Lachlan Water Resource Plan

Surface water resource description
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Acknowledgments

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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 Lachlan Water Resource Plan covers the surface water sources of the Lachlan valley. The plan incorporates two surface water resources, the Lachlan Regulated River Water Source and the Lachlan Unregulated Water Sources. This report is a detailed description of the surface water resources of the Lachlan Water Resource Plan Area (SW10) to provide an understanding of the region and the resources covered by the plan. It describes the location and physical attributes 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 components of the Lachlan Water Resource Plan including the Risk Assessment and Water Quality Plan.

1.1 Overview of the plan area

The Lachlan Water Resource Plan Area (WRPA) comprises the Lachlan catchment which is part of the Murray-Darling Basin in southern NSW (Figure 1). The Lachlan catchment covers around 90,000 km² and represents eight percent of the Murray-Darling Basin.

The Lachlan River begins in the Great Dividing Range near Gunning and flows nearly 1,400 km across western NSW to its junction with the Murrumbidgee River near Oxley. The headwaters rise at elevations of up to 1,400 m, and are characterised by rapidly flowing streams which flow through a mix of steep forested ranges and cleared grazing lands. The undulating landscape of the middle catchment has been extensively cleared but pockets of remnant vegetation remain. The extensive floodplain environment of the western part of the catchment is generally less than 200 m in elevation and features many wetlands and effluent streams. Under normal conditions the Lachlan River is a terminal system with little water flowing past the Great Cumbung Swamp at the end of the river.

The Lachlan River is regulated by Wyangala Dam which is the major water storage in the valley. Wyangala Dam is located at the junction of the Lachlan and Abercrombie rivers about 48 km upstream from Cowra in central west NSW. The dam was completed in 1935 and enlarged to its current capacity of 1,217,000 ML in 1971. It provides a regulated flow along the length of the Lachlan River and into some of the distributary channels at the far end of the catchment. A number of natural lakes have also been modified for use as storages, the largest of these being Lake Cargelligo and Lake Brewster.

The main traditional custodians of the Lachlan catchment are the Wiradjuri, the largest Aboriginal Nation in NSW. Their traditional land extends from the Murray River to beyond Dubbo and west to Balranald. In the far west of the catchment are the traditional lands of the Nari Nari, Ngiyampaa and Yita Yita nations.

The Lachlan WRPA is home to about four per cent of the population of the Murray–Darling Basin. The main centres of Cowra, Parkes and Young have a population of about 10,000 people while Forbes has a population of around 7,000 people (ABS 2011). Small towns with populations ranging from 1,000 to 4,000 people include Blayney, Crookwell, Boorowa, Canowindra, Molong and Grenfell in the upper catchment, and Temora, West Wyalong, Condobolin, Lake Cargelligo and Hillston in the mid to lower catchment.
1.2 Water management units

The surface water of the Namoi WRPA is currently managed through three water sharing plans:

- Water Sharing Plan for the Belubula Regulated River Water Source 2012
- Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2014

The **Lachlan Regulated River Water Source** comprises water between the banks of the Lachlan River and some of its anabranches, from Wyangala Dam storage downstream to the Great Cumbung Swamp.

The **Belubula Regulated River Water Source** comprises water between the banks of the Belubula River, from Carcoar Dam water storage downstream to the junction of the Belubula River with the Lachlan River.

The **Lachlan Unregulated Water Sources** comprise all of the streams upstream of Wyangala Dam (excluding the regulated Belubula River), and all of the tributaries entering the Lachlan River downstream of Wyangala Dam. They are categorised into 23 water sources.

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

1.3 History of water management in the Lachlan WRPA

1.3.1 Early wetland and water management

The former Department of Water Resources began mapping and studying the wetlands of the Lachlan valley in the mid-1980s leading to the preparation of a *Draft Water Management Plan for the Wetlands of the Lachlan Valley Floodplain* (DWR 1990). The plan recognised the value of floodplain wetlands in the valley and aimed to ensure that the water needs of the wetlands were recognised and the river system managed in a way that was sympathetic to the wetland needs. Waterbird studies helped to further define the specific water requirements of the Booligal Wetlands and their value as waterbird habitat (Magrath 1992). The water requirements of the Great Cumbung Swamp were investigated in the late 1990s and the flow threshold for broad scale flooding of the swamp was determined (Brady *et al* 1998). These requirements have subsequently been adopted as environmental flow targets by the MDBA (MDBA 2012).

1.3.2 NSW 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 changes 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 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 Lachlan Regulated River water sharing plan

The Lachlan Regulated River Management Committee was formed in 1997 to determine environmental flow rules that would optimise the allocation of water for environmental values in the Lachlan catchment. The Committee included representatives of the irrigation industry, environmental interests, indigenous communities, the local Catchment Management Board, local
Figure 2: Location of regulated and unregulated water sources of the Lachlan WRPA
councils and government agencies (Department of Land and Water Conservation, National Parks and Wildlife Service, Environment Protection Authority, NSW Agriculture and NSW Fisheries). The Committee’s recommended environmental flow rules were adopted and implemented by the Government in 1998 (DIPNR 2004).

In 2001 the Minister for Land and Water Conservation asked the committee to recommend water sharing rules to be incorporated into a statutory water sharing plan. A draft water sharing plan, including revised environmental flow rules was prepared by the committee and placed on public exhibition in mid-2002. The environmental flow rules in the Plan were similar to the 1998 rules but with significant adjustments to protect irrigation in dry years. These adjustments were incorporated following public comment on the draft plan.

The statutory plan was gazetted on 21 February 2003 and commenced on 1 July 2004. The plan 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.

Critical water shortages in the catchment at the time the plan commenced resulted in almost immediate suspension of the water sharing plan. Whilst suspended, decisions about water management were made by the former Department of Water and Energy in consultation with the former Department of Environment and Climate Change, and State Water under a critical water planning process. Although not bound by the rules of the water sharing plan, water management decisions reflected the plan provisions where possible (NOW 2013). The water sharing plan did not commence operating until September 2011.

The water sharing plan for the Lachlan 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 Lachlan Regulated River was formally replaced. The plan 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 are considered in the development of this water resource plan.

1.3.4 Belubula Regulated River water sharing plan

A number of water sharing rules were already in place in the regulated Belubula River prior to the development of a water sharing plan. These included water accounting and trading rules, a requirement to maintain a minimum flow of 10 ML/d at Helensholme to provide for stock and domestic rights, and a minimum flow release of 2 ML/d to provide for stock and domestic requirements directly downstream of Carcoar Dam. Access to off-allocation flows was introduced for the first time during drought conditions in 2006 when there was little or no water available in the dam for general security licence holders. This allowed water users access to tributary inflows which were available at times in the system (NOW 2013).

Preparation of a water sharing plan commenced in 2010 and was guided by the Belubula Interagency Regional Panel. The Panel consisted of two representatives from Department of Primary Industries (one from the former Office of Water and another covering agricultural and fisheries interests), one representative from the Office of Environment and Heritage, and a representative from the Lachlan Catchment Management Authority who acted as an observer and provided advice on community consultation.

Draft water sharing rules were developed during 2010-2011 in consultation with the Belubula Landholders Association. A draft water sharing plan was placed on public exhibition in March 2012. Written submissions and feedback on the draft rules guided the preparation of the final water sharing plan which commenced in October 2012.
The rules contained in the Water Sharing Plan for the Belubula Regulated Water Source will be reviewed during the development of the Lachlan Water Resource Plan.

1.3.5 Lachlan unregulated water sharing plan

The Lachlan Unregulated River Management Committee was appointed by the NSW Government to make recommendations on a water sharing plan by December 2001. Specifically, the Committee was asked to:

- Develop and recommend key objectives and outcomes
- Advise on water sharing strategies, trading arrangements and performance indicators
- Review public submissions and recommend changes to the draft Minister’s plan
- Review and provide advice on the initial implementation program for the plan.

At this time water sharing plans were being prepared for catchments or sub-catchments with the highest level of hydrologic stress. A draft Water Sharing Plan for Mandagery Creek Water Source was prepared by the committee and placed on public exhibition in April 2002. In addition to the expertise of the committee members, community consultation added significant value to the Committee’s deliberations and shaped the final recommendations of the draft Plan. This consultation included case studies with six local landholders to test the water sharing rules, a community meeting held in Eugowra in October 2001; and discussions with members of the community. Aboriginal consultation was undertaken by the Aboriginal Natural Resource Officer of the former Department of Land and Water Conservation (DLWC 2002).

The final plan was approved by the Minister for Land and Water Conservation in 2003 and the plan 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.

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 remaining unregulated water sources. The Lachlan Interagency Regional Panel was established to guide the development of a ‘macro plan’ for the remainder of the Lachlan 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 late August 2011. The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources commenced on 14 September 2012.

In 2016 the Lachlan Unregulated plan was amended to incorporate the water source previously managed through the Water Sharing Plan for the Mandagery Creek Water Source 2004 which had reached the end of its term. The Lachlan Interagency Regional Panel guided these amendments and consultation with stakeholders was undertaken to ensure the amendments did not have any unintended impacts. The merging of the Mandagery Creek water source into the Lachlan Unregulated plan now allows all water in the catchment to be managed through one plan and brings consistency in management across the plan area.

The rules contained in the Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources will be reviewed during the development of the Lachlan Water Resource Plan.
2. Physical description of the Water Resource Plan Area

2.1 Climate

Rainfall

Average annual rainfall in the Lachlan catchment varies from 1,100 mm per year in the eastern part of the catchment to less than 300 mm in the far west (Figure 3). In the more moderate middle parts of the catchment average annual rainfall is between 400 and 600 mm per year. Rainfall is generally well distributed throughout the year, with slight summer dominance in the upper and middle parts of the catchment (Figure 4).

Climate change modelling for the Central West Region (OEH 2014a) predicts that spring rainfall across the region will decrease over the next 50 years with the greatest reduction in rainfall being around Parkes, Forbes and Cowra. Autumn and summer rainfall is projected to increase across the region over this timeframe (OEH 2014a).

Figure 3: Average annual rainfall in the Lachlan catchment

Figure 4: Average monthly rainfall for selected stations
Evaporation

Evaporation has a strong south-east to north-west gradient across the catchment. Average Class A pan evaporation varies from 900 mm per year in the south-east, to over 2,000 mm per year in the north-west (Figure 5). Evaporation significantly exceeds the monthly rainfall throughout the year. At Condobolin the evaporation in January is nearly 300 mm, more than six times the amount of rainfall generally received in that month (Figure 6). In winter evaporation is around 50 mm per month, compared to monthly rainfall of 30-35 mm.

Figure 5: Average annual evaporation across the Lachlan WRPA

Source: Bureau of Meteorology Climate Data Online

Temperature

Summer temperatures range from mild to hot across the Lachlan WRPA. The higher elevations in the east result in milder temperatures, with Crookwell having an average maximum temperature of 27°C in January. At Forbes, Ivanhoe and West Wyalong maximum summer temperatures range from 32°C to 35°C (CSIRO 2007). Winters are cool to mild with average maximum temperatures in July at Crookwell being 10°C and 14°C to 16°C at Ivanhoe and Forbes (CSIRO 2007). Frosts are common in winter.
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, with the greatest increase in hot days being for the plains north of Hay (the lower Lachlan catchment) 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. For the Lachlan midlands including Parkes and Forbes an additional 20-30 hot days per year are predicted by 2070.

2.2 Land use

European settlement within the catchment began with the establishment of pastoral holdings in the 1830s. Cropping of wheat and other cereals commenced in the 1860s. Today land use in the Lachlan catchment is dominated by extensive agriculture with 68 per cent of the catchment used for livestock grazing, and 17 per cent used for dryland cropping (Table 1). The grazing land is distributed throughout the catchment, while dryland cropping is carried out downstream of Wyangala Dam and through the middle of the catchment where moderate winter rainfall occurs.

While economically important within the region, irrigated crops cover only 1 per cent of the catchment area. Irrigation commenced in the early 1960s, and now covers around 800 km². Around two-thirds of irrigation water is sourced from surface water diversions. In the tablelands fruit, nuts, vegetables and wine grapes are irrigated using high security water while general security water is used for fodder crops (lucerne and maize) and dairy production (EBC Consortium 2011). On the riverine plains irrigated crops include pasture, cereals, oilseeds, vegetables and stone fruit. Cotton is grown mainly in the western part of the WRPA where production levels are closely tied to water availability.

Forestry and conservation areas comprise around 13 per cent of the catchment. Forested areas are concentrated in the Abercrombie River catchment. The majority of land for conservation lies within several large parcels in the lower catchment, as well as smaller areas in the upper catchment.

Table 1: Land use in the Lachlan WRPA

<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>15084</td>
<td>17%</td>
</tr>
<tr>
<td>Grazing</td>
<td>61123</td>
<td>68%</td>
</tr>
<tr>
<td>Irrigation</td>
<td>800</td>
<td>1%</td>
</tr>
<tr>
<td>Mining</td>
<td>14</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Forestry, conservation reserve and native vegetation</td>
<td>11490</td>
<td>13%</td>
</tr>
<tr>
<td>Residential</td>
<td>58</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Urban intensive uses</td>
<td>167</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Water</td>
<td>814</td>
<td>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 map of the Lachlan WRPA

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

The Lachlan WRPA can be divided into four main areas based upon the topography and flow characteristics of the water sources. These are the upland, midland, lowland/distributary and terminal areas of the catchment (Figure 8).

Figure 8: Sub-regions of the Lachlan WRPA

2.3.1 Upland area (upstream of Wyangala Dam)

The Lachlan River rises in the Great Dividing Range just north-west of Lake George and flows north-west into Wyangala Dam. Major tributaries in the upper Lachlan include the Crookwell River, Abercrombie River and Tuena Creek. The rivers in this reach flow within well-defined channels and have only limited floodplains (Green et al. 2011). Photo 1 illustrates the narrow floodplain which is typical of the river in this upper part of the catchment.

The water sources within this upland area are: Abercrombie River above Wyangala, Crookwell River and Lachlan River above Reids Flat.

2.3.2 Midland area (Wyangala Dam to Forbes)

From Wyangala Dam, the Lachlan River flows north-west towards Forbes. Several major tributaries enter the Lachlan River within this reach including the Boorowa River, Back Creek, Belubula River and Mandagery Creek (Photo 2). The Belubula River flows westerly for approximately 60 km from its beginning near Carcoar to its confluence with the Lachlan River downstream of Canowindra. Carcoar Dam was constructed on the upper Belubula River in 1970 to supply water for irrigation and stock and domestic use in the valley.

The water sources within the midland area are: Belubula River above Carcoar Dam, Belubula Tributaries below Carcoar Dam, Boorowa River and Hovells Creek, Burrangong Creek, Crowther Creek, Goonigal and Kangarooby Creeks, Mandagery Creek, Tyagong Creek and Waugoola Creek.
2.3.3 Lowland area (Forbes to Willandra Creek)

Downstream of Forbes, the Lachlan River breaks up into numerous distributary creeks which re-join the river again downstream of Condobolin. The major one is the Wallamundry-Wallaroi Creek system that may carry up to 30 per cent of the river’s flow depending on flow conditions and operation of regulators. Many small private weirs have been built along these anabranches creating a series of pools (Green et al. 2011).

Between Forbes and Condobolin is Lake Cowal, the largest lake in the catchment. During moderate floods, water from the Lachlan River enters the lake via two major waterways. The lake also receives water from the catchment of Bland Creek that flows in from the south. Once full, the water from Lake Cowal flows across a low saddle into the adjoining basin of Nerang Cowal. Downstream of Lake Cowal, Bogandillon Swamp is another large basin which is flooded directly from the Lachlan River or from overflow from Nerang Cowal (Green et al. 2011).

There are two main off-river storages within this section; Lake Cargelligo and Lake Brewster. Modified by weirs and regulators, the lakes are operated in conjunction with Wyangala Dam to supply the water requirements of users in this region. Lake Brewster is subject to fluctuating water levels and its many islands and dead trees make it a valuable waterbird habitat. It is especially known for its large pelican rookeries that support several thousand birds (Green et al. 2011).

The Lake Cargelligo system is comprised of three main basins. The inlet channel, Sheet of Water, is a shallow wetland suitable for wading waterbirds. Near the northern inlet to Lake Cargelligo is Curlew Water, a deep depression used for water skiing. The main body of Lake Cargelligo is a large deep body of water that is used for recreational activities including boating, water skiing, fishing and swimming (Green et al. 2011).
Leaving the river halfway between Condobolin and Lake Cargelligo is Booberoi Creek, an anabranch of the Lachlan River. The creek is regulated for stock and domestic supply along its length. It re-joins the Lachlan River downstream of Lake Cargelligo (Green et al. 2011).

The water sources within this lowland area include: Bogandillon and Manna Creeks, Goobang and Billabong Creeks, Gunningbland and Yarrabandai, Humbug Creek, Lakes Forbes and Back Yamma Creek, Mid Lachlan Unregulated, Mount Hope Area, Naradhan Area, Ooma Creek and Tributaries and Western Bland Creek. Photo 3 shows a typical view of the river in this lowland reach.

### 2.3.4 Terminal system (Willandra Creek to Lower Lachlan)

A series of effluent streams flow intermittently from the lower part of the Lachlan River, delivering water as far as 160-180 km west of the main channel. The Unregulated Effluent Creeks Water Source covers all of the terminal streams within this part of the catchment.

Willandra Creek is the largest of the distributary channels that leave the lower Lachlan River. Flows into the creek are controlled by Willandra Weir on the Lachlan River and a regulator on the creek. Stock and domestic flows are provided along the creek as far as Willandra Homestead in Willandra National Park. Downstream of the national park the creek terminates in a series of lignum swamps and intermittent lakes near Ivanhoe (Green et al. 2011).

Below Willandra Weir the Lachlan River is characterised by numerous distributary channels. The first one downstream of Willandra Weir is Middle Creek, an unregulated watercourse that is inundated during moderate flows in the Lachlan (Green et al. 2011).

Merrowie Creek leaves the Lachlan River upstream of Hillston. Flows into the creek are controlled by Gonowlia Weir with stock and domestic water supplied during winter as far as Cuba Dam, north-west of Booligal. Cuba Dam is one of many storages constructed along the creek that has become valuable waterbird habitat. Twenty kilometres downstream of Cuba Dam, Merrowie Creek enters Lake Tarwong, another valuable area for waterbirds (DWR 1990).

Between Hillston and Booligal the Merrimajeel and Muggabah Creek system forms one of the most valuable wetland habitats in the valley, known as the Booligal Wetlands. The creeks are
distributary channels of Torriganny Creek, an anabranch of the Lachlan River that carries about 60 per cent of the Lachlan River flow upstream of Booligal (Magrath 1992). The creeks begin to flow when the river exceeds around 300 ML per day at Booligal Weir and as the flow increases the creek systems interconnect to inundate extensive areas of floodplain. Flows into the creek system are regulated by Torriganny Weir, which is used to deliver stock and domestic flows during winter. The Booligal Wetlands consist of almost 10,000 ha of lignum swamp that supports large breeding colonies of ibis and other colonial waterbirds during moderate floods (DWR 1990, Magrath 1992). At the end of the creek system is Murrumbidgil Swamp and Lake Merrimajeel that retains water once the creeks have ceased flowing.

On the southern side of the river are several floodrunners that flow south from the river during moderate to high flows. These include Cabbage Garden Creek, Yandumblin Creek and Gums Creek. In this area Moon Moon Lake provides breeding habitat for pelicans and waterfowl when it is flooded under high flows from the Lachlan River (Green et al. 2011).

Downstream from Booligal the floodplain of the Lachlan River is dissected by numerous small flood channels that feed a number of shallow basins on the western side of the river. These include Lake Waljeers, Lake Bullogal and Ryans Lake.

Downstream of the small village of Oxley the Lachlan River enters the Great Cumbung Swamp that comprises a diversity of habitats including reed swamp, river red gum forest, black box woodlands, shallow marshes and open water wetlands (Photo 4). The movement of water within the swamp is controlled by a series of banks and regulators that are operated by local landholders. Brady et al (1998) found that a minimum flow of 2,700 ML/d for more than 30 days at Booligal (equivalent to a total event volume of 320 GL) is needed to inundate most of the swamp, including peripheral river red gum forest, black box and surrounding chenopod shrub land. Water generally does not reach the Murrumbidgee River except in large floods (Green et al. 2011).

Photo 4: The Lachlan River terminates in the extensive floodplain wetlands of the Great Cumbung Swamp.
Paul Packard, OEH
2.4 Streamflow characteristics

The Lachlan River is regulated by Wyangala Dam which provides water for town water supplies, irrigation, stock and domestic use, industry, and environmental flows along the Lachlan River and its effluent channels. The volume and pattern of flows in the Lachlan River has been significantly altered by the construction and enlargement of Wyangala Dam and the growing extraction of water for irrigation and other purposes. At Cowra there has been a significant increase in the base volume of flows as a result of storage releases, with less variability and a gradual increase in base flows reflecting the growing irrigation demand (Green et al 2011).

The capacity of the Lachlan River reaches its maximum at Forbes, with mean daily flow being 3,197 ML. From here stream flows decline significantly as water is lost or diverted to the many effluent channels. At the end of the river at Corrong (upstream of the Great Cumbung Swamp), mean daily flows are reduced to around 17 per cent of those at Forbes (Green et al 2011).

The longest running gauging stations on the river are at Cowra, Condobolin and Booligal where recording of flows commenced in the late 1800s. The average annual flow for the Lachlan River at Cowra is 823,000 ML. In recent decades the Lachlan River has experienced a prolonged period of low flows. Flows in the Lachlan River have been lower than average since 2000 with the exception of 2012 when above average flow was recorded (Figure 9). The year of 2009 was the fifth lowest annual flow in 118 years of record, while 2004 was the ninth lowest on record. The lowest annual flow was in 1902 when just 33,379 ML was recorded. Like elsewhere in the state, the highest flows occurred during the 1950s, when the three highest annual flows were recorded (the largest being 4,455,551 ML in 1952).

Daily stream flows provide an indication of the variability of flow patterns and the peak height of flood events. There have been several large floods in the Lachlan River, the largest of these being in June 1952 when a peak discharge of more than 366,000 ML/d was recorded at Cowra (Figure 10). The most recent flood events in the river were in 2012 and 2016 when flows peaked at more than 74,000 ML/d at Cowra during both events.

Figure 9: Annual flows in the Lachlan River at Cowra 1900–2015
Daily and seasonal streamflow patterns in the unregulated streams vary across the catchment. Figure 11 shows the seasonal variation in daily flows for three streams in the upland, midland and lowland parts of the Lachlan WRPA. High flows (indicated by the 20th percentile flow) are strongly seasonal, occurring mostly from July through to September in the upper and middle parts of the catchment, and from September to December in the lowland streams. The upper Lachlan catchment and the midland tributaries (such as the Mandagery Creek) display similar seasonal trends in flow. In these streams the median daily flow (50th percentile flow) is highest from August to October. The total volume of water in the Lachlan River at Reids Flat is significantly higher compared to Mandagery Creek due to a larger catchment size and higher rainfall in the upper catchment where the Lachlan River begins. The upper catchment experiences more reliable baseflow than the midland tributaries, with dry periods (80th percentile) of very low flows from January to March. Mandagery Creek experiences very low flows more frequently from December to May, which is indicative of the midland region of the Lachlan.

Willandra Creek at Willandra Homestead was the site used to represent unregulated streams and effluents in the lower catchment; however it is at the end of the regulated river system and may not represent natural flows in effluents. This site was selected, as suitable unregulated gauge sites with reliable data are not available in this region of the Lachlan valley. Information from Willandra Creek shows the median daily flow (50th percentile) is persistent throughout the year in the lower Lachlan catchment, with a decline between December and January. Effluent systems typically experience drier periods more frequently and water users in this region are reliant on accessing the larger flood events that occur in the regulated system.
Figure 11: High, median and low daily flows in the Lachlan catchment

**Upper Lachlan catchment**
Lachlan River at Reids Flat (1930-2016)

- 20th percentile daily flow
- Typical daily flow (50th)
- 80th percentile daily flow

**Mid-Lachlan catchment**
Mandagery Creek upstream of Eugowra

- 20th percentile daily flow
- Typical daily flow (50th)
- 80th percentile daily flow

**Lower Lachlan catchment**
Willandra Creek at Willandra Homestead (1946-2016)

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

3.1 Parks and reserves
There is over 3,800 km$^2$ of land conserved within national parks and nature reserves within the Lachlan catchment. The majority of this area lies within the middle and upper parts of the catchment. The majority of reserves are located in the upper catchment above Forbes, however there are several large reserves within the lower catchment that account for 65 per cent of the total conservation area. One of these is Willandra National Park which covers 194 km$^2$ along Willandra Creek. Formerly a large pastoral station, the park was gazetted in 1972 and features a historic shearing shed and homestead, as well as semi-arid grasslands, floodplains and grassy woodland communities. Around 170 bird species have been recorded in the park, including the endangered plains wanderer.

Yathong, Nombinnie and Round Hill Nature Reserves form a large, continuous conservation area north of Hillston. Together they cover more than 2,400 km$^2$ of plain and ridge country, with a variety of woodland communities and the largest continuous strip of mallee in NSW. The reserves support a rich variety of wildlife and form a major area of habitat for a number of rare and endangered plant and animal species including kultarr, mallee fowl, striated grass wren, red-lored whistler, grey falcon and pink cockatoo (NPWS 1996). Yathong Nature Reserve has been formally recognised as an International Biosphere Reserve, designated under the UNESCO Man and the Biosphere program.

One of the largest reserves in the upper catchment is Abercrombie River National Park which covers 190 km$^2$ of the Abercrombie catchment. The park includes the catchments of Silent Creek and the Retreat River, as well as 42 km of the Abercrombie River. The Abercrombie and Retreat Rivers feature deep waterholes which are important habitats for platypus and eastern water rats.

3.2 Wetlands
A total of 471,000 ha of wetlands have been mapped within the Lachlan catchment. Of these, 95 per cent are floodplain wetlands and five per cent are freshwater lakes (Kingsford et al 2003). Wetlands are a common feature of the catchment downstream of Forbes where the floodplain begins to broaden, leading to the formation of numerous anabranches, effluents and lakes.

Lake Cowal, Lake Brewster and Lake Cargelligo are large lakes that fill naturally from the Lachlan River in times of high flows. Lake Cargelligo and Lake Brewster have been modified by the installation of weirs and regulators for use as off-river storages. Lake Cowal is the largest lake in the valley and when fully flooded it connects with nearby Lake Nerang Cowal to cover over 16,000 ha. It retains water for up to three years after a major flood, and when dry the lakebed is used for cropping and grazing.

The distributary effluents at the end of the Lachlan River are lined by black box and lignum swamps, and provide extensive habitat for waterbird breeding. The lignum swamps of Merrowie, Merrimajeel and Muggabah Creeks are collectively known as the Booligal wetlands. They support some of the most extensive areas of lignum in the state and when flooded support breeding colonies of up to 100,000 pairs of ibis (Magrath 1992, Australian Heritage Commission 1998). Flooding in 2016 triggered the largest waterbird breeding event at the site in 20 years, with around 100,000 straw-necked ibis nests recorded in December 2016 (CEWO 2016).

The Great Cumbung Swamp is an extensive complex of wetlands near the confluence of the Lachlan and Murrumbidgee Rivers. In most years the Lachlan River terminates within the swamp. The central feature of the swamp is an extensive area of reed beds which cover almost 4,000 ha. Surrounding this are river red gum woodlands, lignum swamps, shallow marshes and lakes. Together with the adjoining Lowbidgee wetlands, the swamp supports one of the largest
areas of river red gum in NSW. It is also important as waterbird breeding habitat (Dept Environment and Energy 2016).

3.3 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 Lachlan WRPA included:

- 471,011 ha of wetlands in the lower floodplain;
- Nine wetlands with particular values for waterbird and migratory bird habitat, listed in the Directory of Important Wetlands in Australia;
- Native and threatened fish species including the eel-tailed catfish, silver perch, Macquarie perch, golden perch, big-headed gudgeon, olive perchlet, southern pygmy perch, Murray cod, and western carp gudgeon;
- Habitat for threatened frog species such as Sloane’s froglet, Booroolong frog, yellow-spotted tree frog, southern bell frog and stuttering frog;
- Habitat for threatened bird species including magpie goose, Australasian bittern, brolga, black-necked stork, Australian painted snipe, black-tailed godwit, blue-billed duck, eastern osprey, freckled duck and curlew sandpiper;
- Habitat for two threatened bat species including the southern myotis and the greater broad-nosed bat;
- Habitat for threatened plant species including spike rush, dense cord rush, Austral pillwort, Klaphake’s sedge, winged peppercress and Menindee nightshade; and
- Areas of river red gum woodland, black box woodland and lignum.

3.3.1 Ecological values in the regulated river

The analysis shows that parts of the regulated Lachlan River have very high instream values (Figure 12). The Lachlan catchment supports a significant spread of threatened fish species or endangered populations (Figure 13, Figure 14). Eel-tailed catfish and Murray cod were widespread in the regulated river sites, whilst silver perch and Macquarie perch were found mostly upstream of Wyangala Dam. Fish biodiversity was highest in the lower reaches of the Lachlan River between Lake Cargelligo and Hillston.

Most of the regulated river has high to very high ecological values due to a number of factors including high fish diversity, the presence of threatened fish species; and large tracts of riparian vegetation and relatively undisturbed river reaches that provide habitat and contribute to primary production.
Figure 12: Instream values for the Lachlan WRPA

Figure 13: Distribution of threatened fish species within the Lachlan WRPA
3.3.2 Ecological values in the unregulated rivers

Unregulated rivers in the following water sources have high or very high ecological values as assessed by HEVAE (Figure 12):

- In the upper catchment, Abercrombie River above Wyangala water source and the Lachlan River above Reids Flat water source both have high values due to the presence of threatened fish and frog species.
- In the midreaches, Goobang and Billabong Creeks water source and Western Bland water source have high values and high consequence scores due to high naturalness and significant vital habitat.
- Mandagery Creek water source has very high values due to threatened fish and frog species including Eel-tailed Catfish, the Booroolong Frog and Sloanes Froglet.

All of the above ecological values have been considered as part of the Lachlan Risk Assessment for the Lachlan Water Resource Plan.

3.4 Hydrologic Indicator Sites

The hydrologic indicator site approach uses detailed eco-hydrological assessment of environmental water requirements for a subset of key environmental assets and key ecosystems functions across the Basin (MDBA, 2012a, b, d). The environmental assets of the Lachlan River are one of the key hydrologic indicator sites where a detailed assessment was undertaken. Through assessment of the environmental water requirements, the MDBA has determined the “Environmental Sustainable Level of Take” (ESTL) for the Lachlan River (MDBA, 2012a, b, d). The ESTL is a representation of the Sustainable Diversion Limit (SDL); which is the maximum long-term annual average volumes of environmentally sustainable surface water that can be taken from the Basin for consumptive use.
There are 3 hydrologic indicator sites within the Lachlan River water source which are crucial environmental assets and important for determining the environmental water requirements of the Murray-Darling Basin (MDBA, 2012a, b, d). These three sites are:

1. The Booligal Wetlands [approx. 15,000 ha] - which are located on the floodplains of the Merrimajeel and Muggabah Creeks; distributaries of Torriganny Creek, an anabranch of the Lachlan River;
2. Lachlan Swamp – which covers an area of 30,000 ha, and extends from Goonawarra Nature Reserve downstream past Oxley to just above the commencement of the Great Cumbung Swamp; and
3. The Great Cumbung Swamp – which covers an area of 16,000 ha, and comprises the terminal drainage swamp of the Lachlan River and the surrounding floodplain.

The three sites all support forested communities dominated by river red gum (E. camadulensis) black box (Eucalyptus largiflorens) and river cooba (Acacia stenophylla) which provide ecosystem support for waterbird nests. The sites also provide refuge for a diverse assemblage of aquatic species including 19 species of fish, 10 species of crustacean, 8 species of mollusc and 2 species of sponges (MDBA, 2012a, b, d). The hydrologic indicator sites of the Lachlan River met all five criteria used by the MDBA for determining a key environmental asset in the Basin. The wetlands are formally recognised in international agreements; they are natural or near-natural; they provide essential ecosystem habitat; they support state and national threatened species communities; and they are capable of supporting significant biodiversity (MDBA, 2012a, b, d).

“Detailed environmental water requirements led to the specification of site-specific flow indicators to achieve site-specific ecological targets” (MDBA 2012a, p.2). The site specific flow indicators are referenced to a “hydrologic indicator” site or sites. The hydrologic indicator sites, and flows describe at those sites, are intended to represent the broader environmental flow needs of river valleys or reaches (MDBA 2012b). The MDBA identifies five “ecologically significant components of the flow regime”. These components are “cease to flow periods”, “base flows (low flows)”, “freshes”, “full bank flows”, and “overbank flows” (MDBA 2012b, p.21). Freshes are considered as flows that exceed the upper limit of based flows yet below “bank full flows”. Overbank flows are flows that exceed bank full flows. The assessment for unregulated catchments attended primarily to base flow requirements (low flows) “reflecting the prioritisation of efforts on parts of the flow regime that are most sensitive to the determination of [environmental sustainable levels of take and sustainable diversion limits]” (MDBA 2012b, p.39).
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.

Water quality in the Lachlan WRPA varies from poor to excellent. The water quality status map (Figure 15) provides an overview of water quality 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). The water quality management plan prepared as part of the water resource plan will provide further information on the water quality issues in the Lachlan WRPA including possible management strategies.

Figure 15: Water quality condition of the Lachlan 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 Poor
Dissolved oxygen concentrations were within the targeted range for much of the period of analysis. pH was also generally within the target range. Salinity in the upland was mostly low and negatively related to discharge i.e., the highest salinities occur during low flow periods. Nutrients such as nitrogen and phosphorus were low to medium in the upland water sources. Turbidity and suspended sediment were medium to high due to a number of factors including the
widespread conversion of land for cropping, river bank and riparian condition, and the presence of carp. Harmful algal blooms are rare in this part of the catchment.

4.3 Midland region
Condition: Fair to Good

Thermal pollution occurs in the Lachlan River for up to 400 km below Wyangala Dam. This results in water temperatures below natural during the summer months, and above natural during the winter months. This is because the dam infrastructure only allows water to be released from the deeper layers. In the Belubula River thermal pollution may occur for up to 50 km downstream of Carcoar Dam.

Temperature has a wide range of influences on biological processes. 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 result in mortality (Lugg and Copeland 2014). Cold water pollution has the potential to influence the recovery potential of fish communities and reduce the ecological outcomes from environmental water releases in the Lachlan River.

Dissolved oxygen was generally within target ranges. However, like the upland, it can become unpredictable during low and cease-to-flow periods. The pH is generally within the target range, although occasionally elevated in the Belubula River. Salinity levels were low to medium throughout most of the midland section of the catchment, though there were localised areas with higher salinities, notably Boorowa River, Belubula River and Mandagery Creek. There is a risk of crop damage if high salinity water is used for irrigation.

Algal blooms occur within Wyangala and Carcoar Dams in some years.

4.4 Lowland region
Condition: Poor to Good

In the lowland part of the catchment, dissolved oxygen was frequently recorded outside of the target range. This occurs when organic carbon concentrations, nutrients and temperature are high resulting in increased microbial respiration.

Turbidity and suspended sediment were high throughout most of the lowland. As with the upper parts of the catchment these high levels are influenced by a number of factors including the widespread conversion of land for cropping and irrigation, bank and riparian condition, and the presence of European carp. Clay dominated soils also have an increased susceptibility to resuspension within the water column. Nutrients were mostly recorded at high levels throughout the lowland. Algal blooms are common in Lake Cargelligo and also occur in some years at Lake Brewster due to the still, warm water and high levels of nutrients. Salinity in the lowland was generally low making the water excellent for irrigation purposes.

4.5 Terminal region
Condition: Poor

Dissolved oxygen in the terminal region was frequently outside the target range due to increased levels of organic carbon, nutrients and temperature which result in increased microbial respiration. The pH was mostly within the target range and salinity levels were generally low during the period of assessment.

Nutrients, suspended sediments and turbidity were high. These high levels are likely to be influenced by a number of factors including land use, river bank and riparian condition, and the presence of European carp. Harmful algal blooms occur occasionally at some sites in the lower section of the Lachlan River due to the combination of reduced flows and high nutrients.
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 metres are considered to be important for influencing good riparian condition (Jansen et al. 2003). An increase in the presence of large woody debris within rivers has been correlated with an increase in riparian tree cover, reaching a maximum when tree cover reaches 60 per cent (Matheson and Thoms in prep). Large woody debris derived from the riparian zone was associated with primary control on geomorphic stability and habitat heterogeneity in rivers (Brooks and Brierley 2002; Treadwell et al. 2007).

Changes to riparian vegetation can reduce the geomorphic condition of rivers (Brierley and Fryirs 2005). Reduction in geomorphic condition from good to moderate can be linked to reductions in macrophyte and macroinvertebrate assemblages (Chessman et al. 2006a), and freshwater mussel abundance declined in river reaches where geomorphic condition was reduced (Jones and Byrne 2010).

River Styles® recovery potential is synonymous with geomorphic condition. Recovery potential represents geomorphic stability and can indicate 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).

Figure 16 and Figure 17 provide a general overview of riparian and geomorphic condition for the Lachlan WRPA. There has been extensive clearing of riparian vegetation in the upper catchment of the Lachlan and in the upper reaches of unregulated tributaries in the middle reaches of the catchment. The highest areas of remaining riparian vegetation are along the Lachlan River between Cowra and Hillston (Figure 16).

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. Overall, the recovery potential within the middle and lower reaches of the catchment is generally good, while many streams in the upper catchment are classed as having low or moderate recovery potential (Figure 17).
Figure 16: Percent cover of native woody riparian vegetation in the Lachlan WRPA

Figure 17: Geomorphic recovery potential in streams in the Lachlan WRPA
6. River operations and management

6.1 Storages and regulating structures

Regulation of the Lachlan River began as early as the 1860s when landholders began constructing small weirs across the river as insurance against the irregular water supply (DLWC 1996). By the 1880s water from the river was being diverted and stored in the floodplain lakes, and the first major weir (Willandra Weir) was completed in 1891. The conversion of Lake Cargelligo into a permanent storage in 1902 opened the way for large-scale water resource development in the region.

6.1.1 Wyangala Dam

Located on the Lachlan River 48 km upstream of Cowra, Wyangala Dam is the major irrigation storage within the Lachlan catchment (Photo 5). It provides water for town water supplies, irrigation, stock and domestic requirements, industry and environmental flows along the Lachlan River and its effluent channels. The storage has a total capacity of 1,220,000 ML which it draws from a catchment area of around 8,300 km². The dam was completed in 1935 and enlarged to its current capacity in 1971.

The dam has experienced extended periods of low inflows during the drought years of the early 1980s and in most years from 2003-2011 (Figure 20). Inflows to Wyangala Dam were again well below average in 2014-15 with the annual inflow of 259,217 ML being 36 per cent of the long term average annual inflow of 721,406 ML (Burrell et al. 2016). However the high flows experienced in 2016 have again returned the dam to full capacity.

6.1.2 Carcoar Dam

Carcoar Dam is a relatively small storage on the Belubula River six kilometres upstream of the town of Carcoar (Photo 6). Completed in 1970, the dam has a capacity of 36,000 ML and supplies water for irrigation, stock and domestic use within the Belubula valley.

As with Wyangala Dam, storage volumes in Carcoar Dam were lowest during the early 1980s and for an extended period between 2002 and 2011 (Figure 19). Inflows were again well below average in 2014-15 (just 2,716 ML or 17 per cent of the average annual inflow).
6.1.3 Other storages and regulators

Water requirements in the lower Lachlan valley are met through the off-river storages of Lake Cargelligo and Lake Brewster. These are operated in conjunction with Wyangala Dam to supply water for irrigation, stock, domestic and town water supply for users in the lower catchment. Lake Cargelligo is the smaller of the two storages with a capacity of 36,000 ML. Flows into Lake Cargelligo are diverted from the Lachlan River by a fixed crest weir via an inlet channel that can carry up to 800 ML per day. Lake Creek, the natural hydrologic connection to the Lachlan River, is now operated as the outlet channel, capable of releasing up to 1,000 ML per day (DWR 1990).

Lake Brewster was converted into a permanent storage in 1950 and holds up to 154,000 ML of water for irrigation use. Up to 5,000 ML/day can be diverted into the lake from the Lachlan River at Brewster Weir. The lake has an outlet capacity of 2,000 ML per day (DWR 1990).

The Lachlan River is a highly regulated system with numerous weirs and regulators along its length. These structures assist in diverting water into various anabranches and effluents, and provide storage for water users to access water supplies (Figure 20, Table 1). One of the major structures is Jemalong Weir which diverts an average of 40,000 ML/year from the Lachlan River to the Jemalong Irrigation District (Jemalong Irrigation 2016).
Table 2: Major weirs in the Lachlan catchment

<table>
<thead>
<tr>
<th>Weir</th>
<th>Approximate location</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottons Weir</td>
<td>Forbes</td>
<td>Pumping pool for local users and town water supply</td>
</tr>
<tr>
<td>Jemalong Weir</td>
<td>20km downstream of Forbes</td>
<td>Diversions to Jemalong and Wyldes Plains Irrigation District</td>
</tr>
<tr>
<td>Island Creek Weir</td>
<td>Island Creek, 65km downstream of Forbes</td>
<td>Diversions to Wallamundry Creek and Island Creek</td>
</tr>
<tr>
<td>Condobolin Weir</td>
<td>Condobolin</td>
<td>Pumping pool for local users</td>
</tr>
<tr>
<td>Micabil Weir</td>
<td>20km downstream of Condobolin</td>
<td>Pumping pool for local users</td>
</tr>
<tr>
<td>Kiacatoo Weir</td>
<td>40km downstream of Condobolin</td>
<td>Pumping pool for local users</td>
</tr>
<tr>
<td>Booberoi Weir</td>
<td>50km downstream of Condobolin</td>
<td>Diversions to Booberoi Creek</td>
</tr>
<tr>
<td>Cargelligo Weir</td>
<td>Lake Cargelligo</td>
<td>Diversions to Lake Cargelligo</td>
</tr>
<tr>
<td>Brewster Weir</td>
<td>Lake Brewster</td>
<td>Diversions to Lake Brewster</td>
</tr>
<tr>
<td>Willandra Weir</td>
<td>40km upstream of Hillston</td>
<td>Diversions to Willandra Creek</td>
</tr>
<tr>
<td>Gonowlia Weir</td>
<td>20km upstream of Hillston</td>
<td>Diversions to Merrowie Creek</td>
</tr>
<tr>
<td>Hillston Weir</td>
<td>Hillston</td>
<td>Pumping pool for local users and town water supply</td>
</tr>
<tr>
<td>Torriganny Weir</td>
<td>Torriganny Creek, 15km upstream of Booligal</td>
<td>Diversions to Merimajeel and Muggabah Creeks</td>
</tr>
<tr>
<td>Booligal Weir</td>
<td>Booligal</td>
<td>Pumping pool for local users and town water supply</td>
</tr>
</tbody>
</table>

Figure 20: Location of major weirs and regulators in the Lachlan WRPA
6.2 Licensed water use

6.2.1 Lachlan River regulated entitlement and usage

The Lachlan catchment uses around 3.5 per cent of all surface water diverted in the Murray-Darling Basin (CSIRO 2007). Water from Wyangala Dam 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. The majority of the surface water irrigation is by licensed diversions directly from the Lachlan River. The only exception is Jemalong Irrigation District, which diverts water from the Jemalong weir downstream of Forbes.

A total of 666,439 ML of entitlement exists within the Lachlan River and 27,219 ML in the Belubula River (Table 3). Licences are located along the full length of the regulated Lachlan and Belubula systems (Figure 21). Most licences are used for irrigation, whilst a significant proportion are used for mining. One of Australia’s largest gold mines, Cadia Valley Operations, extracts water from the Belubula River (DPI Water 2013).

The majority of these are general security irrigators who account for over 88 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 are used to determine the volume of water that is to be added to an individual’s licence allocation account.

Long term modelling indicates that general security water users in the Lachlan valley receive 100 per cent of their share component plus carryover at the start of a water year in 31 per cent of years. By the end of the water year there they may access 100 per cent of their share component or more in 61 per cent of years (Figure 22).

A total of 28,775 ML of high security entitlement exists within the Lachlan valley. The availability of high security water is guaranteed irrespective of circumstances (except in extreme circumstances) and must be provided for prior to allocating water to other user users. In addition there is 15,545 ML allocated to local water utilities in the Lachlan Regulated River which receives priority over general security water users. No local water utilities extract from the regulated section of the Belubula River.

The regulated Lachlan and Belubula river 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 3: Surface water share components for the Lachlan and Belubula rivers 2015-16

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>Lachlan regulated share component (ML)</th>
<th>Belubula regulated share component (ML)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Stock</td>
<td>12,502</td>
<td>233</td>
<td>12,735</td>
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<td>Local water utility</td>
<td>15,545</td>
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<tr>
<td>Regulated river (general security)</td>
<td>592,801</td>
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<tr>
<td>Regulated river (high security)</td>
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<td>28,775</td>
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<tr>
<td>Regulated river (conveyance)</td>
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<td>17,911</td>
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<tr>
<td>Supplementary water</td>
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<td>3,125</td>
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<tr>
<td>TOTAL</td>
<td>666,439</td>
<td>27,219</td>
<td>693,658</td>
</tr>
</tbody>
</table>
Figure 21: Location of regulated river entitlement
Figure 22: Long term water availability for General Security entitlement in the Lachlan River

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 Lachlan River has been 120,000 ML (Burrell et al. 2016).

Figure 23 shows the water available in the Lachlan River since water sharing 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 beginning of the 2015-16 water year, regulated river users on the Lachlan River had access to 100 per cent of their share component for domestic and stock, local water utility and high security irrigation, while general security irrigators had access to 55 per cent of their share component. Similar allocations were made for the Belubula (Figure 23). Reduced water availability for general security users over the past two years resulted in a reduction in areas planted from previous years and therefore water usage fell in 2014-15 and 2015-16 in both valleys (Figure 24) (Burrell et al. 2016).
Figure 23: Water availability in the Lachlan and Belubula rivers (carry-over + AWD)

Figure 24: Water usage in the Lachlan Regulated River since introduction of water sharing
6.2.3 Unregulated river entitlement

Water users located on the various unregulated tributaries of the Lachlan catchment 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.

There is approximately 52,993 ML of entitlement allocated to water users on unregulated streams in the Lachlan WRPA (Table 4, Figure 25). The majority of licences are used for irrigation, with a significant proportion used for mining and stock water. Water is also extracted from these water sources through basic landholder rights which do not require a licence.

The majority of the unregulated surface water licences are located: around the town of Young, in the headwaters of Burrangong Creek; around the town of Crookwell, within the headwaters of the Crookwell River; within tributaries of the Belubula River including Cadiagullong Creek, Flyers Creek, Cowriga Creek and Swallows Creek; and along Mandagery Creek below Eugowra. There are fewer licences in the north and south-western part of the WRPA as the streams are generally intermittent or ephemeral (DPI Water 2016b).

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>Total share component (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Stock</td>
<td>705</td>
</tr>
<tr>
<td>Local Water Utility (unregulated rivers)</td>
<td>5,617</td>
</tr>
<tr>
<td>Unregulated River Access</td>
<td>46,671</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>52,993</strong></td>
</tr>
</tbody>
</table>

Around 10 per cent of entitlement is allocated for town water supplies. Town water supply is managed by various authorities, the largest being Parkes Shire Council and Central Tablelands Water.

Parkes Shire Council provides water for towns including Parkes, Peak Hill, Alectown, Cookamidgera, Bogan Gate, Trundle and Tullamore (Parkes Shire Council 2010). Much of this is sourced from alluvial water sources, however 1500 ML of entitlement is held within the Goobang and Billabong Creeks Water Source (DPI Water 2016b).

Central Tablelands Water supplies water to Blayney, Millthorpe, Carcoar, Mandurama, Lyndhurst, Cargo, Cudal, Manildra, Canowindra, Eugowra, Grenfell, Woodstock, Gooloogong and Quandialla (CTW 2006). The main water source of Central Tablelands Water is Lake Rowlands, a 4,500 ML dam on a tributary of the Belubula River (CTW 2006) within the Belubula Tributaries below Carcoar Dam Water Source.

In some of the unregulated water sources where water is extracted for town water supply, competition for water during low flows can become an issue between agricultural users and the local water utility. To partly address this competition, the Lachlan Unregulated and Alluvial Water Sharing Plan allows water utilities to extract during periods of very low flow, whilst all other licensed holders are prohibited from extracting.
Figure 25: Location of unregulated entitlement in the Lachlan WRPA
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. 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 26 and Figure 27 show permanent and temporary water licence trades from the start of the water sharing plan in 2004 within the Lachlan Regulated River water source. Variations between years are mostly related to climatic conditions and the volume of water made available to different licence categories.

Between 2007 and 2012 significant volumes of water were purchased from the region for environmental purposes. These were purchased through the NSW RiverBank program (25,000 ML) and the Commonwealth Restoring the Balance program (82,000 ML) (EBC Consortium 2011). This is reflected in the permanent environmental trade volumes in Figure 26.

Figure 26: Permanent trades in the Lachlan River from 2004-05 to 2015-16

![Figure 26: Permanent trades in the Lachlan River from 2004-05 to 2015-16](image)

Figure 27: Temporary trades in the Lachlan River from 2004-05 to 2015-16

![Figure 27: Temporary trades in the Lachlan River from 2004-05 to 2015-16](image)
The low volume of temporary trades prior to 2010 is a reflection of the severe drought conditions during this time during which general security water was limited to just 3 per cent of allocation. Similarly, temporary trades were lower in 2014-15 and 2015-16 than the previous two years due partly to the reduced allocation available to general security licence holders in these years (Figure 27).

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 Lachlan WRPA have gradually increased since the commencement of the water sharing plan in 2004. They currently 127,557 ML comprised of 124,518 ML of general security water, 2,728 ML of high security water and 311 ML of domestic and stock water (Figure 28).

The main entitlement holders of held environmental water are the Commonwealth Environmental Water Holder and the NSW Office of Environment and Heritage. Held environmental water was first used in the Lachlan valley in 2009-10 with the highest use to date being 66,283 ML in 2011-12 (Figure 28).

There is currently no held environmental water in the Belubula River.

Figure 28: Held environmental water share components in the Lachlan WRPA
6.4.2 Planned environmental water

Planned environmental water is defined in the water sharing plan according to rules. The Lachlan valley has two environmental water allowances (EWAs) which are maintained for environmental purposes:

- an environmental water allowance held in Wyangala Dam, known as the Wyangala EWA
- an environmental water allowance held in Lake Brewster, known as the Lake Brewster EWA

Both the Wyangala and Brewster EWAs are each credited with a volume of 10,000 ML subject to certain conditions being met. Water is credited at the beginning of each year (1 July) if the water available for regulated river (general security) access licences is greater than 50 per cent of the licence share components. In water years when the EWAs are not credited on 1 July, water may be credited into the account when the sum of water in the accounts of regulated river (general security) access licences at 1 July, plus the volume of water provided by available water determinations for those licences during the water year, is equivalent to 75 per cent of the total share components of those licences. No water was allocated to either EWA in 2014-15 or 2015-16 as these conditions were not met (Figure 29).

When available the EWAs may be used for a variety of environmental purposes including support of waterbird breeding events, native fish breeding and fish passage, wetland watering, flow variability, and water-dependent Aboriginal cultural values.

There is also a Water Quality Allowance which provides for up to 20,000 ML/year. Releases from this allowance may be made for any water quality management purpose but in particular for reduction of salinity levels and mitigation of blue-green algae impacts. Any water that is not used is forfeited at the conclusion of the water year (Burrell et al. 2016).

Figure 29 shows the availability and usage of environmental and water quality allowances since 2009 in the Lachlan WRPA. The only year to date in which both allowances have been used has been in 2010-11.

Figure 29: Environmental Water Allowance availability and usage in the Lachlan WRPA
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</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>
</tbody>
</table>
Groundwater: Water that occurs beneath the ground surface in the saturated zone.

Groundwater dependent ecosystems: 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.

Harmful algal bloom: An algal bloom that causes negative impacts to other organisms through the production of natural toxins, mechanical damage, or other means.

High flows: Also called bankfull events, these reshape the channel, creating habitats such as pools, bars and benches.

High security licence: 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.

Instream value: 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.

Low flows: 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.

Nitrogen and phosphorous: Chemical nutrients essential for growth and added to many fertilisers.

Overbank flows: High flows that connect the river to floodplain and wetlands allowing the exchange of nutrients and sediment to these areas.

Regulated river: 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.

Replenishment flows: Flows provided along effluent systems to supply water for household, town use and stock.

Riparian: Relating to or living or located on the bank of a natural watercourse, such as a river stream.

Salinity: 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.

Seasonality: The timing of flooding and low flow events.

Share component: 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 (e.g. local water utility, major water utility and domestic and stock).

Kuginis L., Dabovic, J., Byrne, G., Raine, A., and Hemakumara, H. 2016, Methods for the identification of high probability groundwater dependent vegetation ecosystems. DPI Water, Sydney, NSW.
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock watering</td>
<td>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.</td>
</tr>
<tr>
<td>Stratification</td>
<td>The formation of separate water layers.</td>
</tr>
<tr>
<td>Supplementary water</td>
<td>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.</td>
</tr>
<tr>
<td>Water access entitlement</td>
<td>A water product (licence) issued under the Water Management Act 2000.</td>
</tr>
<tr>
<td>Water resource plan</td>
<td>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.</td>
</tr>
<tr>
<td>Water sharing plan</td>
<td>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.</td>
</tr>
<tr>
<td>Water source</td>
<td>The whole or any part of:</td>
</tr>
<tr>
<td></td>
<td>• one or more rivers, lakes or estuaries, or</td>
</tr>
<tr>
<td></td>
<td>• one or more places where water occurs naturally on or below the surface of the ground,</td>
</tr>
<tr>
<td></td>
<td>and includes the coastal waters of the State.</td>
</tr>
</tbody>
</table>

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3 As defined in the Water Management Act 2000
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Cook N and Schneider G 2006, River Styles® in the Hunter Catchment, Science and Information Division, New South Wales Department of Natural Resources, Sydney, NSW.


MDBA 2012a, *Assessment of environmental water requirements for the proposed Basin Plan: Great Cumbung Swamp*. Murray-Darling Basin Authority, Canberra, ACT.

MDBA 2012b, *Hydrologic Modelling to inform the proposed Basin Plan – methods and results*, MDBA publication no.: 17/22, Murray-Darling Basin Authority, Canberra.

MDBA 2012c, Assessment of environmental water requirements for the proposed Basin Plan: Booligal Wetlands, Murray-Darling Basin Authority, Canberra.

MDBA 2012d, Assessment of environmental water requirements for the proposed Basin Plan: Lachlan Swamp, Murray-Darling Basin Authority, Canberra.


