Macquarie-Castlereagh Water Resource Plan

Surface water resource description
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1. Introduction

The NSW Government is developing water resource plans as part of implementing the Basin Plan 2012 (the Basin Plan). Water resource plans will align Basin-wide and state-based water resource management in each water resource plan area. The plans will recognise and build on the existing water planning and management framework that has been established in NSW.

The Macquarie-Castlereagh Water Resource Plan covers all of the surface water sources of the Macquarie, Bogan and Castlereagh rivers. The Plan incorporates the Macquarie and Cudgegong regulated river systems and the Macquarie-Castlereagh unregulated water sources. This report provides a detailed description of the surface water resources of the Macquarie-Castlereagh Water Resource Plan Area (SW11) to provide an understanding of the region and the resources covered by the Plan. It describes the location and physical attributes of the water sources and provides background information on the hydrology, environmental assets and water quality characteristics relevant to these water sources.

This report is intended to provide supplementary information to other water resource reports for the Macquarie-Castlereagh Water Resource Plan including the Risk Assessment and Water Quality Plan.

1.1 Overview of the plan area

The Macquarie-Castlereagh Water Resource Plan Area (WRPA) comprises the catchments of the Macquarie and Castlereagh rivers in the northern part of the Murray-Darling Basin in NSW (Figure 1). The WRPA covers around 91,960 km² and represents seven per cent of the Murray-Darling Basin.

The Macquarie River begins in the Great Dividing Range south of Bathurst, and flows in a north-westerly direction for 960 km until it joins the Barwon River near Brewarrina. The Bogan River rises in the Harvey Ranges near Peak Hill and flows roughly parallel to the Macquarie River across the north-western plains before joining the Barwon River downstream of Brewarrina. In the lower part of the catchment a series of creeks break away from the Macquarie River, connecting with the Bogan River.

The Castlereagh River rises in rugged country in the Warrumbungle Ranges near Coonabarabran and flows south-west, then north-west for 549 km to its confluence with the lower Macquarie River. The river passes through Coonamble and at the far end of the catchment runs parallel to the Barwon River. Here the lower floodplain carries flows from the Barwon River through to the Castlereagh River during major floods. The Castlereagh River joins the Macquarie system close to its confluence with the Barwon River near Brewarrina.

The Macquarie River is regulated by Burrendong Dam which is the major water storage in the valley. The dam was completed in 1967 and is one of the largest water storages in NSW. Windamere Dam, located on the Cudgegong River, provides a regulated supply for water users along the Cudgegong River and water for the towns of Mudgee and Gulgong.

The Wiradjuri people were the original inhabitants of the Macquarie catchment. On the downstream plains the Bogan River formed the boundary between the Wongaibon people to the west and the Wailwan people of the Castlereagh catchment in the east.

The Macquarie–Castlereagh WRPA is home to around 214,000 people (ABS 2011) which represents around nine per cent of the population of the Murray-Darling Basin. Just over half the people live within the cities of Bathurst, Orange and Dubbo which support around 38,000 people and act as regional centres for health, education and business services. Smaller towns within the WRPA include Mudgee (9,830 people), Wellington and Narromine (both around 4,500 people), Coonabarabran, Gilgandra and Coonamble (all around 3,000 people), Nyngan (2,389 people) and Warren (1,599).
1.2 Water management units
The surface water of the Macquarie-Castlereagh WRPA is currently managed through three water sharing plans comprising the regulated Macquarie River, the unregulated Macquarie-Bogan River, and the Unregulated Castlereagh River.

The **Macquarie and Cudgegong Regulated River Water Source** is defined as the water between the banks of all rivers, from the upstream limit of Windamere Dam storage to the junctions of the Macquarie River and its effluent rivers with the Barwon River. It includes a number of distributary channels that leave the Macquarie River downstream of Warren such as Gunningbar Creek, Marebone Creek, Duck Creek, Bulgeraga Creek and Crooked Creek.

The **Macquarie-Bogan Unregulated Water Sources** comprise all of the streams upstream of Burrendong Dam (excluding the regulated Cudgegong River), and all of the tributaries entering the Macquarie and Bogan rivers downstream of Burrendong Dam. There are 30 unregulated water sources managed through this plan.

The **Castlereagh Unregulated Water Source** comprises all of the streams within the catchment of the Castlereagh River. There are seven management zones managed through this plan.

The location of the above water sources is shown in Figure 2.

1.3 History of water management in the Macquarie-Castlereagh WRPA

**1.3.1 Macquarie Marshes Water Management Plan**

The idea of a water allocation for the Macquarie Marshes dates back to the completion of Burrendong Dam in 1967. During the planning and construction of the storage concerns were raised that floodplain inundation and water bird breeding may be adversely affected (Peacocke 1951). The Water Conservation and Irrigation Commission and National Parks and Wildlife Service agreed to an 18.5 GL “Wild Life Allocation.” Due to the wet conditions experienced during the 1970s the first use of the allocation was not until 1979. Further releases were made in 1983 and 1985. During these early releases much was learnt about transmission losses and the effects of wet versus dry antecedent conditions, which greatly affected the area of inundation that could be achieved (Hogendyk 2007).

In 1986 the Macquarie Marshes Nature Reserve was listed as a wetland of international importance under the Ramsar Convention. The lack of formal rules governing the use of the wildlife allocation release combined with increasing irrigation in the valley led to the development of a Water Management Plan for the Macquarie Marshes (DWR and NPWS 1986). This Plan was the first formal plan for the delivery of environmental flows in the Murray-Darling Basin (Hogendyk 2007).

The Plan increased the Wild Life Allocation to 50 GL of high security water. Over the next ten years research projects contributed to better knowledge of the Marshes hydrology and ecology including vegetation studies, groundwater investigations and river modelling. The Macquarie Marshes Catchment Committee was also established to encourage community involvement in managing the Macquarie Marshes (Hogendyk 2007).

The Plan was reviewed and in 1996 a revised plan came into effect (NPWS and DLWC 1996). The 1996 Water Management Plan added an additional 75 GL of general security water and limited off-allocation extraction by water users to 50 GL per year. River modelling indicated that the new Plan represented an increase in annual average inflows from 76 per cent of natural inflows under the 1986 plan to 85 per cent of natural inflows under the new Plan (Hogendyk 2007).
Figure 2: Location of water sources of the Macquarie-Castlereagh WRPA

Macquarie Regulated River Water Source

Cudgegong Regulated River Water Source

Data Sources: © Spatial Services - NSW Department of Finance, Services and Innovation 2016. Murray-Darling Basin Authority. NSW Department of Primary Industries. NSW Office of Environment and Heritage.

Map produced by DPI Water 11 April 2017
1.3.2 NSW Government water reforms
In February 1994 the Council of Australian Governments (COAG) endorsed a strategic framework for the efficient and sustainable reform of the Australian water industry. Following this meeting the NSW Government released a discussion paper in mid-1994 outlining reforms to the management of the state’s rivers and waterways. Early reforms included the development of water quality and river flow objectives, embargoes on new licences on regulated and unregulated rivers in the Murray-Darling Basin to meet an agreed cap on water extractions from the Basin, and a commitment to deliver water to key wetlands.

In 1997 the Government introduced its current program of rural water reforms that aimed to achieve a better balance in water use by more explicit and careful sharing of water between the environment and water uses. This program led to the development of the current legislative framework that defines how water is shared and managed under the Water Management Act 2000.

1.3.3 Macquarie Cudgegong Regulated River Water Sharing Plan
The Macquarie Cudgegong River Management Committee was formed in 1997 to initially determine environmental flow rules for the water source and then develop a river management plan. The committee included representatives from water users, environmental interest groups, the local Catchment Management Board and government agencies involved in water management (the then Department of Land and Water Conservation, National Parks and Wildlife Service, Environment Protection Authority and NSW Agriculture and Fisheries). The committee reached consensus on environmental flow rules for the Macquarie Cudgegong regulated system in 1998.

In 2001 the Minister for Land and Water Conservation asked the committee to recommend water sharing rules to manage both environmental and extractive water through a statutory plan. A draft water sharing plan was prepared by the committee and placed on public exhibition in mid-2002. The statutory plan was approved by the Minister in February 2003. It was based on the recommendations of the committee, submissions received from the community following the public exhibition period, and agreed Government policy at the time. Some amendments were made to the Plan in consultation with the Committee before the Plan commenced on 1 July 2004.

The water sharing plan did not change the share of environmental water allocated to the Macquarie Marshes through the 1996 Water Management Plan, but allowed it to be released in a much more variable and natural manner. This was achieved by transferring the 50 GL of high security water and 75 GL of general security water into 160 GL of general security water. The first release of environmental water to the Macquarie Marshes through the water sharing plan occurred in October/November 2005 (Hogendyk 2007).

The Water Sharing Plan for the Macquarie and Cudgegong Regulated River was amongst the first plans to be implemented in NSW. All of the 31 plans that commenced in 2004 were subject to a formal review towards the end of their ten year period of operation. Through this review process and associated consultation some minor amendments were made to parts of the Plan where there was considered to be no significant impact on water users.

In 2016 the Water Sharing Plan for the Macquarie and Cudgegong Regulated River was formally replaced and will continue operating to ensure continuity of rights to water while the water resource plan is being developed. All issues raised by stakeholders during the review process will be considered in the development of the water resource plan.

1.3.4 Macquarie-Bogan Unregulated Water Sharing Plan
After the first round of water sharing plans commenced in 2004 the government realised that a broader approach was required to implement water sharing in the unregulated water sources.
The Macquarie Interagency Regional Panel was established to guide the development of a ‘macro plan’ for the whole of the Macquarie unregulated catchment. The Plan was based on current government policy for defining water access with refinement of rules based on the local knowledge and expertise of the panel members. The draft water sharing rules were discussed with various specific interest groups in 2010 and were placed on public exhibition in September 2011. The Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources commenced on 4 October 2012.

The rules contained in the Water Sharing Plan for the Macquarie-Bogan Unregulated and Alluvial Water Sources will be reviewed during the development of the Macquarie-Castlereagh Water Resource Plan.

1.3.5 Castlereagh unregulated water sharing plans

The Central West Unregulated Streams Management Committee was established by the Minister for Land and Water Conservation to provide advice on water sharing rules in the Central West region. The Committee included representatives of water users for irrigation and grazing purposes, environmental interests, the Central West Catchment Management Board, local councils and government agencies (the then Department of Land and Water Conservation, National Parks and Wildlife Service, Environment Protection Authority, NSW Agriculture and NSW Fisheries). A draft Water Sharing Plan for the Castlereagh River above Binnaway was developed and placed on public exhibition in mid-2002. During the development of the draft plan, the Committee held public meetings, developed case studies with individual landholders to test the Plan provisions and sought committee member consultation with their constituents.

The Plan was approved by the Minister for Land and Water Conservation in 2003 and commenced on 1 July 2004. The Plan was based on the recommendations of the committee, public submissions received following the exhibition period and the government policy at the time.

Following on from the 2004 plans the NSW Government established Interagency Regional Panels to guide the completion of ‘macro’ water sharing plans for the remainder of the unregulated rivers. The Castlereagh Interagency Regional Panel comprised representatives from DPI Water, DPI Agriculture/Fisheries, Office of Environment and Heritage, and an observer from the Catchment Management Authority (now Local Land Services). Consultation with key stakeholders occurred in mid-2010 before the draft water sharing plan was placed on public exhibition at Coonamble and Gilgandra in December 2010. All submissions were considered before finalising the Water Sharing Plan for the Castlereagh River (below Binnaway) which commenced on 1 October 2011.

In 2016 the water sharing plan for the water sources below Binnaway was amended to incorporate the water source previously managed through the 2004 plan for the Castlereagh River above Binnaway which had reached the end of its term. The Castlereagh Interagency Regional Panel guided these amendments. The merging of the two water sharing plans to form the Water Sharing Plan for the Castlereagh and Alluvial Water Sources allows all water in the catchment to be managed through one plan and brings consistency in management across the plan area.
2. Regional setting

2.1 Climate

Rainfall

The Macquarie and Castlereagh catchments have a dry semi-arid climate. Average annual rainfall in the Macquarie catchment ranges from over 1,200 mm in the south-east to around 300 mm in the north-west. Rainfall across most of the lower catchment averages 300-500 mm/year (Figure 3). Across the Castlereagh catchment annual rainfall varies from around 800 mm in the Warrumbungle Ranges to 400 mm on the riverine plains in the north (Figure 3). Rainfall in the north of the region shows slight summer dominance with January and February being the months of highest rainfall at both Trangie and Coonamble, and the lowest months being August and September (Figure 4). At Mudgee in the upper catchment rainfall is significantly higher and more evenly distributed throughout the year. Summer months receive the highest rainfall while the autumn months are the driest (Figure 4).

Figure 3: Average annual rainfall in the Macquarie-Castlereagh WRPA

Figure 4: Average monthly rainfall for selected stations

Source: Bureau of Meteorology Climate Data Online
Climate change modelling for the Central West Region (OEH 2014a) predicts that spring rainfall across the region will decrease over the next 50 years while autumn rainfall is projected to increase over this timeframe. Summer rainfall is predicted to decrease slightly in the short term (to 2030) but by 2070 is predicted to increase by 20-30 per cent across the WRPA.

Evaporation

Evaporation in the Macquarie catchment has a strong east-west gradient. Average Class A pan evaporation varies from around 900 mm/year in the south-east, to over 2,200 mm/year in the north-west (Figure 5) and is highly seasonal throughout the year. At Trangie mean monthly evaporation in the summer months is more than 250 mm, which is around five times the rainfall received in those months. In winter evaporation is much less, being 50 mm in June and July (Figure 6).

Figure 5: Average annual evaporation across the Macquarie-Castlereagh WRPA

![Average Annual Evaporation Map](image)

Figure 6: Average monthly evaporation at Trangie 1889–2016

![Monthly Evaporation Chart](image)

Source: SILO Patched Point data
Temperature
At the higher elevations in the east, temperatures vary from a winter average minimum of 0°C to a summer average maximum of 25°C. Further west at Bourke, the average winter minimum temperature is around 3°C, ranging up to an average maximum summer temperature of 37°C.

Long-term temperature records indicate that temperatures in the Central West Region have been increasing since the 1970s (OEH 2014a). Climate change modelling for the region predicts that this warming will continue over the next 50 years, with mean temperatures increasing by an average of 0.7°C in the near future (2030) and 2.1°C in the far future (2070). The greatest changes in maximum temperatures will occur in spring and summer with temperatures increasing by 2.5°C by 2070 (OEH 2014a). The number of hot days (>35°C) is also projected to increase, particularly for the plains north-west of Dubbo, where an additional 10–20 hot days per year are predicted in the near future (2030), and an additional 30-40 hot days per year by 2070.

2.2 Land use
European settlement of the Macquarie valley commenced in 1818 when settlers took up land along the rivers and alluvial flats where there was good pasture for cattle. As the main river frontages were taken up, settlement spread along the river tributaries into the ranges.

Land use in the Macquarie-Castlereagh WRPA is dominated by extensive agriculture with over 70 per cent of the catchment being used for grazing and 15 per cent of the catchment used for dryland cropping (Table 1, Figure 7). Forestry, conservation and other native landscapes together account for about 10 per cent of the catchment area.

Although covering only one per cent of the WRPA, irrigated crops are very important to the economy of the region. The Macquarie valley supports a major cotton industry with four cotton gins plus related service providers, freight, and engineering services to support the industry. In years of high water availability up to 50,000 ha of irrigated cotton is grown producing around 400,000 bales of cotton worth around $244 million (EBC Consortium 2011). Other irrigated crops include wheat and cereals, fodder and pasture, lucerne, oilseeds and vegetables.

There is a large wine industry around Mudgee with around 160 wine producers, which between them grow around 3,300 ha of wine grapes (EBC Consortium 2011). The upper catchment also supports around 2,000 ha of lucerne and small plantings of olives, nuts and cherries.

Vegetables are grown on the Macquarie floodplain around Bathurst, while further downstream access to groundwater in the Narromine-Trangie area allows the cultivation of high value crops including apples, citrus, cherries, stone fruit, and grapes.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (sq km)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland Cropping and Horticulture</td>
<td>14,730</td>
<td>16</td>
</tr>
<tr>
<td>Grazing</td>
<td>67,110</td>
<td>72</td>
</tr>
<tr>
<td>Irrigation</td>
<td>919</td>
<td>1</td>
</tr>
<tr>
<td>Mining</td>
<td>16</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Forestry, conservation reserve and native vegetation</td>
<td>9,707</td>
<td>10</td>
</tr>
<tr>
<td>Residential</td>
<td>452</td>
<td>&lt;1</td>
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<tr>
<td>Urban intensive uses</td>
<td>239</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Water</td>
<td>439</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Agricultural and Resource Economics and Sciences, National scale land use 2010-11
Figure 7: Land use of the Macquarie-Castlereagh WRPA

Source: Australian Bureau of Agricultural and Resource Economics and Sciences, National scale land use 2010-11
2.3 Topographic description

The Macquarie-Castlereagh WRPA can be divided into three main areas based upon the topography and flow characteristics of the water sources. These are the upland, midland and lowland regions of the catchment (Figure 8).

Figure 8: Sub-regions of the Macquarie-Castlereagh WRPA

2.3.1 Upland zone

Macquarie and Cudgegong Rivers upstream of Burrendong Dam

The Macquarie River rises in the Great Dividing Range near Oberon and is formed by the junction of the Fish River and Campbells River upstream of Bathurst (Photo 1). From here it flows north-west before entering Burrendong Dam upstream of Wellington. Major tributaries include the Turon and Crudine Rivers; Queen Charlottes and Lewis Ponds Creeks; and Winburndale Rivulet. The rivers of the upper catchment flow within well-defined channels and have only limited floodplains.

The Cudgegong River starts in the Great Dividing Range above Rylstone and flows west into Windamere Dam near Mudgee. Below Windamere Dam the river continues into Burrendong Dam. The three major tributaries of Lawsons, Wyalda and Meroo Creeks flow into the Cudgegong River between the two dams. The upper reaches of the Cudgegong River flow through narrow valleys, broadening into a wide alluvial floodplain below Mudgee.

The water sources within this upland area are: Burrendong Dam Tributaries, Campbells River, Cooyal Wyadra Creek, Fish River, Lawsons Creek, Macquarie River above Burrendong, Piambong Creek, Pipeclay Creek, Queen Charlottes Vale Evans Plains Creek, Summerhill Creek, Turon Crudine Upper Cudgegong River, Winburndale Rivulet.
2.3.2 Midland zone

Macquarie River from Burrendong Dam to Narromine, Castlereagh River upstream of Gilgandra

The Macquarie River flows north-west from Burrendong Dam through the major towns of Dubbo (Photo 2) and Narromine. It is joined by three major tributaries – the Talbragar River which begins at Coolah and enters the river from the north, and the Bell and Little Rivers which begin near Molong and enter the river from the south. Numerous small ungauged creeks also enter the river within this reach. Within this reach the floodplain of the Macquarie River is well defined and relatively narrow.

The Castlereagh River flows from the Warrumbungle Ranges above the town of Coonabarabran. The river sweeps around in a broad circle – south, then west, then north-west – with all of its tributaries on the northern side originating as runoff from the steep volcanic slopes of the Warrumbungles. Major tributaries flowing out of these mountains are Jack Halls Creek, Belar Creek, Greenhall Creek, Yarragrin Creek and Wallumburrawang Creek. The upper Castlereagh River has a highly variable flow pattern. Some tributaries are influenced by springs, while others are dry for up to 25 per cent of the time (DNR 2005).

On the southern side of the river many of the tributaries originate from the similarly rugged ranges of the Coolah Tops. The major tributaries of Binnia Creek, Butheroo Creek and Merrygoen Creek all begin in this area. Towns and villages located on this upper reach of the river are Coonabarabran, Binnaway and Mendooran.

The water sources located within this midland area are: Bell River, Coolbaggie Creek, Little River, Lower Talbragar River, Maryvale Geurie Creek, Molong Creek, Upper Talbragar River and Wambangalong Whylandra Creek in the Macquarie catchment; and Castlereagh River Binnaway to Gilgandra, and Castlereagh River above Binnaway in the Castlereagh catchment.
2.3.3 Lowland zone
Bogan River, Macquarie River downstream of Narromine, and Castlereagh River downstream of Gilgandra

From Narromine, the Macquarie River flows north-west across flat alluvial plains to join the Barwon River between Walgett and Brewarrina. Three major tributaries flow into the Macquarie River in this section: Ewenmar Creek upstream of the marshes; Marthaguy Creek; and the Castlereagh River which enters the Macquarie about 20 km upstream of the confluence with the Barwon River.

The channel capacity of the river decreases progressively downstream of Narromine, and the Lower Macquarie valley is characterised by numerous effluent channels. Between Marebone Weir and Carinda the river flows for 120 km through a meandering network of effluent channels and anabranches including the Macquarie Marshes. Major effluent streams of the lower valley include the Albert Priest Canal (an artificial channel), Gunningbar and Duck Creeks which deliver regulated flows from the Macquarie River to the lower Bogan River; Terrigal Creek which flows north to join Marthaguy Creek; and Crooked and Marra Creeks which converge and flow north into the Barwon River.

The Bogan River starts in the Hervey Range near Peak Hill and flows north-west to Nyngan (Photo 3). The western side of the catchment is drained by four major tributaries: Bullock, Bulbodney, Pangee and Whitbarrow Creeks. The eastern catchment between the Bogan and Macquarie Rivers is ill-defined and has only one major tributary, Mulla Cowal with a catchment area of 1,000 km². The total catchment area of the Bogan River upstream of Nyngan is approximately 18,000 km².

Downstream of Gilgandra the Castlereagh River flows in a north-westerly direction within a limited floodplain. All of the runoff entering the river between Gilgandra and Coonamble
originates from the eastern side of the catchment. The major tributaries are Terrabile Creek, Gulargambone Creek and Baronne Creek, the latter two also having their origins in the Warrumbungle Ranges. The towns of Gilgandra, Gulargambone and Coonamble are all located adjacent to the river.

Downstream of Coonamble the Castlereagh River flows across a broad flat plain towards its junction with the lower Macquarie River (Photo 4). It is joined by several creek systems that contribute flows to the river after localised rainfall. The largest of these are Nebea and Terridgerie Creeks on the east side, and Mowlma and Nedgera Creeks on the west side. Mowlma Creek is a high-flow anabranch of the Castlereagh while the others have their own catchment areas originating on the plains. Nedgera Creek and Mowlma Creeks support the largest remaining areas of floodplain woodland and wetlands in the Castlereagh River (Green et al unpublished).

Downstream of the junction with Nedgera Creek the Castlereagh is joined by several effluents from the Barwon River which deliver water to the river under high flows. These include Cumbadoo Warrambool, Wanouri Creek and Womat Creek. The Castlereagh River enters the Macquarie River approximately 20 km upstream of its confluence with the Barwon River.

The water sources within this lowland area include: Backwater Boggy Cowal, Bulbodney Grahway Creek, Ewenmar Creek, Lower Macquarie River, Marra Creek, Marthaguy Creek, Lower Bogan River, Upper Bogan River, Castlereagh River below Coonamble, Castlereagh River Gilgandra to Coonamble, Nedgera Creek, Teridgerie Creek and Tooraweenah to Coonamble Tributaries.
2.4 Streamflow characteristics

2.4.1 Macquarie River

The Macquarie River is regulated by Burrendong Dam which provides water for town water supplies, irrigation, stock and domestic use, industry, and environmental flows along the Macquarie River and effluents of the lower Macquarie River. The volume and pattern of flows in the Macquarie River has been significantly altered by the construction of Burrendong Dam and the growing extraction of water for irrigation and other purposes.

Like most of the western flowing rivers in NSW, the flow in the Macquarie River decreases with distance downstream once it enters the flat alluvial floodplains of the lower valley. Decreasing channel capacity, irrigation and the presence of numerous effluent channels reduces the mean daily flow of the Macquarie River from over 3,000 ML/day at Dubbo to less than 900 ML/day upstream of the Macquarie Marshes. Further losses to the channels and wetlands of the Marshes result in an average flow of less than 400 ML/day being recorded at the Carinda gauge downstream of the Macquarie Marshes (Green et al 2011).

The longest running gauging station on the river is at Dubbo where flow has been recorded since 1885. Gauges at Warren and Wellington commenced in 1901 and 1909 respectively. The average annual flow for the Macquarie River at Dubbo is 1,175,888 ML. The Macquarie valley experienced a prolonged period of low flows between 2000 and 2010. Since then above average flow has been recorded in 2010 and 2012. The lowest annual flow occurred in 1919 when just 24,145 ML was recorded, while the highest annual flow occurred in 1950 when 10,113,000 ML was recorded over the year (Figure 9).

Figure 9: Annual flow in the Macquarie River at Dubbo 1915–2015

Daily streamflows provide an indication of the variability of flow patterns and the peak height of flood events. There have been several large floods in the Macquarie River at Dubbo (Figure 10). The largest of these was in February 1955 when daily flow peaked at more than 440,000 ML. Despite the generally dry conditions that prevailed over the early half of the 1900s, there were many more small to moderate floods during this period (with peaks of 100,000 to 250,000 ML) than in the latter half of the century. Since the regulation of the valley in 1967, which introduced
significant flood mitigation capabilities, there have only been three moderately large flood events, these being in 1971, 1990 and most recently in December 2010. Widespread rain and flooding along the Macquarie River through December 2010 resulted in the largest flood event in the Macquarie River since 1990 with flow peaking at 143,000 ML/day. The most recent flood in September 2016 recorded a maximum flow of 63,735 ML/d.

Figure 10: Daily flow in the Macquarie River at Dubbo

Daily and seasonal streamflow patterns in the unregulated streams vary across the Macquarie valley. Figure 11 shows the seasonal variation in daily flows for three streams in the upland (Turon River), midland (Talbragar River) and lowland (Bogan River) parts of the Macquarie valley. The upland and midland tributaries display similar seasonal flow trends. High flows (indicated by the 20\textsuperscript{th} percentile flow) are strongly seasonal, occurring mostly from August through to October while the median daily flow (50\textsuperscript{th} percentile flow) is highest from July through to November. However the Turon River in the upland generates higher volumes of water and low flow is more persistent throughout the year than in the Talbragar River. Despite having a catchment area more than three times that of the Turon River, the Talbragar River ceases to flow around 20 per cent of the time and the total volume of flow generated is much lower due to the lower rainfall in the headwaters. This leads to less reliable flow for water users along the midland tributaries of the Macquarie valley.

The Bogan River is typical of a lowland unregulated river. It ceases to flow for up to 50 per cent of the time, with flows decreasing downstream. Figure 11 shows that flow is far less persistent in the lowland area of the valley. High flows can be expected to occur most frequently in February and August, however they may occur at any time throughout the year. The median flow (50\textsuperscript{th} percentile) is zero for much of the year and water users are reliant on accessing and storing high flow events. For this reason there are relatively few share components along the unregulated section of the Bogan River.
Figure 11: High, median and low daily flows in the Macquarie catchment

Turon River at Sofala (Upland Macquarie)  
1950-2016

Talbragar River at Elong Elong (Mid-Macquarie)  
1970-2016

Bogan River at Dandaloo (Lowland Macquarie)  
1971-2016
2.4.2 Castlereagh River

The Castlereagh is an unregulated river that has no major water storages. Streamflows are highly variable and the sandy river bed is often dry. Mean daily flow in the Castlereagh River reaches a maximum of 405 ML at Coonamble after which flows decrease significantly. At the end of the river system, downstream of Nedgera Creek, the mean daily flow is just 86 ML.

There are seven active gauging stations within the catchment, however the records reflect the difficulties of maintaining accurate gauges in the presence of large mobile sand beds with many periods of missing data. This, combined with the fact that many water users access water from beneath the sand beds, means that water sharing rules in the Castlereagh Unregulated and Alluvial Water Sharing Plan are based mostly on visible flow rather than a reference gauge.

The longest period of record in the valley is at Mendooran where gauging commenced in 1913. It was suspended during the 1930s and 1940s and recommenced in 1953. The long term average annual flow at Mendooran is 103,249 ML (Figure 12). In the early part of the record, and during the millennium drought there have been a number of years for which no flow at all has been recorded in the river. The highest annual flows occurred in 1955 and 1956 with 600-700 GL recorded in both years. Drought conditions prevailed in the Castlereagh catchment for the ten years from 2000 to early 2010 however since then there have been a number of flood events.

Figure 12: Annual flow in the Castlereagh River at Mendooran 1913-2010

The largest flood occurred in February 1955 with a peak flow exceeding 118,000 ML at Mendooran. Moderate to large floods up to 50,000 ML/d have occurred on average every 5-10 years. The most recent flood events (recorded on other operating gauges) have occurred in February-March 2012, March 2013, and September 2016 (Rabbidge 2016).

Daily streamflows in the Castlereagh River vary seasonally as illustrated in Figure 13. The lowest median streamflows occur in the summer and early autumn from January to May. It is during this period that the Castlereagh River is most likely to cease flowing, as shown by the 80th percentile flow. High flows are most likely to occur in late winter and spring from July through to the end of September. Summer storms can also result in high flows occurring in February and March.
Figure 13: High, median and low daily flows in the Castlereagh River at Mendooran

Castlereagh River at Mendooran (Mid-Castlereagh catchment) 1968-2016

- 20th percentile daily flow
- Typical daily flow (50th)
- 80th percentile daily flow
3. Environmental assets

3.1 Parks and reserves

There is over 2,000 km$^2$ of land conserved within national parks and nature reserves within the Macquarie-Castlereagh WRPA. The majority of this area lies within the middle and upper parts of the Macquarie catchment while the Castlereagh catchment has around 760 km$^2$ of land reserved for conservation.

Turon National Park protects over 30 km$^2$ of open eucalypt forests and river oaks along the Turon River in the upper Macquarie catchment. Also in the upper catchment is Coolah Tops National Park in the Liverpool Range, which protects the headwaters of the Talbragar River which flows into the Macquarie River near Dubbo. The park features scenic lookouts, waterfalls and basalt ranges, and protects extensive areas of silvertop stringybark and snowgum forest (OEH 2014b).

Goobang National Park near Peak Hill forms an ecological island amongst the heavily cultivated landscape of the central west. Encompassing the Hervey Range, and rising to elevations of up to 800 metres above the surrounding plains, the park forms part of the catchment divide between the Macquarie and the Bogan Rivers. Vegetation communities include dry sclerophyll woodlands, grassy white box woodlands, heathland, and mallee. It supports a number of threatened animal species including the koala, regent honeyeater, glossy black cockatoo, superb parrot, and turquoise parrot (NPWS 2001).

The largest conservation areas in the Castlereagh catchment are Goonoo State Conservation Area south-east of Gilgandra, and Warrumbungle National Park where the headwaters of the Castlereagh River begin. Goonoo State Conservation Area comprises the largest remaining area of blue-leaf ironbark forest in NSW and provides habitat for the endangered malleefowl. Warrumbungle National Park features a rugged volcanic landscape of rocky spires, domes, and deep canyons. It supports a number of vegetation communities including grassy woodlands of white gum and narrow leaved ironbark, rough-barked apple and river red gums along the creek channels, and low shrubby heathlands on more exposed rocky sites. The park supports a large koala population and is the only area in NSW west of the Great Dividing Range where threatened brush-tailed rock-wallabies can be found (OEH 2012a).

The Macquarie Marshes Nature Reserve covers 219 km$^2$ which equates to around 10 per cent of the full extent of the Marshes. The reserve was gazetted in 1971 on an area of land previously set aside in 1900 for the preservation of game (NPWS 1993). The reserve protects the core wetland areas that are most frequently flooded, and contains samples of all the habitat types typical of the Marshes. Significant wetland areas are also located outside the nature reserve on private land, including extensive river red gum woodlands and some of the largest waterbird rookeries in the Marshes. In 2008 the Australian Government purchased the property ‘Pillicawarina’ which connected the north and south portions of the nature reserve and in 2012 an additional property, ‘Creswell,’ was added to the Nature Reserve.

3.2 Wetlands

Over 438,000 ha of wetlands have been mapped within the Macquarie and Castlereagh catchments of which 99 per cent are floodplain wetlands (Kingsford et al. 2003).

The Macquarie Marshes are listed as a wetland of international importance under the Ramsar Convention (Photo 5). The Ramsar site comprises the Macquarie Marshes Nature Reserve and two privately owned wetlands – Mole Marsh just outside the northern part of the Nature Reserve and the ‘Wilgara wetlands,’ 20 km east of the Reserve. The Macquarie Marshes contain a wide range of vegetation types including river red gum woodland, water couch grasslands, coolibah and black box woodlands, lignum swamps, reed swamps, cumbungi and river cooba. The diversity of vegetation communities within the Macquarie Marshes provides habitat for an array of wildlife including 233 bird species, 29 species of native mammal, 15 frog species, 60 reptile species and 11 native fish species (Dept Environment and Energy 2016).
The Macquarie Marshes were listed as a Ramsar site in 1986 after meeting five of the nine criteria, with two of these specifically relating to their value as waterbird habitat. The Macquarie Marshes are significant for colonial waterbirds, being one of the few remaining sites in Australia to support large breeding colonies of straw-necked ibis. They are also one of the few sites in NSW where magpie geese breed (Kingsford and Thomas 1995), and support some of the largest breeding colonies of intermediate egret, rufous night heron and royal spoonbill in southern Australia (OEH 2012b).

There are very few wetlands within the Castlereagh catchment as much of the floodplain in the lower catchment has been cleared for agriculture. Kingsford et al. (2003) mapped 17,000 ha of wetlands within the catchment, with most of this area representing two large areas of floodplain woodland and shallow swamps that are associated with Nedgera and Mowlma Creeks on the lower floodplain.

3.3 Hydrologic indicator sites

The Murray-Darling Basin Authority has identified the Macquarie Marshes as a key environmental asset within the Murray-Darling Basin and an important site for the determination of the environmental water requirements of the Basin. The Authority has undertaken a detailed eco-hydrological assessment of the water requirements of the Macquarie Marshes (MDBA 2012). Along with the flow requirements of other hydrologic indicator sites, these water requirements were integrated within the hydrological models used to determine the Environmentally Sustainable Level of Take (the ESLT) for the Basin Plan.

3.4 High ecological value aquatic ecosystems

The High Ecological Value Aquatic Ecosystem (HEVAE) framework consists of five key criteria (diversity, distinctiveness, naturalness, vital habitat and representativeness) that can be used at a range of scales to map and prioritise aquatic assets for water management (Aquatic Ecosystems Task Group 2012). The HEVAE framework was applied by DPI Water to assign an
ecological value to instream assets across NSW using four of the five criteria (the representativeness criteria was not used due to insufficient data).

Key aquatic assets that were included in assessing ecological values in the Macquarie WRPA included:

- Wetlands of international significance listed under the Ramsar Convention
- A number of endangered ecological communities (EEC) including carex sedgeland, coolibah-black box woodlands, carbeen open forest and the lowland Darling River EEC
- A diverse range of vegetation including river red gum forest and woodland, black box woodland and lignum
- Habitat for threatened bird species including Australasian bittern, Australian painted snipe, black-necked stork, black-tailed godwit, blue-billed duck, brolga, cotton pygmy-goose, curlew sandpiper, eastern osprey, freckled duck and magpie geese
- Threatened native fish species including Murray cod, olive perchlet, silver perch, trout cod and purple spotted gudgeon, and threatened populations of eel-tailed catfish
- Habitat for threatened species such as Sloane’s froglet, green and golden bell frog, Booroolong frog, yellow-spotted tree frog, southern bell frog, greater broad-nosed bat and river snail
- Other flow-dependent assets including the Macquarie River channel, the lower Macquarie River, and the effluent Creeks (e.g. Marrra Creek, Crooked Creek and Duck Creek) on the western side of the Marshes.

3.4.1 Ecological values in the regulated river

Parts of the regulated Macquarie River and lower Bogan River have very high instream values (Figure 14). The assessment shows a significant spread of threatened fish species and endangered ecological communities in the Macquarie-Castlereagh WRPA (Figure 15, Figure 16). Eel-tailed catfish are widespread in the Bogan, Macquarie and Castlereagh Rivers and trout cod are found in the middle reaches of the Macquarie River (Figure 15). Other threatened species found include silver perch, Murray cod and purple-spotted gudgeon.

Most of the regulated Macquarie River has high to very high ecological values due to a number of factors including the presence of a Ramsar site, the presence of threatened fish species; the presence of endangered ecological communities and large tracts of riparian vegetation and relatively undisturbed river reaches that provide habitat and contribute to primary production.

3.4.2 Ecological values in the unregulated rivers

Unregulated rivers in the following water sources have very high or high ecological value as assessed by HEVAE:

- Wambangalong Whylandra Creek supports endangered species (fish and frogs) and endangered ecological communities
- Lower Bogan River has endangered ecological communities and threatened frog species
- In the upland zone the Fish River supports several species of endangered frogs
- In the midland zone, Upper Talbragar, Maryvale-Geurie, and Coolbaggie Creek have high ecological values and consequence scores
- In the lowland zones the Upper Bogan, Bulbodney-Grahway Creek, Backwater-Boggy Cowel, Ewenmar Creek, Marra Creek, Lower Macquarie River (unregulated) and Marthaguay Creek all have high ecological values.
Figure 14: Instream values for the Macquarie-Castlereagh WRPA

Figure 15: Distribution of threatened fish species within the Macquarie-Castlereagh WRPA
Figure 16: Endangered ecological communities in the Macquarie-Castlereagh WRPA
4. Water quality

4.1 Background

Degradation of water quality can put stress on a range of aquatic organisms, affect Aboriginal cultural and spiritual uses of water, increase the cost of drinking water treatment, contribute to public health risks, and decrease the suitability of water for irrigation (DPI Water 2016a).

Water quality condition in the Macquarie-Castlereagh WRPA varies from poor to good. The water quality status map (Figure 17) provides an overview of water quality condition within the plan area. Water quality condition index scores are an integrated indicator of total nitrogen, total phosphorus, pH, turbidity and dissolved oxygen at main monitoring locations in the Plan area. The scores were calculated using the frequency and amplitude of exceedance of water quality targets listed in the Basin Plan between the years 2010-11 and 2014-15. Specific indices were also included for thermal pollution, harmful algal blooms, and salinity for irrigation water.

Water quality problems occurring within the catchment are mostly caused by a combination of alteration to natural flow regimes and land use change (DPI Water 2016a; DPI Water 2016b). The following sections provide a summary of the water quality status and issues in the different areas of the Plan (DPI Water 2016a).

Figure 17: Water quality condition of the Macquarie-Castlereagh WRPA

WaQI Scores: Blue = Excellent (100-95), Green = Good (94-80), Orange = Fair (79-60), Red = Poor (59-1).
4.2 Upland region
Condition: Fair to Good

Dissolved oxygen concentrations were mostly within the targeted range for the period of analysis. pH was also generally within the target range but was occasionally elevated in the Turon and Macquarie Rivers. Salinity in the upland was mostly low and negatively related to discharge ie, the highest salinities occur during lowest flow periods.

Nutrients (nitrogen and phosphorus) and suspended sediments were mostly within the target ranges for the upland water sources. Harmful algal blooms occur regularly during the warmer months in both Windamere and Burrendong dams, and less frequently in Ben Chifley Dam.

4.3 Midland region
Condition: Poor to Good

Thermal pollution occurs in the Macquarie River for up to 400 km below Burrendong Dam (DPI Water 2016b). This results in water temperatures below natural during the summer months, and above natural during the winter months. Burrendong Dam recently had a thermal curtain installed in order to help mitigate the risk from cold water pollution. The thermal curtain allowed the drawing of warmer surface waters towards the dam outtake. Unfortunately, technical issues associated with the operation of the curtain have resulted in the curtain being temporarily removed pending design modification. The risks associated with cold water pollution downstream of Burrendong Dam therefore remain (DPI Water 2016b).

Temperature has a wide range of influences on biological processes, where the release of cold water can interrupt important biological cues such as spawning in fish and other fauna. It can also reduce the growth rate of fish and increase mortality (Lugg and Copeland 2014).

Thermal impacts in the Cudgegong River below Windamere Dam are much smaller with only a small change in water temperature during bulk water releases in summer. This is because Windamere Dam has a variable level offtake (DPI Water 2016b).

Dissolved oxygen, pH, and suspended sediments were generally within target ranges in the midland water sources and salinity levels are low. Nutrients such as nitrogen and phosphorus are generally within target ranges except in the Talbragar River and below Burrendong Dam where they are elevated.

4.4 Lowland region
Condition: Poor

All four sites in the lowland part of the WRPA are assessed as having poor water quality scores. Dissolved oxygen levels were frequently recorded outside of the target range due to increased levels of organic carbon, nutrients and high temperatures, which result in increased microbial respiration.

pH was generally within the target range and salinity is low, however nutrients in all three major streams (Macquarie, Castlereagh and Bogan) are high. Turbidity and suspended sediment were high. These high levels of turbidity can be influenced by a number of factors including land use, riverbank and riparian condition, and the presence of European carp. Clay dominated soils also have an increased susceptibility to re-suspension within the water column.
5. Riparian and geomorphic condition

Riparian vegetation is a key attribute connecting rivers and terrestrial ecosystems. It is important for controlling river bank stability, mitigating runoff, influencing instream processes and providing habitat for a range of biota (Lovett and Price 2007). Leaf litter derived from riparian vegetation is a key contributor of allochthonous energy sources into rivers, driving primary production and stimulating the development of food chains (Robertson et al. 1999; Westhorpe et al. 2010). Native riparian vegetation cover greater than 60 per cent and a riparian buffer zone width of up to 30 m are considered to be important for influencing good riparian condition (Jansen et al. 2003).

River Styles® recovery potential is related to geomorphic condition. It gives an indication of the capacity of a stream to return to good condition or to a realistic rehabilitated condition (Brierley and Fryirs 2005). Streams rated as having conservation or rapid recovery potential are likely to be the most stable and in a good condition, whereas streams with low recovery potential may never recover to a natural condition or may continue to decline quickly without intervention (Cook and Schneider 2006).

There has been extensive clearing of riparian vegetation throughout the Macquarie-Castlereagh WRPA. The highest areas of remaining riparian vegetation occur within conservation reserves in the upper Macquarie and upper Castlereagh catchments, along the Macquarie River downstream of Warren, and along the Bogan River (Figure 18).

For river recovery potential river reaches identified as being ‘strategic’ can be in good, moderate or poor geomorphic condition. These reaches are often undergoing rapid change and should be a focus for action to control degradation. The recovery potential within the lower reaches of the catchment is generally good, however many streams in the upper catchment of the Macquarie River and Castlereagh River are classed as having low recovery potential (Figure 19).
Figure 19: Geomorphic recovery potential in streams in the Macquarie-Castlereagh WRPA
6. River operations and management

6.1 Storages and regulating structures

6.1.1 Burrendong Dam

Burrendong Dam is located on the Macquarie River just below its junction with the Cudgegong River, about 30 km upstream from Wellington. It is the largest storage in the Macquarie catchment and one of the largest storages in NSW. Completed in 1967 the dam has a total operating capacity of 1,678,000 ML which includes 489,000 ML of airspace for flood mitigation purposes. In addition to irrigated agriculture and environmental flows, the dam provides water for town supplies, industry and domestic requirements, flood mitigation and recreation, and a 19 megawatt hydroelectric power station which generates using summer irrigation and flood mitigation (Water NSW 2016).

The dam experienced extended periods of low inflows during the drought years from 2003 to 2011 (Figure 20, Photo 6). Storage levels again fell to around 20 per cent of capacity during 2014-15 with the annual inflow of 152,256 ML being only 15 per cent of the long-term average inflow (Burrell et al. 2016). However the significant inflows received in 2016 returned the storage to 100 per cent capacity.

Burrendong Dam is a popular inland sport and recreation destination, offering year-round attractions for water sports and fishing enthusiasts, nature lovers, bushwalkers, campers and picnickers.

Figure 20: Burrendong Dam storage levels 1993-2016

![Burrendong Dam mean daily storage (ML)](image)

Photo 6: Burrendong Dam during drought in 2008
Dayle Green
6.1.2 Windamere Dam

Windamere Dam is on the Cudgegong River 30 km upstream of Mudgee (Photo 7). It has a storage capacity of 368,120 ML. The earth and rockfill dam was completed in 1984 to provide town water supply for Mudgee and Gulgong and water for irrigators and stock and domestic users along the Cudgegong River. A 55 m variable inlet tower allows for control over the quality and temperature of water released to the river.

Windamere Dam has been full to capacity only twice since it was constructed – for an extended period in the early 1990s and again in 2001-2002 (Figure 21). From 2006 to 2010 the storage was operating under severe drought conditions with storage volumes dropping to less than 15 per cent of capacity in 2010. The past five years have seen storage levels recover to around 50 per cent of capacity. In 2014-15 the annual inflow to Windamere Dam was 9,944 ML which is 18 per cent of the long-term average inflow (Burrell et al. 2016).

Windamere Dam offers similar recreational opportunities as Burrendong Dam. Windamere Dam is regularly stocked with golden perch, Murray cod, silver perch, and catfish.

Figure 21: Windamere Dam storage levels 1985-2016
6.1.3 Other storages and regulators

A number of smaller dams within the upper Macquarie catchment provide for town water supplies.

Oberon Dam on the Fish River is operated as part of the Fish River Water Supply Scheme and was completed in 1946. It services a number of water users including the towns of Lithgow and Oberon. Water is also transferred by Water NSW to meet urban water demands in the upper Blue Mountains, and Delta Electricity has an entitlement for use in their Wallerawang power station. Oberon Dam is classed as alpine waters and is well-known for its trout fishing with brown trout and rainbow trout stocked annually.

Ben Chifley Dam is the major water storage for Bathurst City Council. Located on Campbells River, water is released from the dam and diverted by Council from the Macquarie River downstream. Suma Park Dam was completed in 1962 and is the major water supply for the city of Orange. The towns of Rylstone and Kandos are supplied from Rylstone Dam on the Cudgegong River upstream of Windamere.

Downstream of Burrendong Dam there are five weirs that regulate the diversion of water within the Lower Macquarie River (Figure 22).

- Dubbo, Narromine and Gin Gin weirs are all ponding structures that provide pumping pools for irrigation diversion.
- Warren Weir controls the diversion of flow into Gunningbar Creek from which further regulators supply Duck Creek, Crooked Creek and the Albert Priest Canal.
- Marebone Weir is located just upstream of the Macquarie Marshes. It supplies water to Marra Creek on the southern side of the river, and Bulgeraga Creek (via Marebone Break) on the northern side of the river.

Figure 22: Location of weirs in the Macquarie-Castlereagh WRPA
6.2 Licensed water use

6.2.1 Regulated river entitlement and usage

The Macquarie catchment uses around 4 per cent of all surface water diverted in the Murray-Darling Basin (CSIRO 2008). Water from Burrendong and Windamere dams is released on an annual basis to meet the needs of general security and high security irrigators, stock and domestic users, and town water supplies.

A total of 725,175 ML of entitlement exists within the WRPA, which is associated with the regulated Macquarie-Cudgegong River (Table 2). Licences are located along the full length of the river however the largest volumes of entitlement occur along the lower Macquarie River below Narromine.

The majority of these are general security irrigators who account for 87 per cent of the regulated entitlement in the WRPA. The availability of general security water is less reliable and is affected by storage levels. Available water determination announcements at the beginning of each water year determine the volume of water that is added to an individual’s licence allocation account.

Long term modelling indicates that general security water users in the Macquarie-Cudgegong valley receive 100 per cent of their share component plus carryover at the start of a water year in 24 per cent of years. By the end of the water year general security users have access to 100 per cent of their share component plus carryover in 43 per cent of years (Figure 24).

Around 17,913 ML of high security entitlement currently exists within the WRPA for irrigation, town water supply, and research purposes. The availability of high security water is guaranteed (unless exceptional drought conditions occur) and must be provided for prior to allocating water to other user users. In addition there is 18,805 ML allocated to local water utilities, which also receive priority over general security water users.

There is 49,998 ML of entitlement for supplementary water within the Macquarie and Cudgegong system. When flows in the river are greater than orders, access to this surplus water is declared. During these times, irrigators can divert water without debit to their general security account.

The regulated Macquarie and Cudgegong systems are managed under an annual accounting system. Under this system water is set aside to enable the delivery of essential requirements in a repeat of the lowest period of inflows. The remaining water held in storage is then distributed to licence holders as allocation, which may be adjusted throughout the year if water resources improve. The maximum volume of water that can be carried over from one water year to the next is 1 ML per share for general security and conveyance licence holders. No carryover is permitted for all other types of access licences.

Table 2: Regulated river share components for the Macquarie-Castlereagh WRPA 2016

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>Macquarie regulated share component (ML)</th>
<th>Cudgegong regulated share component (ML)</th>
<th>TOTAL (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Stock</td>
<td>5,269</td>
<td>724</td>
<td>5,993</td>
</tr>
<tr>
<td>Local water utility</td>
<td>16,205</td>
<td>2,600</td>
<td>18,805</td>
</tr>
<tr>
<td>Regulated river (general security)</td>
<td>612,573</td>
<td>19,893</td>
<td>632,466</td>
</tr>
<tr>
<td>Regulated river (high security)</td>
<td>12,500</td>
<td>5,413</td>
<td>17,913</td>
</tr>
<tr>
<td>Supplementary water</td>
<td>48,686</td>
<td>1,312</td>
<td>49,998</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>695,233</strong></td>
<td><strong>29,942</strong></td>
<td><strong>725,175</strong></td>
</tr>
</tbody>
</table>
Figure 23: Distribution of regulated entitlement in the Macquarie-Castlereagh WRPA
The actual water used each year varies depending on rainfall and the amount of water available in the accounts. Since the water sharing plan began in 2004 the average annual water use from the Macquarie River has been 179,352 ML (Burrell et al. 2016).

Figure 25 shows the water available in the Macquarie River since the water sharing plan commenced in 2004. The first half of this period was affected by the Millennium drought, when general security licences had very low allocations. At the start of the 2015-16 water year 100 per cent of share component was available for domestic and stock, local water utility and high security irrigators, while general security irrigators had access to just 13 per cent of their share component. The reduced water availability for general security users in recent years is reflected in the reduced levels of water usage in 2014-15 and 2015-16 (Figure 26).

General security irrigators in the Cudgegong River have received their full share component (or close to it) in most years (Figure 27). At the beginning of the 2015-16 water year general security irrigators had 64 per cent of their share component available while all other licence categories had 100 per cent. Average annual usage in the Cudgegong regulated river since commencement of the water sharing plan is 5,787 ML (Burrell et al. 2016). In 2015-16 the reduced water available to general security users resulted in water usage being below the average at around 4,000 ML (Figure 28).
Figure 25: Water availability in the Macquarie Regulated River

![Water availability in the Macquarie Regulated River](image)

Figure 26: Water usage in the Macquarie Regulated River

![Water usage in the Macquarie Regulated River](image)

Figure 27: Water availability in the Cudgegong Regulated River

![Water availability in the Cudgegong Regulated River](image)

Figure 28: Water usage in the Cudgegong Regulated River since introduction of water sharing

![Water usage in the Cudgegong Regulated River since introduction of water sharing](image)
6.2.2 Unregulated river entitlement

Water users located on the various unregulated tributaries of the Macquarie-Castlereagh WRPA are entitled to extract water with an unregulated water licence. These licences are subject to a range of access conditions, including cease to pump triggers that protect the health of the watercourses. Detailed water use is not available in the unregulated rivers because currently there is not broad scale metering in these water sources. Water is also extracted from these water sources through basic landholder rights, which do not require a licence.

There is approximately 310,586 ML of entitlement allocated to water users on unregulated streams in the Macquarie-Castlereagh WRPA (Table 3). These water users are managed through two separate water sharing plans – the Macquarie-Bogan Unregulated and Alluvial plan and the Castlereagh Unregulated and Alluvial plan.

The majority of the unregulated licences managed through the Macquarie-Bogan plan are located in the upper catchment, such as on the Bell River, Molong Creek, Summerhill Creek and Macquarie River above Burrendong Dam however licensed volumes in these water sources are generally low (Figure 29). The majority of entitlement by volume is located in the lower end of the catchment, in the Lower Bogan River and Lower Macquarie River water sources, where large volumes of water are available for extraction under special (high flow) access licences. Most of the unregulated entitlement is used for the irrigation of crops including vegetables, fodder, seed crops and cotton (NOW 2012).

Four of the unregulated water sources within the Macquarie-Bogan water sharing plan are classified as being of high economic significance to local communities due to their dependence on commercial water extraction. These are Fish River, Macquarie River above Burrendong, Molong Creek and Queen Charlotte’s Vale Evans Plains Creek (NOW 2012).

The majority of the unregulated licences managed through the Castlereagh Unregulated water sharing plan are located in the Castlereagh River above Binnaway water source. Most of the remaining licences are located along the Castlereagh River between Binnaway and Coonamble. Many of the licences in this downstream reach extract from the coarse grained river bed sediments via spear points which allow access to water up to a depth of about 8 m below the water pump. Water extracted from the Castlereagh River is mainly used in spring and autumn as a supplement to rainfall for fodder and cereal crops (Rabbidge 2016).

Table 3: Unregulated share components for the Macquarie-Castlereagh WRPA 2016

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>Macquarie-Bogan share component (ML)</th>
<th>Castlereagh share component (ML)</th>
<th>TOTAL (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Stock</td>
<td>1,517</td>
<td>229</td>
<td>1,746</td>
</tr>
<tr>
<td>Domestic and Stock (Town Water Supply)</td>
<td>2,455</td>
<td>0</td>
<td>2,455</td>
</tr>
<tr>
<td>Local Water Utility</td>
<td>29,124</td>
<td>1,771</td>
<td>30,895</td>
</tr>
<tr>
<td>Unregulated River Access</td>
<td>113,358</td>
<td>17,312</td>
<td>130,670.5</td>
</tr>
<tr>
<td>Major Utility</td>
<td>15,876</td>
<td>0</td>
<td>15,876</td>
</tr>
<tr>
<td>High Flow</td>
<td>44,501</td>
<td>3,330</td>
<td>47,831</td>
</tr>
<tr>
<td>Unregulated River (Regulated Supply)</td>
<td>68,901</td>
<td>0</td>
<td>68,901</td>
</tr>
<tr>
<td>Unregulated River (Regulated Supply – LWU)</td>
<td>1,850</td>
<td>0</td>
<td>1,850</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>277,582</strong></td>
<td><strong>22,642</strong></td>
<td><strong>300,224</strong></td>
</tr>
</tbody>
</table>
Figure 29: Distribution of unregulated entitlement in the Macquarie-Castlereagh WRPA
Around 10 per cent of unregulated entitlement within the WRPA is allocated for town water supplies and is managed by various local government authorities as listed in Table 4. The largest water supply schemes are operated by Bathurst Regional Council, which diverts water from the upper Macquarie River, and Orange City Council which extracts water from Summerhill Creek. Some of the suppliers listed in Table 4 also extract water from alluvial water sources.

In some of the unregulated water sources competition for water during low flows can be an issue between agricultural users and the local water utility. In recognition of the role of local water utilities in meeting “critical human needs” the water sharing plans currently operating in the WRPA allow access to very low flows for town water supply purposes (below the cease-to-pump level), while other licensed holders are prohibited from extracting.

There is one Major Water Utility within the WRPA, this being the Fish River Water Supply Scheme. The scheme, which is operated by Water NSW, supplies water to Oberon and Lithgow (from Oberon Dam), to various townships in the Blue Mountains and to Delta Electricity for power generation. There are also numerous minor customers that extract water from the Scheme for domestic supply. The Fish River scheme is licensed to divert 15,876 ML/year from the upper Macquarie catchment.

Table 4: Town water supply entitlements from unregulated water sources

<table>
<thead>
<tr>
<th>Local Water Utility</th>
<th>Water source</th>
<th>Town supplied</th>
<th>Entitlement (ML/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathurst Regional</td>
<td>Macquarie above Burrendong</td>
<td>Bathurst</td>
<td>17,500</td>
</tr>
<tr>
<td>Bathurst Regional</td>
<td>Winburndale Rivulet</td>
<td>Bathurst</td>
<td>1,000</td>
</tr>
<tr>
<td>Bogan Shire</td>
<td>Bulbodney Grahway Creek</td>
<td>Nyngan</td>
<td>1,290</td>
</tr>
<tr>
<td>Bogan Shire</td>
<td>Bulbodney Grahway Creek</td>
<td>Coolah, Girilambone</td>
<td>34</td>
</tr>
<tr>
<td>Cabonne Shire</td>
<td>Bell River</td>
<td>Cumnock</td>
<td>80</td>
</tr>
<tr>
<td>Cabonne Shire</td>
<td>Little River</td>
<td>Yeoval</td>
<td>102</td>
</tr>
<tr>
<td>Cabonne Shire</td>
<td>Molong Creek</td>
<td>Molong</td>
<td>502</td>
</tr>
<tr>
<td>Cobar Shire</td>
<td>Bulbodney Grahway Creek</td>
<td>Cobar</td>
<td>600</td>
</tr>
<tr>
<td>Coonamble Shire</td>
<td>Castlereagh River Gilgandra to Coonamble</td>
<td>Gulargambone</td>
<td>58</td>
</tr>
<tr>
<td>Gilgandra Shire</td>
<td>Castlereagh River Gilgandra to Coonamble</td>
<td>Gilgandra</td>
<td>1,500</td>
</tr>
<tr>
<td>Gilgandra Shire</td>
<td>Tooraweenah to Coonamble Tributaries</td>
<td>Tooraweenah</td>
<td>37</td>
</tr>
<tr>
<td>Greater Lithgow</td>
<td>Fish River</td>
<td>Tarana</td>
<td>15</td>
</tr>
<tr>
<td>Mid Western Regional</td>
<td>Cooyal Wialdra Creek</td>
<td>Gulgong</td>
<td>111</td>
</tr>
<tr>
<td>Mid Western Regional</td>
<td>Upper Cudgegong River</td>
<td>Rylstone</td>
<td>2,500</td>
</tr>
<tr>
<td>Narromine Shire</td>
<td>Upper Bogan River</td>
<td>Tomingley</td>
<td>22</td>
</tr>
<tr>
<td>Orange City</td>
<td>Summerhill Creek</td>
<td>Orange</td>
<td>7,800</td>
</tr>
<tr>
<td>Parkes Shire</td>
<td>Upper Bogan River</td>
<td>Tullamore</td>
<td>10</td>
</tr>
<tr>
<td>Warrumbungle Shire</td>
<td>Castlereagh above Binnaway</td>
<td>Coonabarabran</td>
<td>959</td>
</tr>
<tr>
<td>Warrumbungle Shire</td>
<td>Binnaway to Gilgandra</td>
<td>Merrygoen</td>
<td>175</td>
</tr>
<tr>
<td>Wellington Shire</td>
<td>Bell River</td>
<td>Euchareena</td>
<td>15</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>34,310</strong></td>
</tr>
</tbody>
</table>
6.3 Water trading

In 1983-84 the temporary transfer of water licences (allocation trade) was introduced in regulated systems to facilitate business flexibility and optimise the benefits of water use to the NSW economy. Additionally, in 1989 permanent trades (entitlement trade) in regulated systems were provided for, and the NSW water market commenced to rapidly grow.

The implementation of water sharing planning has removed barriers to the efficient operation of these water markets, facilitating more efficient and better-informed trades. This has been achieved through the inclusion of clear rules for trading in water sharing plans, the separation of the water licence from the land title in 2004, and the establishment of public registers in 2004, showing the volume and price paid for access licences.

Permanent trades include both share assignments and the sale of the licence entitlement. There has been significant acquisition of environmental share components in the Macquarie valley under NSW and Commonwealth buy-back schemes since 2006 (Figure 30). The majority of water traded is general security water however there is also smaller amounts of supplementary and high security water traded permanently.

Temporary trades are temporary assignments of shares where water in a licence holder’s account is sold, but ownership of the licence is retained. Figure 31 and Figure 32 show temporary water licence trades within the Macquarie-Cudgegong Regulated River water source. Variations between years are mostly related to climatic conditions and the volume of water made available to different licence categories.

Assignments in relate to water that is traded into licences, and assignments out relate to water that is traded out of licences. A lot of temporary trading occurs between licences within the Macquarie River, while the majority of temporary transfers (75 per cent) in the Cudgegong River Management Zone are transferred downstream to the Macquarie River. The net assignments out of the Macquarie relate to the shares that have been temporarily traded to the Cudgegong. Similarly the net assignments out of the Cudgegong show the transfers to the Macquarie.

Trading activity is highest in the years of plentiful flow (most recently 2012-13 and 2013-14). Trading activity has decreased in the past two years due to the low levels of general security water available to Macquarie water users during these seasons.

Figure 30: Permanent trades for environmental and commercial use
6.4 Environmental water

Water sharing plans allow for two types of environmental water. Held environmental water is an entitlement that is held by a licence-holder for environmental watering purposes. Planned environmental water is water that is prescribed under the rules of a water sharing plan.

6.4.1 Held environmental water

The volumes of held environmental water in the Macquarie River have gradually increased since the commencement of the regulated water sharing plan in 2004 and currently total 173,742 ML of general security water, 40 ML of domestic and stock water, and 9,744 ML of supplementary water (Burrell et al. 2016) (Figure 32). An additional 901 ML is available in the Cudgegong River.

The Commonwealth Environmental Water Holder currently holds 133,766 environmental share components and the NSW Office of Environment and Heritage holds 50,433 environmental share components. Held environmental water was first used in the Macquarie valley in 2007-08 with the highest use to date being in 2012-13 (Figure 33). No held environmental water has been used in the Cudgegong River since the commencement of the water sharing plan however water has been traded to the Macquarie River for use (Burrell et al. 2016).
6.4.2 Planned environmental water

Planned environmental water is defined in the water sharing plan according to rules. The Macquarie-Cudgegong Regulated River water sharing plan provides for an environmental water allowance (EWA) of 160,000 ML which may be used to improve environmental outcomes in the Macquarie Marshes and the Macquarie River between Burrendong Dam and the Macquarie Marshes.

The EWA is credited at the beginning of each water year (1 July) subject to certain conditions being met. The availability of the allowance is linked to general security availability and is subject to the shares announced through the available water determinations at the start of each year. The reduced shares available to general security users in 2014-15 and 2015-16 limited the amount of water available for environmental purposes in these years (Figure 34).

The volume credited to the EWA is split between two sub-allowances. Sub-allowance 1 (translucent) receives 60 per cent of the volume and sub-allowance 2 (active) receives 40 per cent of the volume. The translucent allowance may be released subject to certain flow conditions being met and is designed to enhance natural tributary flows between Burrendong Dam and Marebone Weir. The active allowance may be used to support wetland health in the Macquarie Marshes, fish breeding and dispersal or waterbird breeding events where those needs cannot be met by releases made under the translucent allowance.

Figure 34: Environmental water allowance in the Macquarie-Cudgegong River
<table>
<thead>
<tr>
<th><strong>Glossary</strong></th>
<th><strong>Definition</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aquatic ecosystems</strong></td>
<td>Ecosystems that are dependent on flows, or periodic or sustained inundation/waterlogging for their ecological integrity. Examples include wetlands, rivers, karst and other groundwater-dependent ecosystems, saltmarshes, estuaries and areas of marine water not exceeding 6 m deep at low tide.</td>
</tr>
<tr>
<td><strong>Allocation</strong></td>
<td>The volume of water assigned to water allocation accounts in a given season, defined according to rules in the relevant water plan.</td>
</tr>
<tr>
<td><strong>Allocation assignment</strong></td>
<td>The transfer of water between licence holder allocation accounts as a result of a trade agreement. The assignment becomes part of the receiver’s allocation account water for the current water year.</td>
</tr>
<tr>
<td><strong>Available water determination (AWD)</strong></td>
<td>A determination referred to in section 59 of the <em>Water Management Act 2000</em> that defines the proportion of the share component that will be available for extraction under each category of water access licence.</td>
</tr>
<tr>
<td><strong>Basic Landholder Rights</strong></td>
<td>Means domestic and stock rights, harvestable rights or native title rights.</td>
</tr>
<tr>
<td><strong>Cold water pollution</strong></td>
<td>An artificial decrease in the temperature of water in a natural river.</td>
</tr>
<tr>
<td><strong>Dissolved oxygen</strong></td>
<td>Measured concentration of oxygen dissolved in water.</td>
</tr>
<tr>
<td><strong>Domestic consumption</strong></td>
<td>Consumption of water for normal household purposes in domestic premises on the land.</td>
</tr>
<tr>
<td><strong>Ecological value</strong></td>
<td>The perceived importance of an ecosystem which is underpinned by the biotic and/or abiotic components and processes that characterise that ecosystem.</td>
</tr>
<tr>
<td><strong>Ecosystem</strong></td>
<td>A specific composition of animals and plants that interact with one another and their environment.</td>
</tr>
<tr>
<td><strong>Ecosystem functions</strong></td>
<td>The processes that occur between organisms and within and between populations and communities. They include interactions with the nonliving environment that result in existing ecosystems and bring about dynamism through changes in ecosystems over time.</td>
</tr>
<tr>
<td><strong>Effluent</strong></td>
<td>An effluent stream is one which leaves the main river and does not return.</td>
</tr>
<tr>
<td><strong>Endangered ecological community</strong></td>
<td>Ecological communities as listed in Schedule 1 of the <em>Threatened Species Conservation Act 1995</em> or Schedule 4 of the <em>Fisheries Management Act 1994</em>.</td>
</tr>
<tr>
<td><strong>Eutrophication</strong></td>
<td>The process where an accumulation of nutrients in water bodies leads to rapid growth of aquatic plants.</td>
</tr>
<tr>
<td><strong>Farm dams</strong></td>
<td>Private dams that are used to intercept catchment runoff that would otherwise contributed to streamflow or recharge of aquifers. Primarily located on hillsides (does not include floodplain harvesting dams).</td>
</tr>
<tr>
<td><strong>General security licence</strong></td>
<td>A category of water access licence implemented under the <em>Water Management Act 2000</em>. Forms the bulk of the water access licence entitlement volume in NSW and is a low priority entitlement i.e. only receives water once essential and high security entitlements are met in the available water determination process.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td>Water that occurs beneath the ground surface in the saturated zone.</td>
</tr>
<tr>
<td><strong>Groundwater dependent ecosystems</strong></td>
<td>Ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.</td>
</tr>
<tr>
<td><strong>Harmful algal bloom</strong></td>
<td>An algal bloom that causes negative impacts to other organisms through the production of natural toxins, mechanical damage, or other means.</td>
</tr>
<tr>
<td><strong>High flows</strong></td>
<td>Also called bankfull events, these reshape the channel, creating habitats such as pools, bars and benches.</td>
</tr>
<tr>
<td><strong>High security licence</strong></td>
<td>A category of licence water access licence implemented under the Water Management Act 2000. Receives a higher priority than general security licences but less priority than essential requirements in the available water determination process.</td>
</tr>
<tr>
<td><strong>Instream value</strong></td>
<td>Ecological condition value of river reaches based upon High Ecological Value Aquatic Ecosystems (HEVAE). In NSW HEVAE was calculated using four criteria: distinctiveness, diversity, naturalness and vital habitat.</td>
</tr>
<tr>
<td><strong>Low flows</strong></td>
<td>Flows that are confined to the lower part of the channel; also often called base flows. These flows are between pools and riffle areas between pools. Generally defined as the 80th percentile flow.</td>
</tr>
<tr>
<td><strong>Nitrogen and phosphorous</strong></td>
<td>Chemical nutrients essential for growth and added to many fertilisers.</td>
</tr>
<tr>
<td><strong>Overbank flows</strong></td>
<td>High flows that connect the river to floodplain and wetlands allowing the exchange of nutrients and sediment to these areas.</td>
</tr>
<tr>
<td><strong>Regulated river</strong></td>
<td>Gazetted under the NSW Water Management Act 2000 and is a river where downstream flows are regulated by a major state-owned storage. Downstream licence holders can order water against a held entitlement.</td>
</tr>
<tr>
<td><strong>Replenishment flows</strong></td>
<td>Flows provided along effluent systems to supply water for household, town use and stock.</td>
</tr>
<tr>
<td><strong>Riparian</strong></td>
<td>Relating to or living or located on the bank of a natural watercourse, such as a river stream.</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>The concentration of sodium chloride or other dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre. Conversion factor is 0.64 mg/l TDS = 1000 µS/cm = 1 dS/m.</td>
</tr>
<tr>
<td><strong>Seasonality</strong></td>
<td>The timing of flooding and low flow events.</td>
</tr>
<tr>
<td><strong>Share component</strong></td>
<td>An entitlement to water specified on the access licence, expressed as a unit share or in the case of specific purpose licences, a volume in megalitres (eg. local water utility, major water utility and domestic and stock).</td>
</tr>
</tbody>
</table>

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Stock watering  The watering of stock animals being raised on the land but does not include the raising of stock animals on an intensive commercial basis that are housed or kept in feedlots or buildings for all (or a substantial period) during which the stock animals are being raised.

Stratification  The formation of separate water layers.

Supplementary water  Formerly known as off-allocation water, this is surplus flow resulting from storm events that cannot be captured in storages or weirs. When the water is not needed to meet current demands or commitments, then it is considered surplus to requirements and a period of Supplementary Access is announced. Supplementary Water Access Licence holders can only pump water against these licences during these announced periods. Other categories of licence holders may also pump water during these periods.

Water access entitlement  A water product (licence) issued under the Water Management Act 2000.

Water resource plan  A plan made under the Commonwealth Water Act 2007 that outlines how a particular area of the Murray–Darling Basin’s water resources will be managed to be consistent with the Murray–Darling Basin Plan. These plans set out the water sharing rules and arrangements relating to issues such as annual limits on water take, environmental water, managing water during extreme events and strategies to achieve water quality standards and manage risks.

Water sharing plan  A plan made under the Water Management Act 2000 which sets out the rules for sharing water between the environment and water users within whole or part of a water management area or water source.

Water source  The whole or any part of:
- one or more rivers, lakes or estuaries, or
- one or more places where water occurs naturally on or below the surface of the ground
and includes the coastal waters of the State.

3 As defined in the Water Management Act 2000
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