated the benefit of delivering water through the entire year, particularly when ecological needs would otherwise not be met due to limited demand for operational flow resulting in flows ceasing unnaturally. For example:

- Several consecutive years of stable winter flows in Gunbower Creek, along with a spring rise, are considered to have been key to the observed improvement in the structure of Murray cod populations (Bloink et al. 2019).
- Winter flows, supported by water for the environment, in the Edward/Kolety-Wakool River system have prevented cease to flow conditions (caused by the winter shut down of the irrigation season) This has resulted in over a hundred kilometres of instream habitat throughout Yallakool Creek-Wakool River and Colligen Creek-Niemur River systems. The provision of winter flows has assisted with the movement of native fish, such as silver perch, throughout the system (Watts et. al., 2019). It is also expected that winter flows into the Edward/Kolety-Wakool River system will protect aquatic plants from frost damage and improve their rate of recovery in the following spring, however, will take more time to observe over multiple seasons (Watts et al. 2018).
- Further downstream, flows in winter enabling releases over the barrages and through fishways to the Coorong are essential for allowing pouched lamprey to complete their life cycle. Peak migration for pouched lamprey is understood to occur in August (Bice et al. 2020).
- In late summer and autumn, at a time when the majority of flow in the river is used for consumptive purposes, limited flows reach the end of system., Providing environmental water for the end of system during this period is highly important, however at times, system constraints have made this difficult to achieve. Environmental flow at this time of year has been critical in maintaining Lower Lakes water levels above 0.5 m AHD while still providing some connectivity to the Coorong through fishway flows. A sharp drop in lake levels over summer and autumn 2020 may have limited recruitment and health of small bodied fish in the Lower Lakes, which had spawned strongly during the 2019 spring pulse (Scott Wedderburn pers. comm. 2020).

Additional key findings that are specific to locations in the River Murray are summarised in Table 6.

**Table 6:** Key lessons learned in the Murray River

Theme	Lesson learned
Native fish	<ul style="list-style-type: none"> <li>• The results of Murray cod movement and survival, in response to the natural flooding event and associated hypoxic conditions in November and December 2016, has provided strong evidence for the importance of providing connectivity between the River Murray and its anabranch systems (Watts et al. 2019). Specifically, it is vital that connectivity is maintained prior to, during and after these events to allow fish to disperse and seek refuge and then return to the anabranch after the event has passed (Watts et al. 2019).</li> <li>• Despite necessary reductions in the large body native fish hydrograph in Gunbower Creek due to constraints in the system, monitoring in winter 2018 indicated that a reduced flow rate of 200 ML/day still provided adequate habitat and connectivity for Murray cod (NCCMA, 2020). This reduced flow rate will be targeted again in 2020-21 hydrograph.</li> <li>• Water for the environment has been successfully delivered to stimulating native fish spawning in several river systems, including in the River Murray valley. In the Mid-Murray, excellent recruitment has been observed across several native species over multiple years (Raymond et al. 2018). However, evidence of recruitment is more limited in other areas that are less permanently flowing (Watts et al. 2019, Ye et al. 2020). This has implications for increasing efforts to coordinate flows to achieve flow cues required to stimulate successful breeding in other areas, such as for golden perch in the Lower River Murray.</li> <li>• In the Edward/Kolety-Wakool River system, a slow recovery of the Murray cod population appears to be underway after the 2016 flood and related fish kills. This system also appears to provide a nursery area for silver perch, with periods of high flow in summer seeming to trigger spawning (Watts et al., 2018). Concerns remain about the lack of golden perch spawning or recruitment in this system over the past six years (particularly if a natural blackwater event similar to summer 2016 were to occur), highlighting the importance of golden perch migration into this system from the Darling and/or the Murray systems (Watts et al. 2019).</li> <li>• Monitoring of lamprey in winter-spring of 2019 has demonstrated that the migration season for lampreys is longer than previously understood, extending into late spring with peak migrations of short headed lamprey in September and October and August for pouched lamprey (Bice et al. 2020). During periods of limited water availability, releases through Goolwa and Mundoo barrages may elicit greater outcomes in relation to lamprey migrations compared to Tauwichee, given the proximity of these barrages to the Murray Mouth and fresher environment downstream of these barrages (Bice et al. 2020).</li> <li>• Successful spawning of black bream is known to occur in summer (late December to early February) with barrage releases between 600-5 000 ML/day and temperature of 18-25 degrees Celsius, 1-2 weeks after a ~10 000-20 000 ML/day pulse out the barrages.</li> <li>• Flows of greater than 20 000 ML/day at the SA border are found to be required to create a flowing river in the lower Murray, requiring coordination of Murray and tributary flows in dry years.</li> </ul>

Theme	Lesson learned
Native Vegetation	<ul style="list-style-type: none"> <li>• Areas of floodplain and wetland vegetation that have been able to be inundated for several consecutive years are showing benefit. <ul style="list-style-type: none"> <li>○ In Barmah Forest, low-level overbank spring flows have resulted in exceptionally good Moira grass growth and flowering was (particularly within grazing exclusion zones) during 2018-19 and 2019-20 (GB CMA 2020a).</li> <li>○ Wetland vegetation cover and diversity of species within wetlands in Gunbower Forest, indicates that environmental water delivery has provided an opportunity for wetland plants to germinate, flower and set seed (NCCMA 2020).</li> <li>○ River red gums that have received water following the 2016-17 flood have healthier canopies than those red gums in areas that remained dry (Mallee CMA 2020, North Central CMA 2020).</li> </ul> </li> <li>• Vegetation located at higher elevation floodplain and wetlands, or vegetation that has not been able to have follow-up water delivered, are more stressed. These results demonstrate the importance of consecutive watering events to consolidate the outcomes from natural floods to see sustained improvements in vegetation condition.</li> <li>• Providing a slow rate of recession to flows enables native water plants to avoid being stranded and drying out prior to completing their life-cycle (Watts et al. 2015).</li> <li>• The duration and extent of the 2016 flood wiped out many areas of in-stream aquatic plants (Watts et al. 2018). This highlights the importance of understanding the impact of duration and depth of flows on aquatic plant communities as noted in other MER monitoring sites (Dyer et al. 2018).</li> </ul>
Waterbirds	<ul style="list-style-type: none"> <li>• During dry and moderate years water for the environment can assist in maintaining foraging and breeding habitat and support localised bird breeding events. Recent research indicates that regular small-scale breeding events are likely to be key in maintaining populations. While unlikely to be contributing to population growth, they are important in maintaining genetic diversity in the population and providing some new recruits each year (McGinness et al. 2019). It is likely that large scale breeding events will only occur in wetter years where more broader landscape cues apply.</li> </ul>
Water quality	<ul style="list-style-type: none"> <li>• High flows through Millewa Forest have been demonstrated to provide a productivity boost into the Edward/Kolety-Wakool River system (Watts et al. 2016). If delivered at a cooler time of year to avoid poor water quality, the NSW Mid-Murray forests can play a role in providing food resources to the adjacent rivers and creeks.</li> <li>• Refuge flows during floods can also be effective in mitigating the risk of hypoxic water conditions caused by heatwave conditions during summer (Watts et al. 2019), particularly in the Niemur Creek and Wakool River systems. Similarly, water for the environment maintained oxygen levels in the Rufus River (flows into the River Murray from Lake Victoria), during a period of low oxygen in the water during natural flood in 2016-17 (Ye et al. 2018). Maintaining oxygen levels in localised areas can provide refuge habitats for aquatic organisms.</li> <li>• Pulsing water through Tauwichee barrages to opportunistically coincide with favourable wind and swell conditions has demonstrated to be effective in providing freshwater flow into the Coorong and reducing salinity levels albeit briefly.</li> </ul>

Theme	Lesson learned
	<ul style="list-style-type: none"> <li>• Maintaining flow through the fishway at the barrages for extended periods (e.g. 3 months during 2019-20 summer) are insufficient to prevent Coorong salinities increasing to 45 grams per litre. This represents a management threshold with levels above becoming lethal for some estuarine plants and animals (Taylor 2010).</li> <li>• Following three consecutive years of low barrage flows (average ~650 GL/year), South Lagoon salinities rose well above the 100 grams per litre management threshold during the 2019-20 summer, indicating that significantly more barrage flows are required to maintain a healthy South Lagoon.</li> </ul>
Connectivity and water delivery	<ul style="list-style-type: none"> <li>• Monitoring results from the Southern Spring Flow in 2019-20 indicated environmental watering resulted in a significant generation of carbon and nutrients from Barmah-Millewa floodplain and an increase in zooplankton abundance downstream of forest and in the Lower River Murray (CEWO 2020a). Reducing the carbon load on the floodplain will also reduce the risk of black water events during future flows.</li> <li>• A trial in the Yallakool Creek-Wakool River system during August-September 2018 (trialled delivery of flow at 800 ML/day instead of the existing limit of 600 ML/day) highlighted: <ul style="list-style-type: none"> <li>○ the importance of having a long lead in time for planning such an event with local land holders, agencies, community members and monitoring providers</li> <li>○ the need to have access to alternative delivery arrangements (such as the Murray Irrigation network) to deliver target flow rates in the event that WaterNSW infrastructure is unable to meet those flow rates</li> <li>○ the flow inundated one low level bridge in the Bookit Island area in the mid Wakool River and one creek crossing on Black Dog Creek, but this did not limit landholders access to their properties</li> <li>○ the flow trial increased lateral connectivity within the river system, increasing the wetted area by an average of 10.2 per cent (Watts et al. 2018).</li> </ul> </li> <li>• Where water availability allows and there are suitable natural triggers, early season delivery of environmental water assists in avoiding delivery constraints that arise during the irrigation season (spring-summer).</li> <li>• Fishways at the barrages (rock ramp and trapezoidal) continued to operate when Lower Lake levels fell below 0.6 m AHD, when previously thought to become non-functional. This provides future option of managing water levels below 0.6 m while continuing releases through the fishways.</li> <li>• Particularly in dry years, environmental water is critically important in supporting continuous flows through the barrages to the Coorong throughout the year, maintaining a connection between the river and the Coorong estuary to support a functioning river system.</li> </ul>

### 3.12.7 Bibliography

- Belcher, C., Borrell, A., Davidson, I. and Webster, R. (2018), *Australasian Bittern Surveys in the Murray Valley and Barmah National Parks 2018*
- Bice, C., Zampatti, B., Ye, Q. and Giatas, G. (2020). Lamprey migration in the lower River Murray in association with Commonwealth environmental water delivery in 2019. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.
- Bloink C., Halliday B., Robinson W. and Stevenson K. (2019). Gunbower TLM fish monitoring 2019. A report to the North Central Catchment Management Authority by Ecology Australia.
- Bureau of Meteorology (BoM) (2020) Climate outlooks – weeks, months and seasons. [ONLINE] Available at <http://www.bom.gov.au/climate/outlooks/#/temperature/maximum/anomaly/fortnightly/0>. [Accessed 11 June 2020].
- Commonwealth Environmental Water Office (2020a). Southern Spring Flow 2019 – Wrap-up <https://www.environment.gov.au/water/cewo/publications/southern-spring-flow-2019-wrap-up>
- Commonwealth Environmental Water Office (2020b). Wind, waves and wi-fi – A winning combination for the Coorong <https://www.environment.gov.au/cewo/media-release/wind-waves-wi-fi>
- Department of Environment, Land, Water and Planning (DELWP) (2015). *Long Term Watering Plan: Victorian Murray*, The State of Victoria Department of Environment, Land, Water and Planning, Melbourne.
- Department for Environment and Water (2020) Native fish recovery <https://www.environment.sa.gov.au/news-hub/news/articles/2020/01/native-fish-recovery-congolli>
- Department of the Environment (2011a). Environmental Water Delivery: Koondrook-Perricoota Forest, prepared by SKM and Hale, J., Commonwealth Environmental Water Office.
- Department of the Environment (2011b). Environmental Water Delivery: Yarrawonga to Tocumwal and Barmah-Millewa, prepared by Ecological Associates and SKM, Commonwealth Environmental Water Office.
- Department of Environment, Water and Natural Resources [DEWNR]. (2015). Long Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area.
- Dyer, F., Broadhurst, B., Tschierschke, A., Thiem, J., Thompson, R., Driver, P., and Bowen, S. (2018). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Lower Lachlan river system Selected Area 2017-18 Monitoring and Evaluation Technical Report. Commonwealth of Australia, 2018.
- Ecological Associates. (2010). The Environmental Watering Requirements of the South Australian River Murray.
- Ecological Associates. (2015). Environmental Water Management Plan for the River Murray from Lock 6 to Lock 10 – System Characterisation.
- Gehrig, S. (2018) Assessment of the responses of littoral and riparian vegetation to weir pool manipulations in Weir Pools: 7, 8, 9 and 15 of the River Murray. Final Report prepared for the Murray–Darling Basin Authority by the School of Life Sciences Albury–Wodonga and Mildura
- Goulburn Broken Catchment Management Authority (2020a). Barmah Forest Seasonal Watering Proposal (SWP) 2020-2021 (VEWH Addendum). Goulburn Broken Catchment Management Authority, Shepparton.
- Goulburn Broken Catchment Management Authority (2020b). Barmah Forest Early Observations for 2019-20. Goulburn Broken Catchment Management Authority, Shepparton.
- Hale, J. and SKM (2011). Environmental Water Delivery: Edward-Wakool. Commonwealth Environmental Water Holder for the Australian Government. Canberra.
- Kingsford, R., Porter, J. and Brandis, K. (2019). Aerial Waterbird Survey of Specified Environmental Assets: Notification of survey completion and 2019 Summary report

Mallee Catchment Management Authority. (2020). (in prep) Hattah Lakes & Lindsay Mulcra Walpolla Early Observations for 2019-20.

Murray–Darling Basin Authority (MDBA) (2019). Basin-wide environmental watering strategy. Second edition. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority (MDBA) (2012a). Assessment of environmental water requirements for the proposed Basin Plan: Gunbower-Koondrook-Perricoota Forest. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority. (2012b). Assessment of environmental water requirements for the proposed Basin Plan: Riverland Chowilla Floodplain. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority (MDBA) (2012c). Barmah-Millewa Forest Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority. (2012d). Chowilla Floodplain Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority. (2012e). Coorong, Lower Lakes and Murray Mouth Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority. (2012f). Hattah Lakes Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority. (2012g). Hydrologic modelling to inform the proposed Basin Plan: Methods and results. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority (MDBA) (2012h). Koondrook-Perricoota Forest Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority (MDBA) (2012i). Gunbower Forest Environmental Water Management Plan. Murray–Darling Basin Authority, Canberra.

Murray-Darling Basin Authority. (2018). Chowilla Floodplain Report Card 2017-18  
<https://www.mdba.gov.au/managing-water/water-for-environment/chowilla-floodplain-report-card-2017-18>

Murray-Darling Basin Authority (2020), Discover the Basin – Catchments:  
<https://www.mdba.gov.au/discover-basin/catchments>. [Accessed 2 June 2020].

Murray Lower Darling Rivers Indigenous Nations (MLDRIN) (2020). *First Nations Environmental Water Guidance Project. MLDRIN Member Nations 2020-21 Priorities*. Report provided to Commonwealth Environmental Water Office.

New South Wales Forests. (2020). (in prep) Koondrook-Perricoota Forest Early Observations for 2019-20.

North Central Catchment Management Authority. (2020). (in prep) Gunbower Early Observations for 2019-20.

North Central Catchment Management Authority (CMA) (2020). Draft Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2020-21. North Central Catchment Management Authority, Huntly, Victoria.

North Central Catchment Management Authority (CMA) (2017). Draft Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2017–18. North Central Catchment Management Authority, Huntly, Victoria.

North Central Catchment Management Authority (CMA) (2016a). Seasonal Watering Proposal for the Central Murray Wetland Complex 2016–17. North Central Catchment Management Authority, Huntly, Victoria.

North Central Catchment Management Authority (CMA) (2016b). Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2016–17. North Central Catchment Management Authority, Huntly, Victoria.

North Central Catchment Management Authority (CMA) (2015a). Seasonal Watering Proposal for the Central Murray Wetland Complex 2015–16. North Central Catchment Management Authority, Huntly, Victoria.



- North Central Catchment Management Authority (CMA) (2015b). Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2015–16. North Central Catchment Management Authority, Huntly, Victoria.
- North Central Catchment Management Authority (CMA) (2014a). Seasonal Watering Proposal for the Central Murray Wetland Complex 2014–15. North Central Catchment Management Authority, Huntly, Victoria.
- North Central Catchment Management Authority (CMA) (2014b). Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2014–15. North Central Catchment Management Authority, Huntly, Victoria.
- North Central Catchment Management Authority (CMA) (2013). Seasonal Watering Proposal for Gunbower Forest and Gunbower Creek 2013–14. North Central Catchment Management Authority, Huntly, Victoria.
- Nicol, J.M., Frahn, K.A., Gehrig, S.I., and Marsland, K.B. (2019). Lower Lakes Vegetation Condition Monitoring – 2018-19. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.
- Paton, D.C., Paton F.L. and Bailey C.P. (2018) Condition Monitoring of the Lower Lakes, Coorong and Murray Mouth Icon Site: Waterbirds in the Coorong and Lower Lakes 2018. The University of Adelaide and The Department for Environment and Water.
- Raymond, S. Tonkin, Z. Duncan, M. and Robinson, W. (in prep). Barmah-Millewa Fish Condition Monitoring: 2019.
- Raymond, S. Duncan, M. Tonkin, Z. and Robinson, W. (2018). Barmah-Millewa Fish Condition Monitoring: 2018.
- Roberts, J. and Marston, F. (2011). Water regime for wetlands and floodplain plants: A source book for the Murray–Darling Basin.
- South Australia Department for Environment & Water. (2020). (in prep) Early Observations for 2019-20.
- Taylor, B. (2010). Ecological Justification for the South Lagoon Salinity Reduction Scheme – A Discussion Paper. Department of Environment and Natural Resources, Adelaide, South Australia.
- Ye, Q., Giatas, G., Aldridge, K., Busch, B., Brookes, J., Gibbs, M., Hipsey, M., Lorenz, Z., Maas, R., Oliver, R., Shiel, R., Woodhead, J. and Zampatti, B. (2018). Long-term Intervention Monitoring of the Ecological Responses to Commonwealth Environmental Water Delivered to the Lower Murray River Selected Area in 2016/17. A report prepared for the Commonwealth Environmental Water Office by the South Australian Research and Development Institute, Aquatic Sciences.
- Ye, Q., Giatas, G., Brookes, J., Furst, D., Gibbs, M., Oliver, R., Shiel, R., Zampatti, B., Aldridge, K., Bucater, L., Busch, B., Hipsey, M., Lorenz, Z., Maas, R., and Woodhead, J. (2020). Commonwealth Environmental Water Office Long-Term Intervention Monitoring Project 2014–2019: Lower Murray River Technical Report. A report prepared for the Commonwealth Environmental Water Office by the South Australian Research and Development Institute, Aquatic Sciences.
- Ye, Q., Bucater, L., Furst, D., Lorenz, Z., and Giatas, G. and Short, D. (2019). Monitoring salt wedge dynamics, food availability and black bream (*Acanthopagrus butcheri*) recruitment in the Coorong during 2018-19. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.
- Wallace, T., Daly, R., Aldridge, K., Cox, J., Gibbs, M., Nicol, J., Oliver, R., Walker, K., Ye, Q. & Zampatti, B. (2014). River Murray Channel Environmental Water Requirements: Ecological Objectives and Targets.
- Watts R.J., Bond N.R, Grace M.R., Healy S., Howitt J.A., Liu X., McCasker N.G., Thiem J.D., Trethewie J.A. (2019). 'Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool River System Selected Area Technical Report, 2018-19'. Report prepared for Commonwealth Environmental Water Office. Commonwealth of Australia
- Watts, R.J., McCasker, N., Baumgartner, L., Bowen, P., Burns, A., Conallin, A., Dyer, J.G., Grace, M., Healy, S., Howitt, J.A., Kopf, R.K., Wassens, S., Watkins, S. and Wooden I. (2013). Monitoring the ecosystem responses to Commonwealth environmental water delivered to the Edward-Wakool river system, 2012–13. Institute for Land, Water and Society, Charles Sturt University, Final Report. Prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.
- Watts, R.J., McCasker, N., Howitt, J.A., Thiem, J., Grace, M., Kopf, R.K., Healy, S., Bond, N. (2017). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool

River System Selected Area Evaluation Report, 2016–17. Report prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.

Watts, R.J., McCasker, N., Howitt, J.A., Thiem, J., Grace, M., Kopf, R.K., Healy, S., Bond, N. (2016). 'Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool River System Selected Area Evaluation Report, 2015-16'. Report prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.

Watts, R.J., McCasker, N., Thiem, J., Howitt, J.A., Grace, M., Kopf, R.K., Healy, S., Bond, N. (2015). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool Selected Area Technical Report, 2014-15. Institute for Land, Water and Society, Charles Sturt University, Prepared for Commonwealth Environmental Water.

Watts, R.J., McCasker, N., Thiem, J., Howitt, J.A., Grace, M., Healy, S., Kopf, R.K., Dyer, J.G. Conallin, A., Wooden I., Baumgartner L. and Bowen P. (2014). Monitoring the ecosystem responses to Commonwealth environmental water delivered to the Edward-Wakool river system, 2013–14. Institute for Land, Water and Society, Charles Sturt University, Final Report. Prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.

Watts R.J., McCasker N.G., Howitt J.A., Thiem J.D., Grace M.R., Trethewie J.A., Healy S., Bond N.R. (2018). 'Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool River System Selected Area Technical Report, 2017-18'. Report prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.

Webster, R (2010). Environmental monitoring of Werai forest environmental flow: 2009–2010. Report prepared for NSW Department of Environment, Climate Change and Water by Ecosurveys Pty Ltd.

Wedderburn, S., Whiterod, N. and Gwinn, D. (2019). Determining the status of Yarra Pygmy Perch in the Murray–Darling Basin