Department of Primary Industries
Office of Water

Environmental flow response and socio-economic monitoring

Lachlan Valley - progress report 2011

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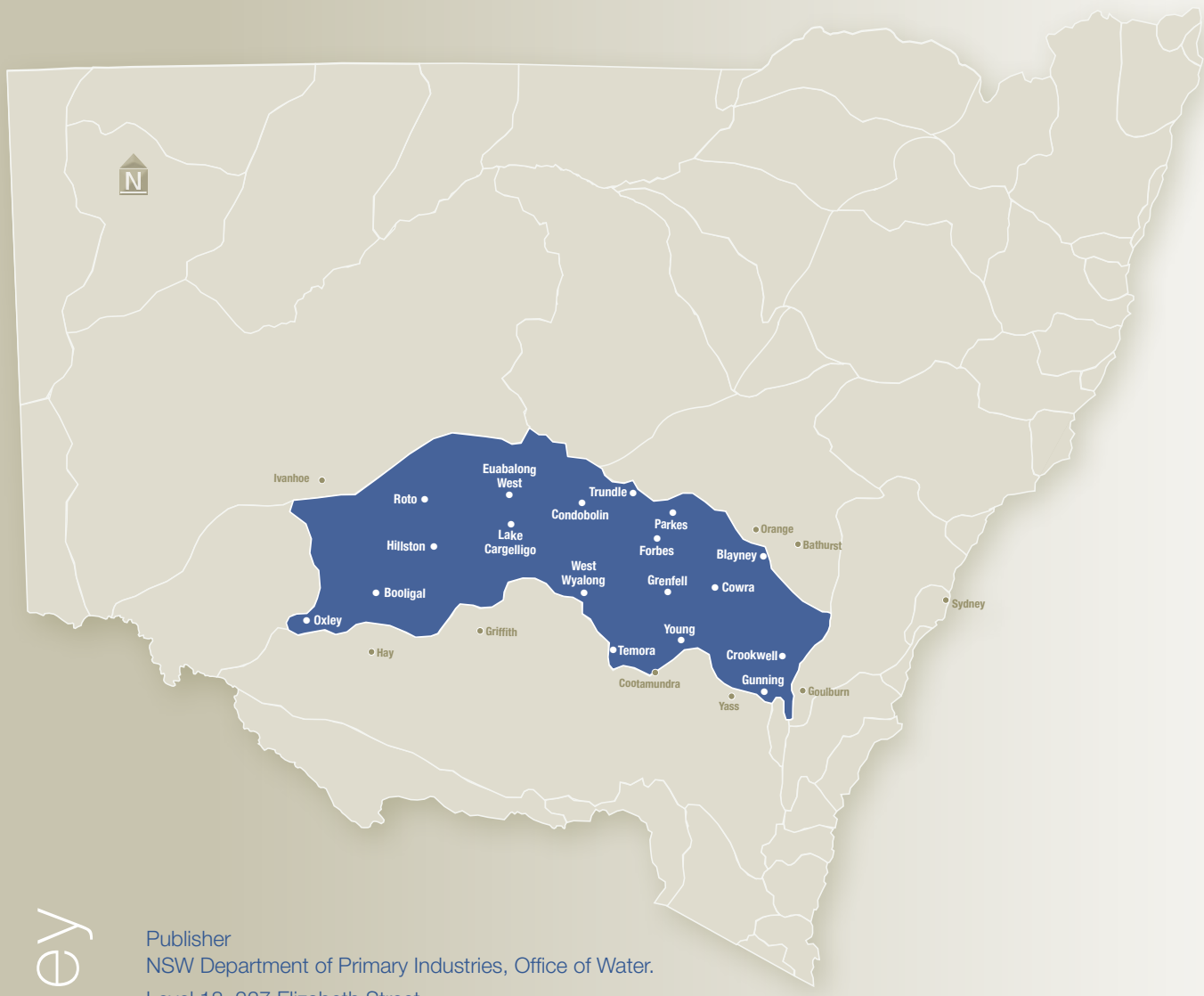

Lachlan Valley

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The NSW Office of Water manages the policy and regulatory frameworks for the state's surface water and groundwater resources, to provide a secure and sustainable water supply for all users. It also supports water utilities in the provision of water and sewerage services throughout New South Wales.

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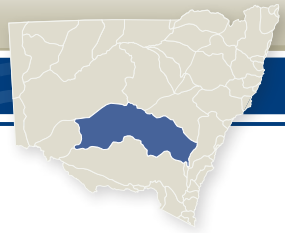


Introduction

WHAT IS THE PURPOSE OF THIS REPORT?

This report provides an update on the monitoring and evaluation activities undertaken in 2010-11 to assess the ecological and socio-economic performances of water sharing plans adopted in the Lachlan Valley. It provides an interim assessment of outcomes of the investigations and identifies priority needs for future monitoring and evaluation activities.

WHY DO WE NEED TO MONITOR WATER SHARING PLANS?

Water sharing plans provide water to meet environmental and socio-economic needs, and spell out the rules governing access to water. The Lachlan Valley contains a number of important environmental assets and supports a valuable irrigation industry. Nationally important environmental assets include Booligal Swamp (Figure 1), Great Cumbung Swamp (Figure 2) and Lake Cowal (Figure 3 and see www.environment.gov.au).

It is important to know whether the water sharing plans are meeting their environmental objectives, so that their effectiveness can be reviewed at the end of their 10-year period of operation. This information will be used to make informed decisions on how the plans might be improved when they are renewed. To achieve this, the NSW Office of Water undertakes ecological monitoring and evaluation activities focused on specific clauses and performance indicators within the plans.

FIGURE 1
Sampling macroinvertebrates in the nationally significant Booligal Swamp, December 2010.

Image courtesy of Patrick Driver

FIGURE 2
Lake Marrool in the Great Cumbung Swamp. Factors such as grazing, forestry and fire all need to be considered in addition to water availability in monitoring and reporting.

WHAT WATER SHARING PLANS ARE CURRENTLY IN PLACE?

Three water sharing plans in the Lachlan Valley are currently gazetted (Figure 4):

- Water Sharing Plan for the Lachlan Regulated River Water Source 2003
- Water Sharing Plan for the Mandagery Creek Water Source 2003 (Unregulated River)
- Water Sharing Plan for the Lower Lachlan Groundwater Source 2003 (this plan commenced on 1 February 2008).

More details of these plans can be found on the NSW Office of Water's website www.water.nsw.gov.au go to Water Management > Water Sharing Plans.

Image courtesy of Joseph Cairns

FIGURE 3
Lake Cowal.

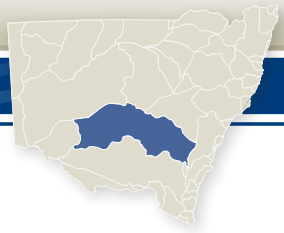
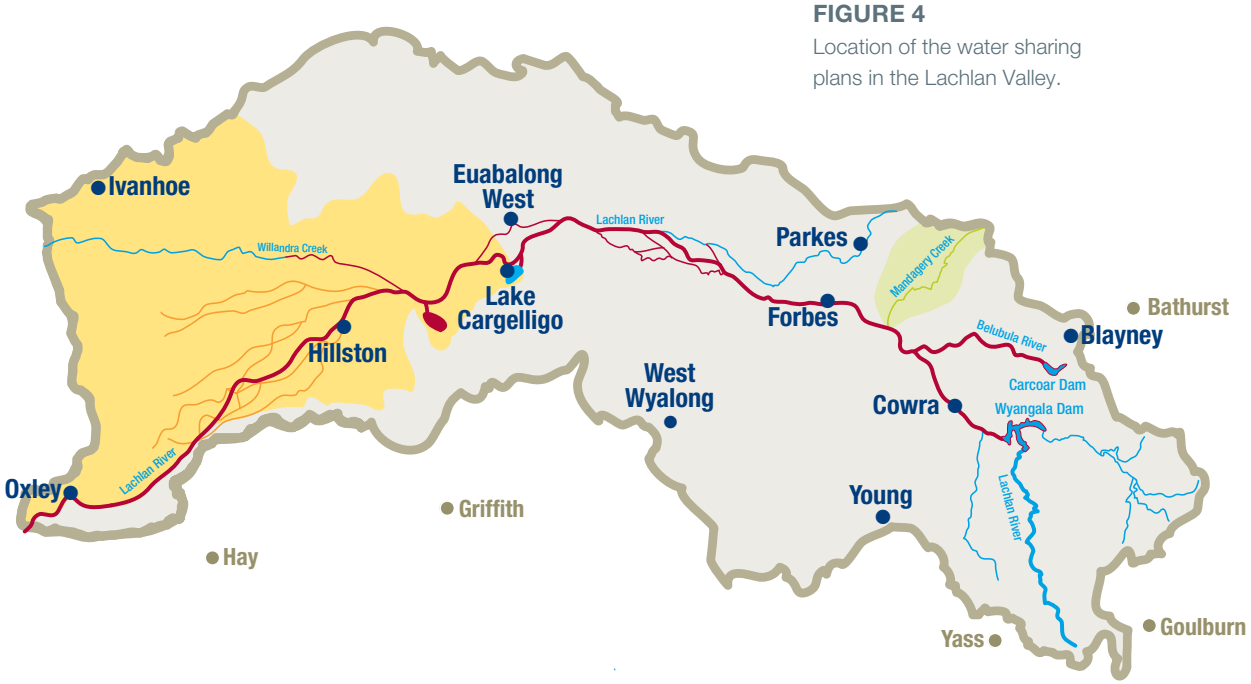
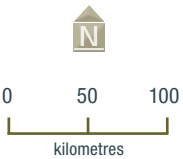


FIGURE 4
Location of the water sharing plans in the Lachlan Valley.



LEGEND

- Lachlan Regulated River Water Source
- Mandagery Creek Water Source (Unregulated River)
- Lower Lachlan Groundwater Source



available water determinations

WHAT HAS INFLUENCED THE WATER SHARING PLANS' OPERATION IN 2010-11?

Regulated rivers - water availability

Water availability for general security access licences for the Lachlan Regulated River Water Source was zero per cent at the start of the 2010-11 water year and increased to 117 per cent in April 2011, where it remained until June 2011. Figures 5 and 6 show the water availability for general security access licences in the Lachlan Regulated River Water Source over the last 31 and 9 years respectively.

The Water Sharing Plan for the Lachlan Regulated River Water Source commenced on 1 July 2004 and was suspended on the same day owing to severe drought conditions. It recommenced on 16 September 2011.

Unregulated rivers - water availability

Annual allocations to all categories of access licences for the Mandagery Creek Water Source were 100 per cent, although given the low flows in most streams, this quantity may not have been extractable.

Groundwater - water availability

Annual allocations to all categories of access licences (excluding supplementary water) for the Lower Lachlan Groundwater Source were 100 per cent. Supplementary water access licences were 0.7 megalitres per share entitlement.

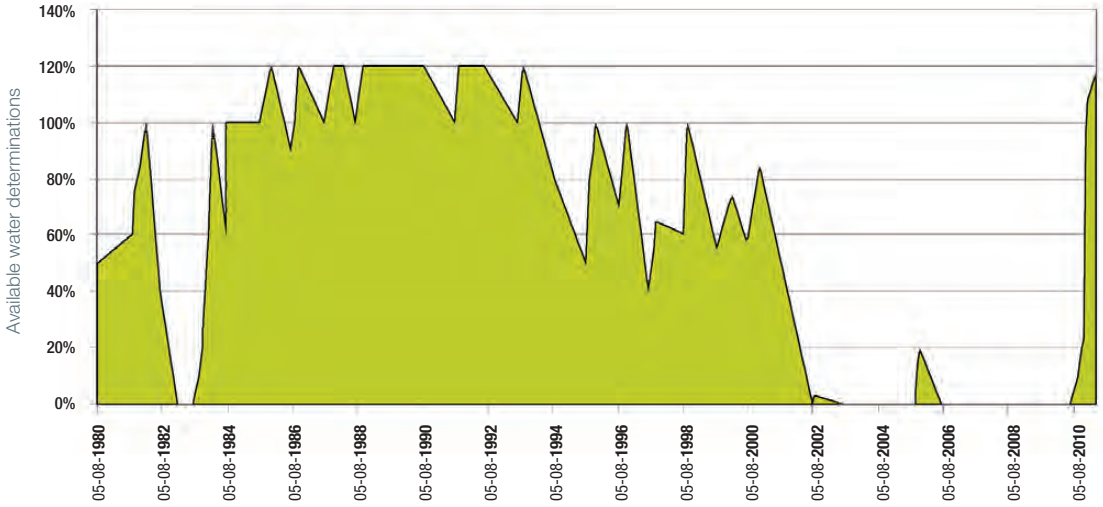


FIGURE 5
Available water determinations for Lachlan Regulated River Water Source from 1980 to 2011 (indicative only).

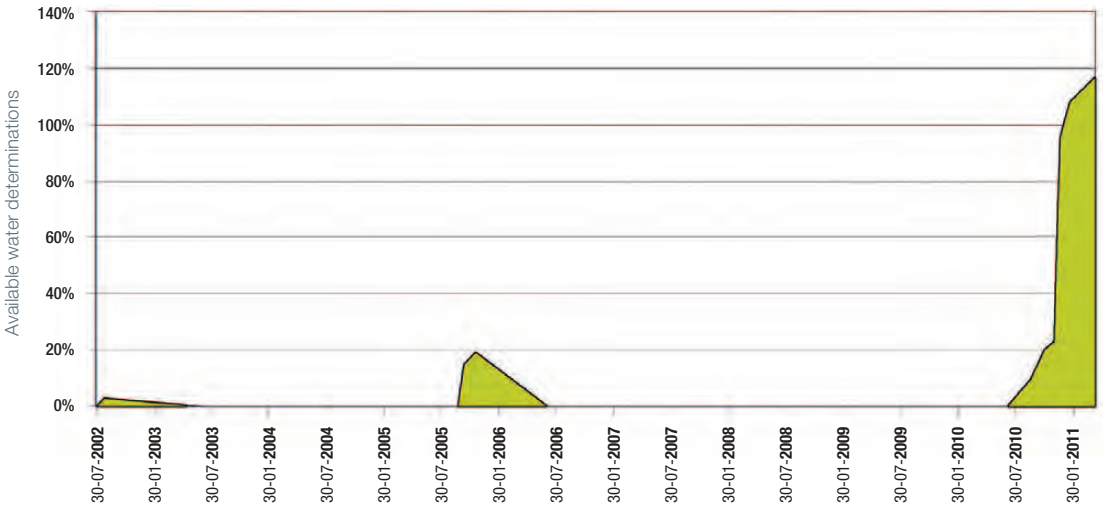


FIGURE 6
Available water determinations for Lachlan Regulated River Water Source from 2002 to 2011 (indicative only).

WHAT ENVIRONMENTAL ISSUES ARE ADDRESSED BY THE WATER SHARING PLANS?

Regulated rivers water sharing plans

The Water Sharing Plan for the Lachlan Regulated River Water Source includes flow rules that govern translucency (the partial release of an inflow into the main river below Wyangala Dam at the same time as water flows into the storage). Translucent environmental flows provide the most water for the environment during wet years, supplying up to 350,000 megalitres per year (approximately 23 per cent of average total river system inflows) between 15 May and 15 November every year, sufficient to produce a flow downstream of Lake Brewster of 3,500 to 8,000 megalitres per day, and are designed to continue down the river as would have occurred before the dam's construction.

Additionally, every year, a 20,000 megalitre volume of water called an environmental contingency allowance (ECA) is banked for environmental purposes when the general security allocation exceeds 50 per cent as at 1 July. This volume is split equally between Wyangala Dam and Lake Brewster. The water is intended to be released downstream of these storages for environmental benefits.

Since 2006, purchased 'adaptive environmental water' (AEW) is also used. AEW is owned by both state (at the time of this report, state environmental water entitlement holdings were about 38 gigalitres; www.environment.nsw.gov.au Riverbank 26 gigalitres and Lake Brewster AEW Licence 12 gigalitres) and commonwealth governments (at the time of this report, commonwealth environmental water holdings were about 83 gigalitres; www.environment.gov.au).

The effects of environmental flows by all these three types of environmental water (translucency, ECA and purchased) are monitored and reported on.

The water sharing plan also establishes a 20,000 megalitre water quality allowance to be released for any water quality purpose, but particularly to reduce salinity levels and blue-green algal impacts (Clause 15(3)).

Unregulated rivers water sharing plans

The Water Sharing Plan for the Mandagery Creek Water Source sets cease-to-pump rules to protect very low flows and salinity levels downstream, and sets daily flow sharing rules to protect a proportion of flows for the environment.

Groundwater sharing plans

Groundwater modelling and calculations based on ecological monitoring measurements have provided sustainable extraction volumes, which have been incorporated into the water sharing plans for each groundwater source in the Lachlan catchment. The sustainable extraction volume is that which may be extracted without compromising the integrity of the water source and any ecosystems that may depend on it. Where relevant, each plan provides for the needs of existing or additional groundwater-dependent ecosystems.

The Water Sharing Plan for the Lower Lachlan Groundwater Source (commenced 1 February 2008) establishes the sustainable extraction volume for the Lower Lachlan Alluvial Groundwater Source.

The Draft Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources (scheduled for commencement in 2012) establishes the sustainable extraction volume for both the Upper Lachlan and Belubula alluvial groundwater sources.

For the Lachlan Fold Belt Fractured Rock (LFBFR, plan not yet commenced), the calculated sustainable extraction volume is based on infiltration of 25 per cent of recharge into non, high-value conservation or environmental portions of the LFBFR. This is the extraction limit or sustainable yield at a 25 per cent sustainability factor.

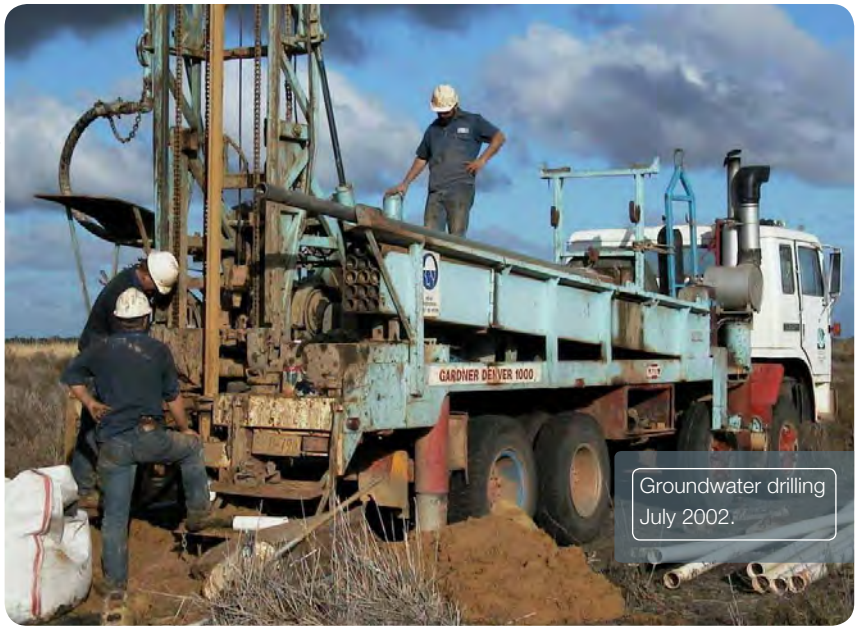


Image courtesy of Martin O'Rourke

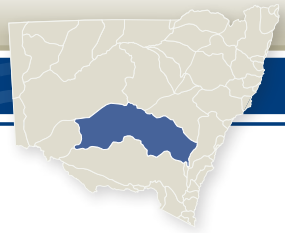
Groundwater drilling July 2002.

The total entitlement for LFBFR is less than the sustainable limit, so this source has unassigned water that could potentially be issued in line with a controlled allocation order.

For the Orange Basalt Fractured Rock (OBFR, plan not yet commenced) the calculated sustainable extraction volume is based on infiltration of 50 per cent of recharge into non, high-value conservation or environmental portions of the OBFR. This is the extraction limit or sustainable yield at a 50 per cent sustainability factor. The total entitlement for OBFR is less than the sustainable limit, so additional volumes potentially could be issued in line with a controlled allocation order.

For the Young Granite Fractured Rock (YGFR, plan not yet commenced) the calculated sustainable extraction volume is based on infiltration of 50 per cent of recharge into non, high-value conservation or environmental portions of the YGFR. This is the extraction limit or sustainable yield at a 50 per cent sustainability factor. The total entitlement for YGFR is less than the sustainable limit, so additional volumes could potentially be issued in line with a controlled allocation order.

More details on the water sharing plans, visit www.water.nsw.gov.au go to Water Management > Water Sharing Plans.



ecological monitoring

WHAT ECOLOGICAL MONITORING IS OCCURRING?

Regulated rivers water sharing plans

Water Sharing Plan for the Lachlan Regulated River Water Source

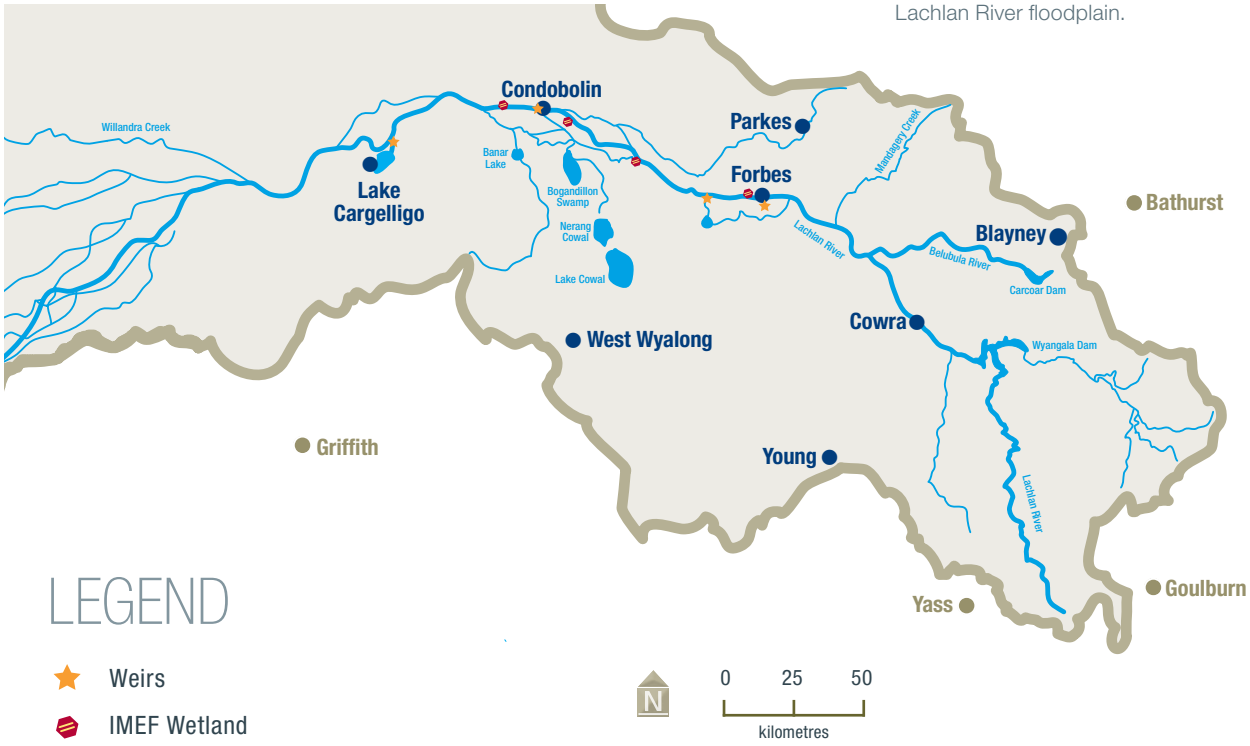
The following projects are under way in the Lachlan Regulated River Water Source:

Watering Lachlan wetlands during flood and drought

The NSW Government, including the NSW Office of Water, the NSW Office of Environment and Heritage and the Fisheries section of the Department of Primary Industries, has monitored releases of environmental water allowances in Lachlan wetlands since the 1980s.

In 1998, the Integrated Monitoring of Environmental Flows (IMEF) program was developed, and established sites in key wetland areas (Figures 7-9), rivers and water storages prone to developing algal blooms. IMEF has now been incorporated into a single program for monitoring and modelling environmental flows in both

FIGURE 7 The mid Lachlan, the upper half of the Lachlan River floodplain.



regulated and unregulated water sources.

Currently, the NSW Office of Water supports the environmental water advisory groups, which coordinate the delivery of all discretionary environmental water (water not subject to fixed rules within the water sharing plan). The Office of Environment and Heritage coordinates these groups, and reports against how well environmental flows meet legislation and policies in relation to threatened species and communities, such as the lower Lachlan ecological community, which is recognised as a threatened community (DPI 2005). The Office of Environment and Heritage has purchased and now manages locations where key environmental flow targets are set. These include 2,574 hectares on Booligal Station and 1,463 hectares of Lachlan Swamp, both of which are part of nationally significant wetlands.

The environmental water advisory groups operate in accordance with a RiverBank water use plan, in this case for the Lachlan Water Management Area No 1. The Lachlan Riverine Working Group serves as the Lachlan environmental water advisory group (see www.lrwg.com.au), which is coordinated in close partnership with the Lachlan Catchment Management Authority, other government agencies such as NSW Fisheries (Department of Primary Industry) and community representatives (for example, graziers and irrigators).

The NSW Office of Water continues to assess the water sharing plan through targeted monitoring and further development of models that are used to assess environmental flow delivery effectiveness.

Links to other projects

Since the inception of the water sharing plan, the NSW Office of Water has conducted numerous related investigations, as detailed below.

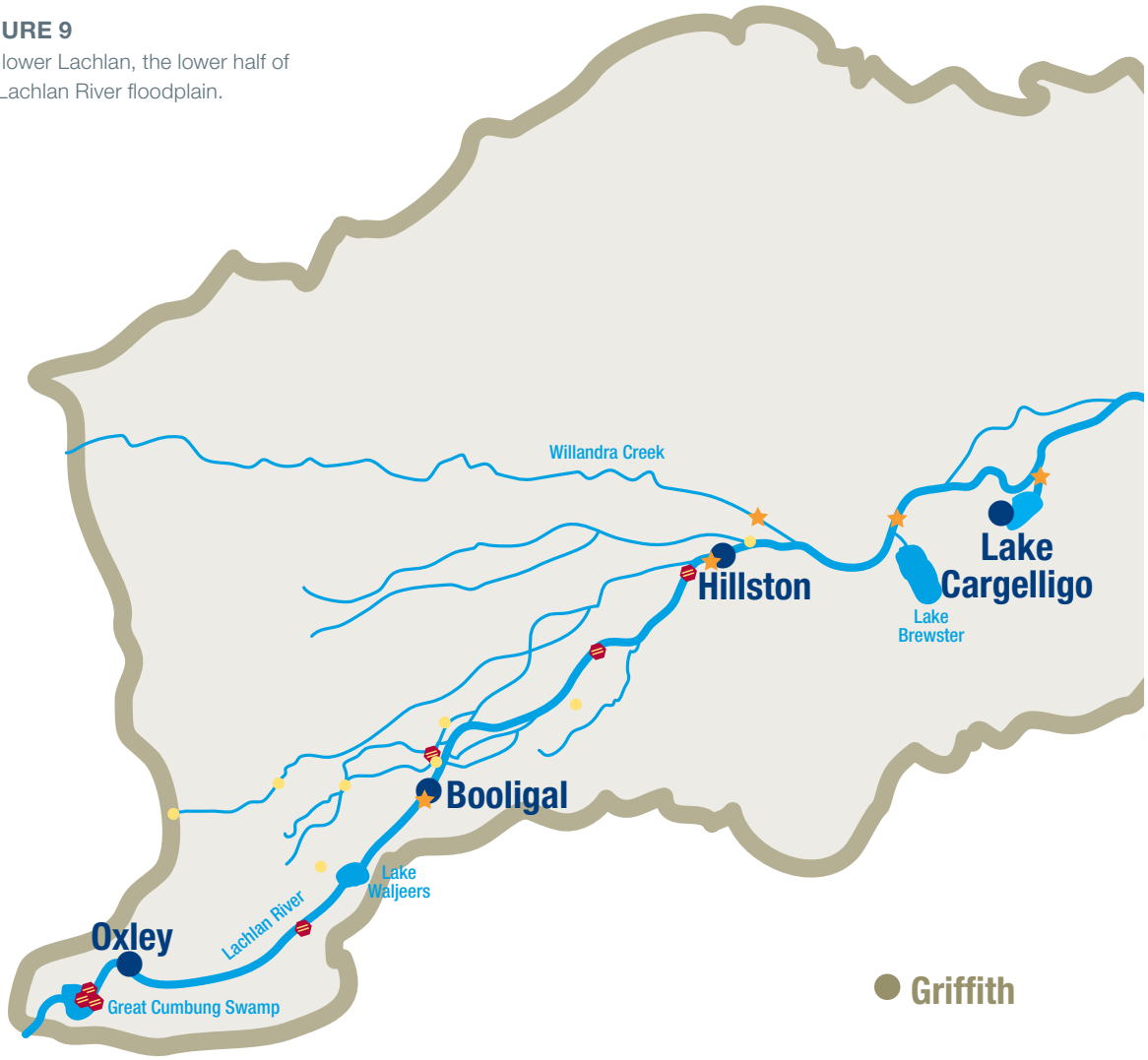
LiDAR data to build hydrodynamic models of floodplain inundation

Funded under the IMEF program, the use of LiDAR (Light Detection and Ranging) to create wetland digital terrain models was first tested in the Macquarie Marshes (www.aamgroup.com/resources/pdf/publications/news/ScanHoriz072006.pdf). The successful trial led to a statewide project to acquire LiDAR data for the development of wetland hydrodynamic models. The project identified core management areas and areas where hydrodynamic modelling could provide advice on the best use of environmental water. The locations and technical specifications were determined in consultation with key stakeholders. Numerous agencies are now using the data to build hydrodynamic models of floodplain inundation.

Image courtesy of Patrick Driver

FIGURE 8
Wilga Lagoon, a mid-Lachlan wetland monitoring site.

FIGURE 9
The lower Lachlan, the lower half of the Lachlan River floodplain.



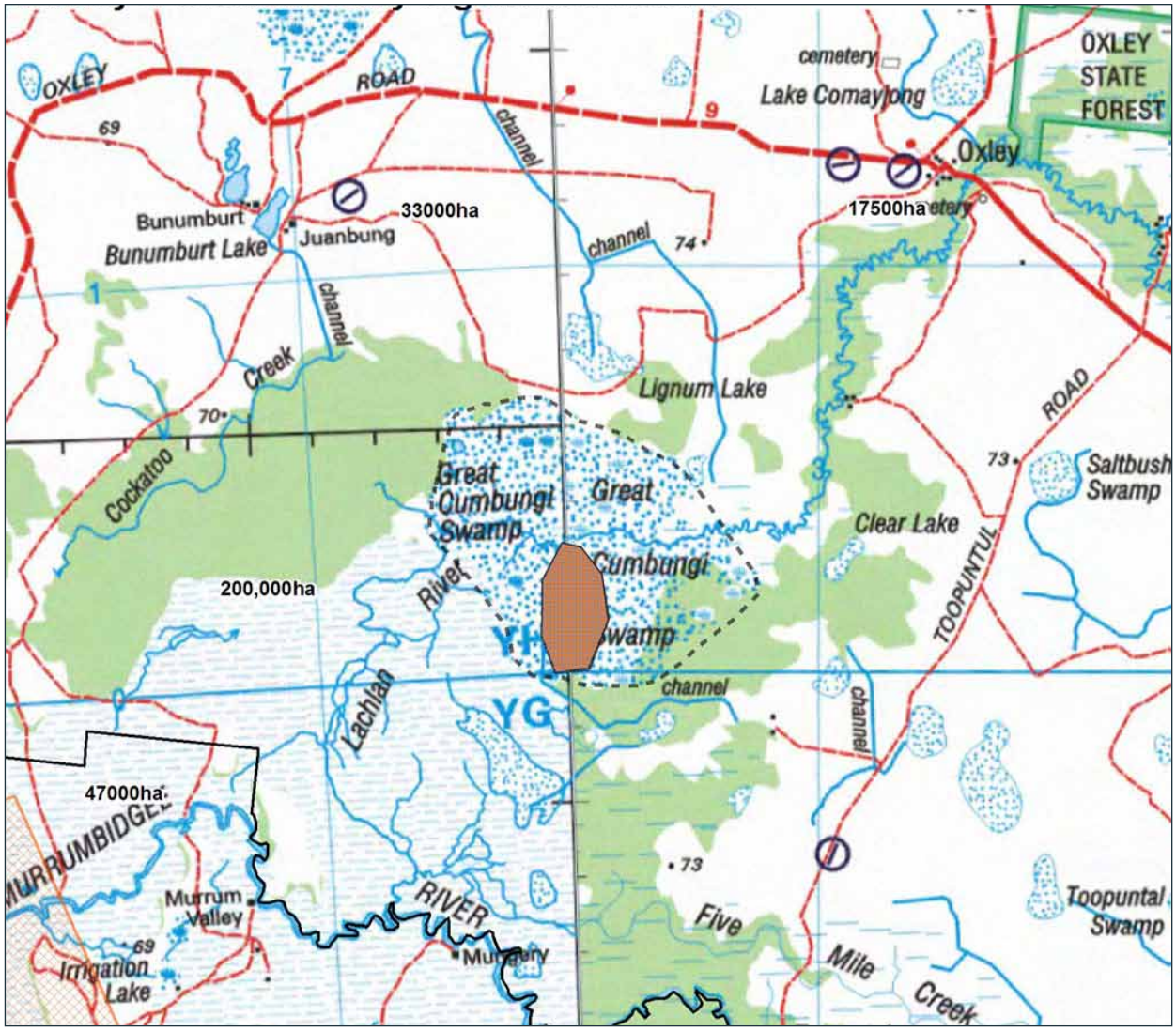
LEGEND

- Weirs
- IMEF Wetland
- Wetland Feature

N

0 25 50
kilometres

FIGURE 10 The Great Cumbung Swamp, showing the high priority modelling area that was identified for LiDAR data acquisition.



Focus point

IMEF reedbed modelling site

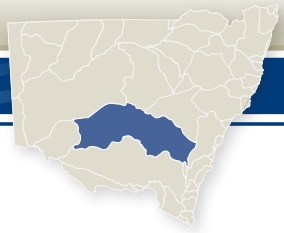
High priority modelling area

Lowbridge flood control and irrigation district boundary

N

0 1 2 3 4 5

kilometres



Additional LiDAR data covering the Great Cumbung Swamp in the Lachlan Valley (Figure 10) was purchased to create a hydrodynamic model under a project led by the Lachlan Catchment Management Authority.

Mapping of geomorphic layers

Mapping of geomorphic layers across the Lachlan catchment began with the development of the Water Sharing Plan for the Belubula Regulated River and Alluvial Water Sources. The information will be critical in identifying which components of the landscape are most affected by flow rules and in assessing how assets such as wetlands and river pools will respond to the management of flows and land. The NSW Office of Water and the Lachlan Catchment Management Authority will map the remainder of the catchment.

Ecosystem models

The NSW Office of Water and the eWater Cooperative Research Centre developed ecosystem models. This work benefits from closely linked studies from all over NSW, including carbon cycling work, wetland studies from the Murrumbidgee River to the Gwydir-Gingham wetlands, numerous within-stream studies of algal production and fish recruitment, climate change modelling (including of wetlands), and climate change modelling done by the NSW Office of Water's hydrologists for the CSIRO's Sustainable Yield Program.

Other NSW Office of Water's work includes assessing the potential risks associated with climate change. Projections on the impact of climate change on wetlands such as the Great Cumbung Swamp and the Booligal Swamp indicate the need to manage flows carefully so as to ensure that water is available for wetland maintenance during drier years. The climate change models used in this work are being verified for their effects on how well rules within the water sharing plans can be implemented.

Prevention and mitigation of algal blooms

One of the key sources of information used in setting the water quality allowance under the water sharing plan is the Central West Regional Algal Coordinating Committee (www.water.nsw.gov.au go to Water Management > Water Quality > Algal Information > Central West Regional Algal Coordinating Committee).

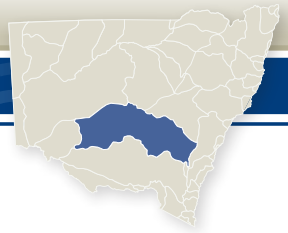
The Central West Regional Algal Coordinating Committee coordinates routine monitoring of algal and cyanobacterial (blue-green algal) blooms by councils, State Water and the NSW Office of Water in the Lachlan and Macquarie valleys (Figure 11). The water storages monitored include Wyangala Dam, Carcoar Dam, Lake Cargelligo, Lake Curlew, Lake Brewster, Lake Forbes and Lake Cowal; weir pools at Willandra, Hillston and Booligal; and river locations at Condobolin and Corrong.

Wedgetail Eagles at Great Cumbung Swamp.

Image courtesy of Tracy Fulford

FIGURE 11 Map of algal monitoring sites.

FIGURE 12 Map of salinity monitoring sites.



Mitigation of river salinity

Numerous upland stations (Figure 12) are maintained by the NSW Office of Water's hydrometric staff to ensure an accurate time series of electrical conductivity (EC) data, which are used to estimate and manage the risk of salinity downstream. Stations maintained for this purpose include Boorowa River at Prossers Crossing, the Belubula River at the Needles and upstream of Canowindra, and Mandagery Creek at Smithfield. Other sites established or to be reopened (with EC to be installed in the next 6 months) include Hovells Creek and Crowther (Back) Creek. All established sites have telemetry updated to the web every hour.

At-risk lowland weirs (Figure 12) also have telemetered EC data (apart from Brewster, which is monitored and managed by State Water). EC data are measured at Nanami, Lake Cargelligo Weir, Willandra Weir, Hillston Weir, Booligal Weir and Four Mile Weir (near Oxley); and at Forbes, Cowra and Condobolin.

River pools as drought refugia

To provide critical information for the management of water during drought, including for the Lachlan Riverine Working Group, the NSW Office of Water and the Fisheries section of the Department of Primary Industries monitored the responses of lower Lachlan refugia during 2009-10.

The NSW Office of Water's Lower Lachlan Drought Refugia Project was undertaken over summer, when the Lachlan River below Condobolin ceased flowing owing to drought (*Pepper et al. 2010*). This project investigated the impacts of low flows and cease-to-flow periods on the instream aquatic habitat. Key aquatic refugia sites were selected in Booberoi, Willandra, Hillston and Booligal weir pools and in Lake Cargelligo. Results may assist in setting minimum flows and in managing the water quality allowance in the future. Some monitoring is still taking place in some of the weir pools.

Water Sharing Plan for the Belubula Regulated River and Alluvial Water Source (in preparation)

Ecological monitoring in the Belubula River Regulated River and Alluvial Water Source will work off established gauging stations. Estimates of the success of water management for environmental outcomes will be based on estimated flow requirements of key flora and fauna considered to rely on flows within this river. The groundwork for this approach is described in the section below covering the Water Sharing Plan for Lachlan Unregulated and Alluvial Water Sources (in preparation).

Unregulated rivers water sharing plans

Water Sharing Plan for the Mandagery Creek Water Source

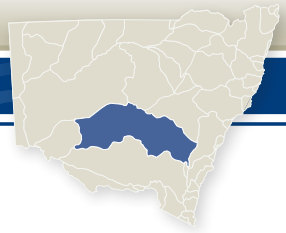
A study at Mandagery Creek (Figure 13) aims at developing a GIS model to predict natural barriers to upstream movement by fish (waterfalls, cascades) using a digital elevation model and other spatial data, and at calculating upstream connectivity for fish movements on the basis of man-made barriers, distance and any other relevant information.

Field verification involving photo-point monitoring and low flow gauging is planned for the Mandagery Creek Water Source. The aim is to assess how well the current access rules are meeting the plan's objectives of protecting water levels in natural river pools during periods of no flow (and wetlands where appropriate), and of protecting natural low flows. The work will analyse flow and assess the basic needs of aquatic plants and animals. Following field verification, the need for any adjustment of the boundaries of flow classes will be recommended. At this stage, preliminary investigations for the selection of field sites have been completed.

Mandagery Creek has a high output of salt, and therefore electrical conductivity readings are assessed continuously at Smithfield.

Figure 13
Mandagery Creek after major floods in December 2010.

Image courtesy of Patrick Driver



Water Sharing Plan for Lachlan Unregulated and Alluvial Water Sources (in preparation)

Surface water monitoring

The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources is anticipated to commence in mid 2012. The NSW Office of Water is investigating the impacts of low flows on river pools during drought and other conditions across many rivers in NSW, including in the nearby upper Macquarie. The methods developed in these programs will inform any on-ground monitoring program in the upper Lachlan area. Assessment approaches will likely be rapid rather than intensive, such as photo-point monitoring and use of telemetered stream data. At this stage no ecological monitoring sites have been established except for hydrometric sites that are being used to assess the risk of downstream salinity. River pool locations identified in the Belubula River investigations above will be considered when on-ground monitoring locations are determined.

Ecological monitoring in downstream unregulated sites such as Merrimajeel, Muggabah (near Booligal) and Merrowie creeks continues as part of the implementation of the Water Sharing Plan for the Lachlan Regulated River Water Source. These creeks lie outside the Lachlan Regulated River Water Source but within the Lachlan Water Management Area. This situation means that environmental flows in these creeks continue to be managed with other environmental flows by the Lachlan Riverine Working Group.

Groundwater monitoring - Upper Lachlan Alluvium

The Upper Lachlan Alluvial Groundwater Source lies beneath the Lachlan River and its tributaries from approximately 30 kilometres upstream of Cowra to Lake Cargelligo. The following projects have recently been completed to assist the development of the water sharing plan for this groundwater source.

Groundwater flow models

In collaboration with the National Water Commission, the NSW Office of Water's modelling team has completed a numerical groundwater flow model for the Upper Lachlan alluvial aquifer. The draft groundwater flow model report was completed (Bilge 2010) in June 2010, and the final version is due for publication early in 2012 (at www.water.nsw.gov.au).

A three-dimensional finite-difference groundwater model was constructed in the Groundwater Vistas modelling package using the United States Geological Survey's MODFLOW 2000™ simulation code. The model includes three layers to represent the alluvial sequence and an inactivated fourth layer to represent the underlying Lachlan Fold Belt bedrock assemblage. The model produced predictive scenarios for three climate assumptions (wet, medium and dry) under three extraction regimes (no pumping, current development and full allocation).

Bore construction

Drilling was undertaken in the Upper Lachlan Alluvial Groundwater Source to fill gaps in aquifer structure and piezometric level data. Sixteen bore holes at eight sites were drilled, totalling 899 metres. Each bore hole has been completed as a monitoring piezometer and is now incorporated into the routine time-series water level monitoring program of the NSW Office of Water. The project was completed in October 2010. The bore holes will assist in monitoring and managing groundwater levels and in reruns of groundwater flow models.

Groundwater sharing plans

Water Sharing Plan for the Lower Lachlan Groundwater Source

Metered groundwater extraction has been monitored to assess whether sustainable volumes are being exceeded, and whether groundwater levels are stable or in recovery. Groundwater level recovery is particularly evident over the previous water year, when usage has reduced in response to wetter weather. The NSW Office of Water is collaborating with other government agencies to identify groundwater-dependent ecosystems where they occur.

plan provisions being monitored

WHICH PLAN PROVISIONS ARE WE MONITORING?

Regulated rivers water sharing plans

Water Sharing Plan for the Lachlan Regulated River Water Source

Clause 10: Objectives

The objectives of the plan are to:

(a) Maintain or restore the key environmental features of the Lachlan River system by a river flow regime that, as much as possible, mimics natural conditions in order to make provision for:

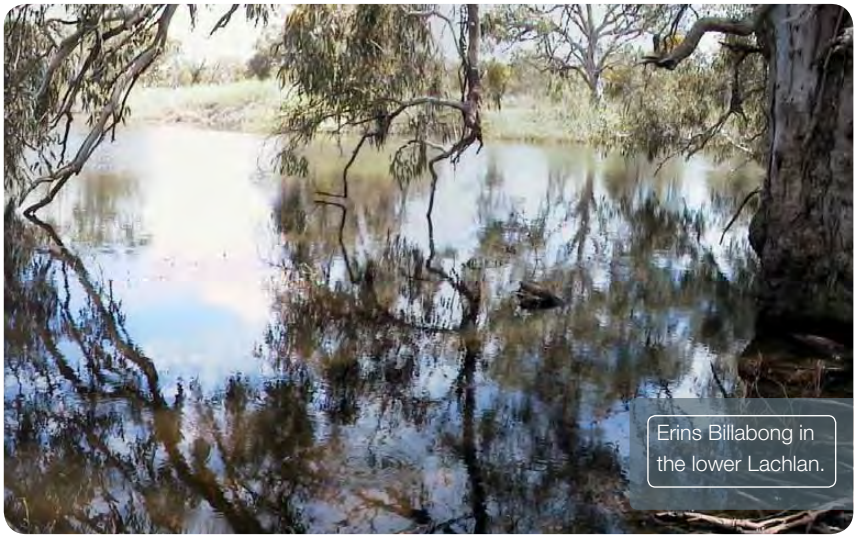
- (i) a diversity of natural in-stream and riparian habitat and biota
- (ii) the restoration, by naturally triggered flooding, of the riverine floodplain to its previous rich mosaic of ecosystems
- (iii) the improved health and function of wetlands as frequency and duration of inundation is restored
- (iv) an abundance and diversity of native aquatic species
- (v) an abundance and diversity of native water birds
- (vi) the restoration of water quality that supports aquatic ecosystems
- (vii) the recovery of threatened species, communities and populations.

(b) Provide water to ensure that the social needs and amenity values of the Lachlan Valley community continue to be met by providing for:

- (i) supplies of water that deliver a range of recreational and amenity opportunities
- (ii) that aesthetic values are maintained
- (iii) water management that recognises social impacts.

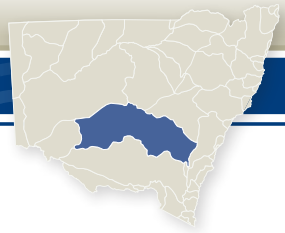
(c) Recognise, respect and incorporate the spiritual, economic and aesthetic values of the water source to provide for:

- (i) the recognition and protection of the traditional rights of Aboriginal people
- (ii) protection of sacred sites
- (iii) the maintenance of traditional rights of access to birds, fish, crustacea and other traditional foods
- (iv) the protection of the cultural, spiritual and identity aspects of rivers and wetlands.



Erins Billabong in the lower Lachlan.

Image courtesy of Peter Lyod Jones



Clause 12: Performance indicators

The performance of the plan is assessed against changes in:

(a) the ecological condition of the water source and dependent ecosystems

(b) the low flow regime

(c) the moderate to high flow regime

(d) water quality in the water source

(e) benefits derived from water extraction and use.

Clause 15: Planned environmental water

(1) The plan establishes rules for the management of translucent releases from Wyangala Dam water storage during the period 15 May to 15 November, but only if the inflows into the water storage since 1 January that calendar year have exceeded 250,000 megalitres and when the combination of Wyangala Dam inflows plus downstream tributary inflows would produce a flow downstream of Lake Brewster as specified in the plan.

Tributary inflows occurring at any time when the translucent release conditions under this clause are satisfied are not to be extracted or diverted to, or stored in any storages except to the extent by which they exceed the flow required to satisfy the required flow rate downstream of Lake Brewster. Water flows required to meet translucent release flow targets are not to be taken or used for any other purpose.

Before the end of year 5 of this plan, the Minister must review the requirement that inflows into Wyangala Dam water storage since 1 January in a calendar year must have exceeded 250,000 megalitres before translucent releases may be made and assess the environmental and socio-economic impacts of reductions in the required volume of inflow.

(2) The plan establishes rules for the management of an environmental contingency allowance held in Wyangala Dam water storage and one held in Lake Brewster. A total of 10,000 megalitres is to be credited to each account subject to rules relating to the total volume held in the water allocation accounts of regulated river (general security) access licences. Water credited to the two accounts may be released for ecological purposes such as completion of waterbird breeding events, promotion of fish breeding, promotion of fish passage, watering wetlands and increasing flow variability, in accordance with procedures established by the Minister.

(3) The plan establishes rules for the management of a water quality allowance. The rules require 20,000 megalitres to be credited to the account on 1 July each year. The water may be released for any water quality management purpose, but in particular for the reduction of salinity levels and the mitigation of blue-green algae impacts.

Clause 31: Volume of the long-term average

The plan sets a long-term average extraction limit.

Clause 61: Minimum flow levels

A visible flow should be maintained in the Lachlan River at Geramy.

Clause 62: Water delivery and channel capacity constraints

The maximum delivery capacity or operating channel capacity shall be determined as specified by the Minister, taking into account:

(a) inundation of private land or interference with access

(b) the effects of inundation on the floodplain and associated wetlands

(c) expected transmission losses

(d) capacities of water management structures controlled by the department

(e) the State Water Management Outcomes Plan targets.

At the commencement of the plan, maximum flows were limited to:

- 6,600 megalitres per day between Wyangala Dam and Jemalong Weir (the valve capacity of Wyangala Dam)
- 2,600 megalitres per day between Jemalong Weir and Willandra Weir
- 390 megalitres per day in the Wallamundry Creek system
- 1,200 megalitres per day in Goobang and Bumbuggan creeks
- 500 megalitres per day in Willandra Creek
- 2,400 megalitres per day between Willandra Weir and Merrowie Creek
- 1,500 megalitres per day between Merrowie Creek and Torrigany split
- 420 megalitres per day between Torrigany split and Booligal
- 310 megalitres per day downstream of Booligal.

Clause 63: Rates of change of releases from water storages

Rules specified by the Minister regarding rates of change to releases from water storages should take into account:

(a) environmental considerations

(b) damage to river banks

(c) public safety.

Unregulated rivers water sharing plans

Water Sharing Plan for the Mandagery Creek Water Source

Clause 11: Objectives

The objectives of the plan are to:

(a) Identify and recognise the key ecological features dependent on flows in this water source

(b) Protect natural water levels in pools of creeks and rivers during periods of no flow

(c) Protect natural low flows

(d) Protect or restore a proportion of moderate flows (freshes) and high flows

(e) Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems

(f) Maintain or imitate natural flow variability of all rivers

(g) Maintain a flow regime that supports in-river habitat, endemic aquatic species, endemic riparian vegetation and the recovery of threatened species

(h) Deliver a range of recreational and amenity opportunities within the natural flow regime

(l) Encourage water-use-efficient practices

(m) Provide a platform for future sustainable economic development

(o) Implement water sharing that recognises, respects and protects the spiritual, economic and aesthetic values of the landscape

(p) Recognise the contribution of this water source to the downstream water systems

(q) Protect and improve water quality in the Mandagery Creek Water Source through the management of flows.

Clause 13: Performance indicators

The performance of the plan is assessed against changes in:

(a) low flows

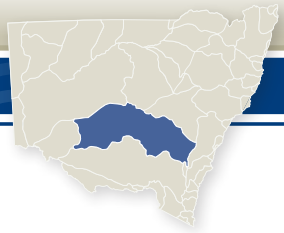
(b) moderate to high flows

(c) the ecological condition of this water source and dependent ecosystems

(d) the economic benefits derived from water extraction and use.

Clause 17: Flow classes

The sharing of daily flows is based on flow classes set by the plan for six management zones within the water source.



Clause 35: Long-term average extraction limit

The plan sets a long-term average extraction limit for the Lachlan Unregulated Extraction Management Unit.

Clause 45: Total daily extraction limit

The plan sets a total daily extraction limit for each flow class within each management zone established in Clause 17.

Clause 73: Amendment of very low flow provision

The Minister may vary the very low flow levels for each management zone set in Clause 17 within a small range following field verification that natural water levels in river pools and wetlands during periods of no flow and natural low flow regimes are protected.

Clause 74: Amendment of high flow conversion factors

The Minister may, following field verification of high flows, amend clause 55 (which relates to rules for access licence dealings which alter the times, rates or circumstances specified access licence extraction components) to include conversion factors associated with the surrender of A class individual daily extraction limits in return for the issue of C class individual daily extraction limits between management zones 1, 2, 3 and 4, to apply from years 6 to 10 of the plan. The field verification should assess the degree to which protection or restoration of a portion of freshes and high flows is met.

Groundwater sharing plans

Water Sharing Plan for the Lower Lachlan Groundwater Source

The Water Sharing Plan for the Lower Lachlan Groundwater Source (commenced 1 February 2008) establishes the proportion of recharge water that can be extracted without compromising the integrity of the water source. This is the extraction limit or sustainable yield. The NSW Office of Water is monitoring whether groundwater use exceeds this sustainable yield.

Clause 12: Performance indicators

The performance of the plan is assessed against changes in:

(a) groundwater extraction relative to the extraction limits

(b) climate-adjusted groundwater levels

(c) water levels adjacent to identified groundwater-dependent ecosystems

(d) groundwater quality

(e) the economic benefits derived from groundwater extraction and use

(f) the structural integrity of the aquifer.

Clause 18: Planned environmental water

The planned environmental water is the physical water contained in the storage component of the groundwater source plus the established portion of the average annual recharge, minus the amount required for supplementary water access permitted under Clause 25D (which relates to the share components of supplementary water access licences), as varied by Clause 29 of the plan.

Access to water under supplementary water access licences in the water source will not be permitted after 30 June 2017. From that date, the full established portion of average annual recharge of this groundwater source will be reserved for the environment.

The Minister may amend the planned environmental water after 30 June 2010 to include a greater proportion of the average annual recharge to the groundwater source as planned environmental water on the basis of further studies of groundwater ecosystem dependency.

Clause 27: Extraction limits

The plan sets the extraction limit for the Lower Lachlan Groundwater Source at 108,000 megalitres per year, plus total water made available

to supplementary water access licences, plus the total requirements for basic landholder rights.

Clause 29: Available water determinations

The available water determination made at the start of each water year after 2007-08 for supplementary water access licences will be reduced by 0.1 megalitres per unit of share component each year, reaching 0 megalitres per unit at the start of the 2017-18 water year.

Clause 37: Water level management

The Minister may declare that to protect water levels within the groundwater source, local access rules are to apply in a defined area known as a 'local impact area'.

Clause 38: Water quality management

The Minister may declare that to protect water quality within the groundwater source, local access rules are to apply in a defined area known as a 'local impact area'.

Clause 39: Protection of aquifer integrity

The Minister may declare that to protect the integrity of the aquifers within the groundwater source, local access restrictions are to apply in a defined area known as a 'local impact area'.

WHAT HAS THE ECOLOGICAL MONITORING TOLD US SO FAR?

Regulated rivers water sharing plans

Water Sharing Plan for the Lachlan Regulated River Water Source

Watering lower Lachlan wetlands during flood and drought

The environmental flow rules are intended to naturally inundate wetlands, especially nationally significant wetlands in the lower Lachlan such as Booligal Swamp and the Great Cumbung Swamp. A much more comprehensive list of Lachlan wetlands and the anticipated effect of the (then developing) water sharing plan on them can be found within the document 'Lachlan Floodplain Wetlands: Adaptive Water Management Framework' (*Driver et al. 2002*). These effects are continually being reassessed. To this end, *Barma et al. (2010)* assessed the flow and inundation behaviour of 20 wetlands between Brewster and Oxley for pre-development ('natural'), historic and current development scenarios. Commencement and volume-to-fill requirements for each wetland were estimated along with relative watering priorities. The relevance of the findings in ecological and management terms is still being assessed, but the work has added hydrological and remote sensing rigour to existing models, and has enabled more local, wetland-scale work on lower Lachlan wetland watering requirements, especially in the nationally significant Booligal Wetlands and Lachlan Swamp (BWR 2010).

Analyses of the performance of the environmental flow rules over 100-year scenarios using Integrated Monitoring of Environmental Flows (IMEF) wetland inundation models and the IQQM river model have continually shown that the plan largely achieves its goals, with environmental water clearly showing benefits for wetland biota such as colonial nesting birds in Booligal Swamp. Additionally, lower Lachlan swamps and billabongs gain more from the environmental flow rules than wetlands in the middle of the Lachlan, as intended. These waterbird nesting events tend to be larger after the end of drought, and probably more so when other major Murray-Darling Basin wetlands are not in flood (modelled for the Lachlan and Border rivers: *Driver et al. 2010*; Figure 14). Field observations of actual environmental flows support these modelling conclusions, especially in relation to post-drought responses.

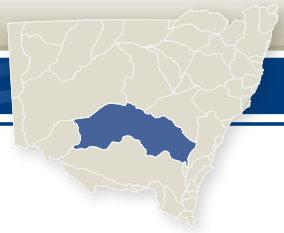
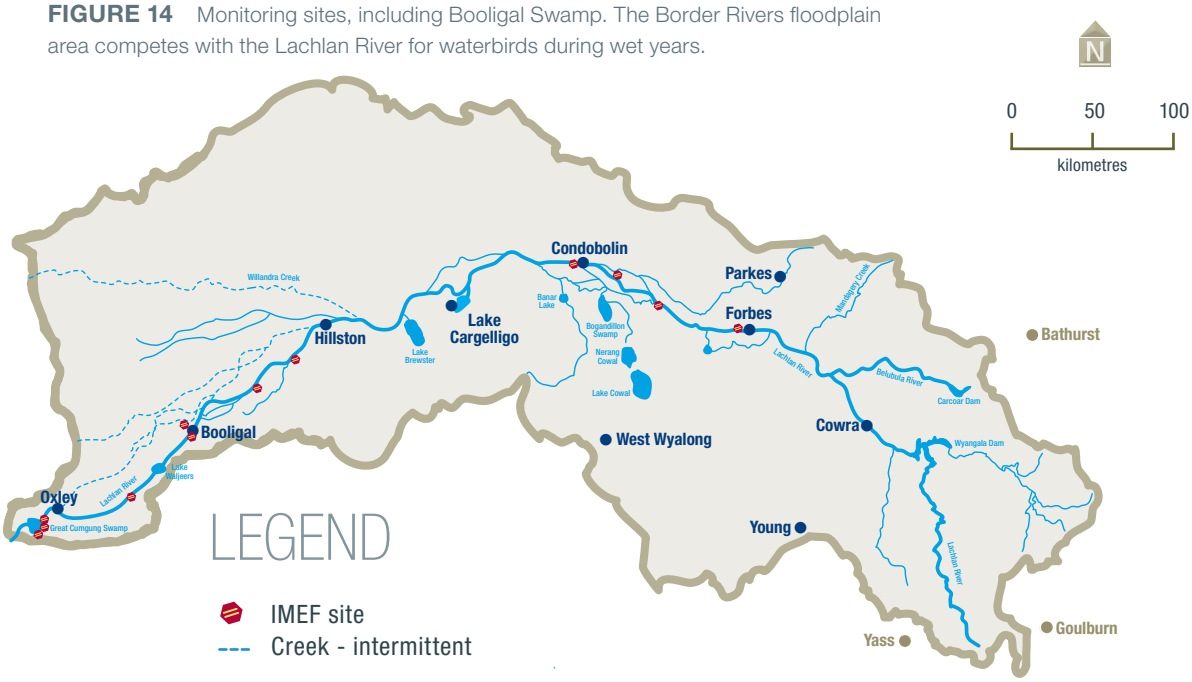


FIGURE 14 Monitoring sites, including Booligal Swamp. The Border Rivers floodplain area competes with the Lachlan River for waterbirds during wet years.



For example, there was a major bird breeding event in 2010-11 that included about 64,000 pairs of straw-necked ibis and 600 pairs of the nationally listed glossy ibis, as well as royal spoonbills, white ibis and freckled ducks.

This was the first significant bird breeding event in the Booligal Wetlands since 2000, which was also the last time the threatened freckled duck (*Stictonetta naevosa*) was seen breeding there (Figure 15).

Flooding of at least 3 months is usually required to allow aquatic plants and then other key wetland features to establish. This is also the major period during which

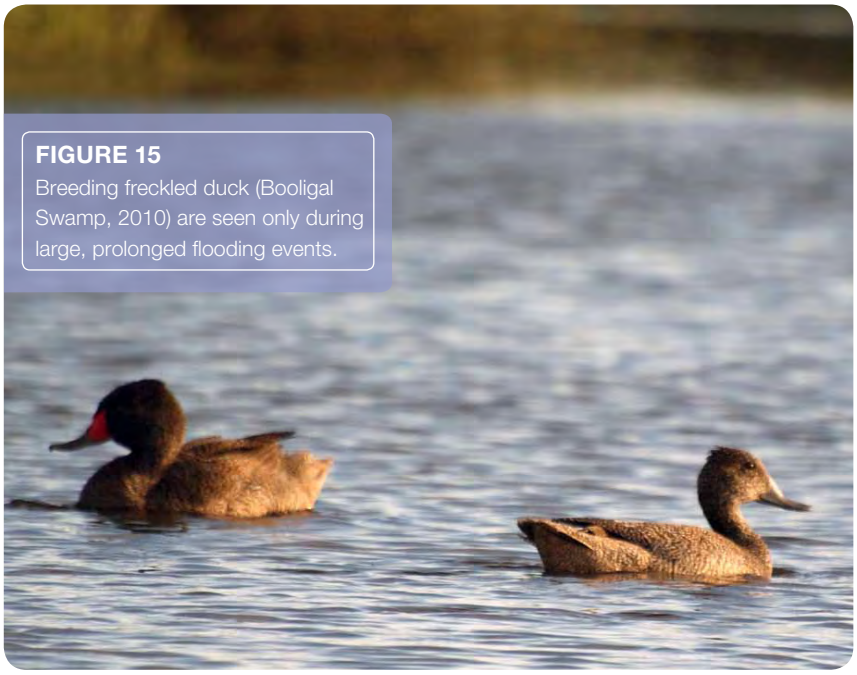


FIGURE 15
Breeding freckled duck (Booligal Swamp, 2010) are seen only during large, prolonged flooding events.

Image courtesy of Patrick Driver.

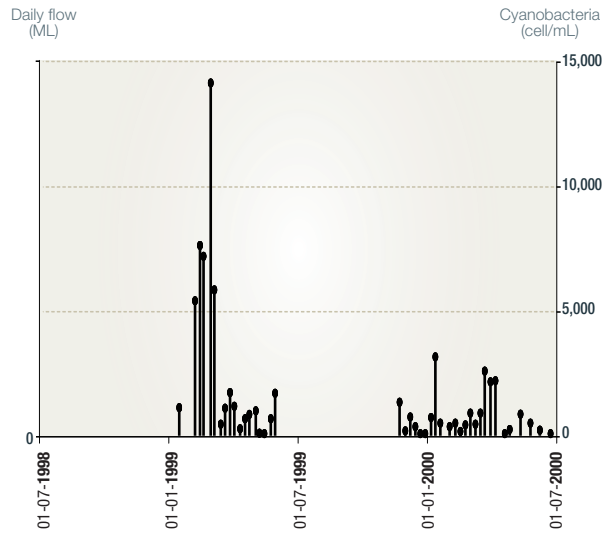
invertebrate species re-establish. The rebuilding of these invertebrate communities, which is essential to wetland function, continues to be important up to 6 months later, especially in drier catchments where early-establishment communities tend to be more dominated by strong fliers and drought-resistant species rather than by species associated with established wetland vegetation (for example, the Namoi and Lachlan catchments versus the Murrumbidgee catchment; *Driver et al. 2007*). Analyses by the NSW Office of Water and the Australian National University suggest, however, that even small environmental flows delivered during the peak of the drought in 2005 helped wetlands such as the Great Cumbung Swamp (the terminal wetland of the Lachlan River) stay alive (*Driver et al. 2011*). Flows sent to the bottom of the river and passed through the shallow aquifer underlying the lower Lachlan allowed deeper-rooted plants such as common reed, and presumably also many of the river red gums, to persist throughout the drought. IMEF monitoring in Booligal Swamp and the Great Cumbung Swamp showed that with the breaking of the drought in 2010-11, aquatic plants such as water milfoil (*Myriophyllum species*) and associated fauna such as birds of prey and aquatic invertebrates are gradually returning. Lachlan billabongs also benefited from floods and environmental flows after the drought, but in many cases the recovery appears to be slower, with less water, poor water quality (for example, highly alkaline) and the scarcity of some animals known to be common before drought; for example, sacred kingfishers (*Todiramphus sanctus*) in 'Hazelwood Billabong' near Hillston (Figure 9).

Prevention and mitigation of algal blooms and river salinity

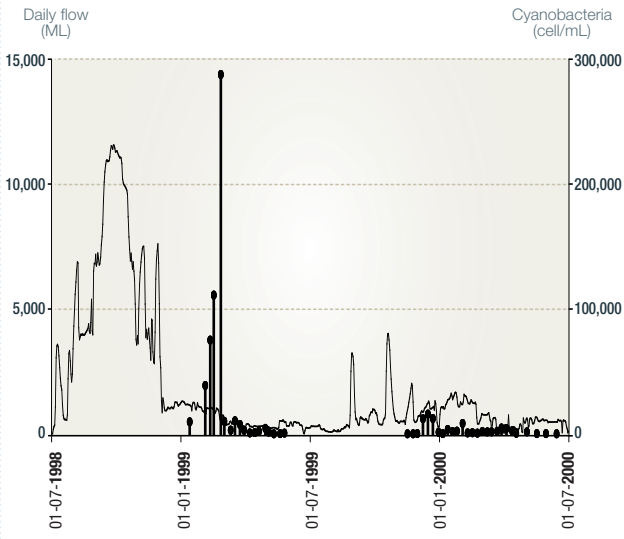
IMEF investigations focused on algal (cyanobacterial) responses during pre-drought 1998-2000 (*Thurtell et al., unpublished*) found blooms in the lower Lachlan in two of the three years (Figure 16). Although weir pools were subject to thermal stratification and high nutrient concentrations, the primary cause of the blooms was algal contaminated water releases from Lake Brewster, an off-river storage.

The investigation concluded that the source of water was more important than discharge volumes in determining whether cyanobacterial blooms persisted. This conclusion has important implications for river management, and suggests that environmental flows will have little impact on cyanobacterial abundance. Without improvement in Lake Brewster water quality, greater reliance had to be placed on replacement flows from Wyangala Dam, particularly in summer. This is considered to be detrimental to the river, because unseasonal high flows will be required along the length of the regulated Lachlan. High counts (above 15,000 cells per millilitre) were not observed at the upstream Forbes Weir and Lake Brewster Weir, but they were recorded at the three downstream sites in the summer of 1998-99 (Figure 16).

The cause of the high cyanobacterial concentrations in the lower Lachlan in the summer of 1998-99 was clearly the outflow of cyanobacteria-laden water from Lake Brewster, which discharges to the Lachlan River between Lake Brewster Weir and Willandra Weir (Figures 11 and 17). Peak concentrations in the river during this period increased about 20 fold. The lake was discharging between 800 and 1,200 megalitres per day from late July 1998, contributing the bulk of downstream river flow from late December 1998 until the end of February 1999, when outflow ceased. Grab samples taken from the centre and outlet of the lake, as part of the Regional Algal Coordinating Committee monitoring program, showed concentrations above 10,000 cells per millilitre during summer. The March decline in cyanobacterial populations in the riverine weir pools closely followed

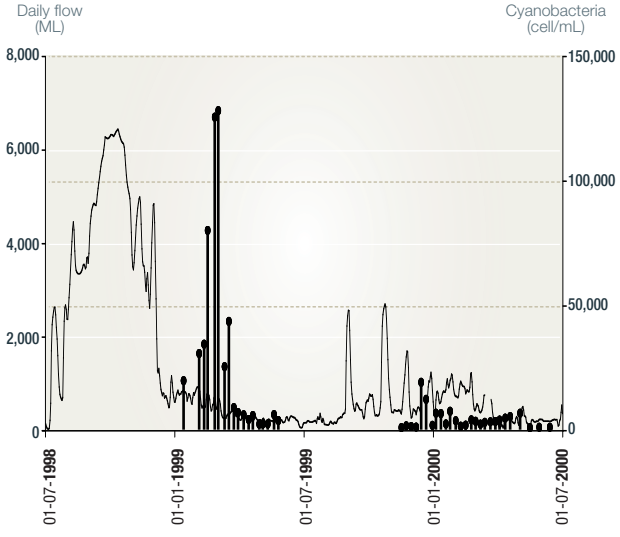


Lachlan River at Lake Brewster Weir.

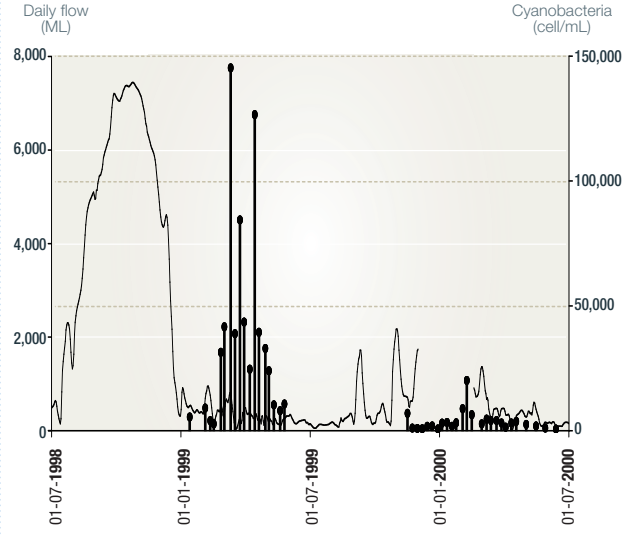


Lachlan River at Willandra Weir.

FIGURE 16 Daily flow and spot cyanobacterial cell concentrations in the Lachlan River at 4 sites, July 1998 - June 2000. Flow data are not available for Lake Brewster Weir.



Lachlan River at Hillston Weir.



Lachlan River at Booligal Weir.

the cessation of this discharge. As a consequence of the role of Lake Brewster outflows, cyanobacteria cell counts in the weir pools of the lower river did not show a negative relationship with river flow.

The massive blooms in the lower river did not recur during the summer of 1999-2000, which was wetter and cooler than the previous summer. Measurements of surface and bottom water temperatures showed that although all four weir pools (Lake Brewster, Willandra, Hillston and Booligal) stratified at some time during the summer, the vertical temperature differences were not great (maximum of 4.7 °C in Lake Brewster Weir pool, 2.2°C in Willandra Weir pool, 2.2 °C in Hillston Weir pool and 3.4 °C in Booligal Weir pool), and pronounced stratification did not persist for long periods. Vertical temperature differences were inversely related to flow (Figure 18).

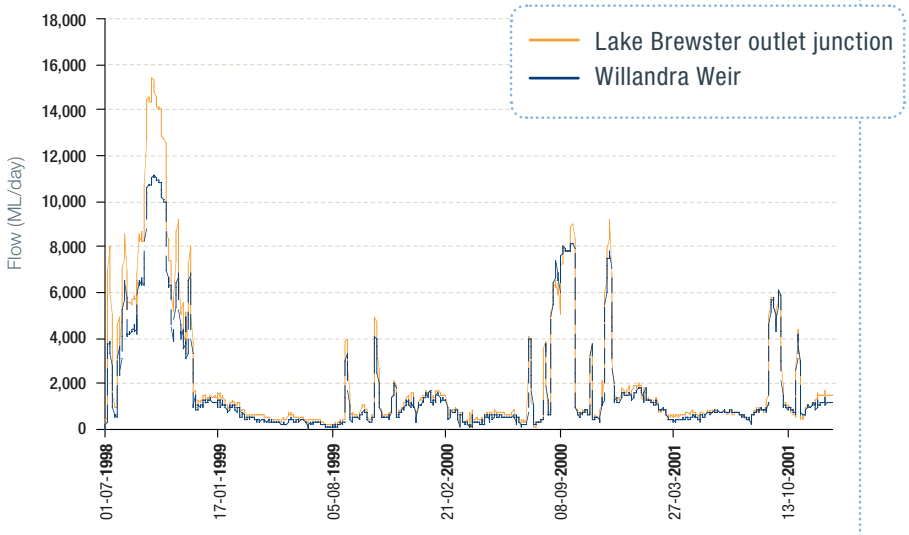
Lake Cargelligo and Lake Brewster are shallow, eutrophic and turbid, and have frequent cyanobacterial blooms (*Thurtell et al. 2003*). Both increased the electrical conductivity, turbidity, nutrient contents and cyanobacteria in the Lachlan River downstream when discharging. This was particularly evident in the cyanobacterial blooms at Willandra Weir, downstream of Lake Brewster. The extent and magnitude of the impact depended on the volume

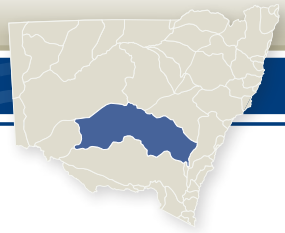
Water quality monitoring in Willandra Weir Pool.

Image courtesy of Darce Pepper

FIGURE 17

Daily flow release from Lake Brewster into the Lachlan River, shown at the junction of outlets, and also downstream at Willandra Weir, July 1998 - December 2001.



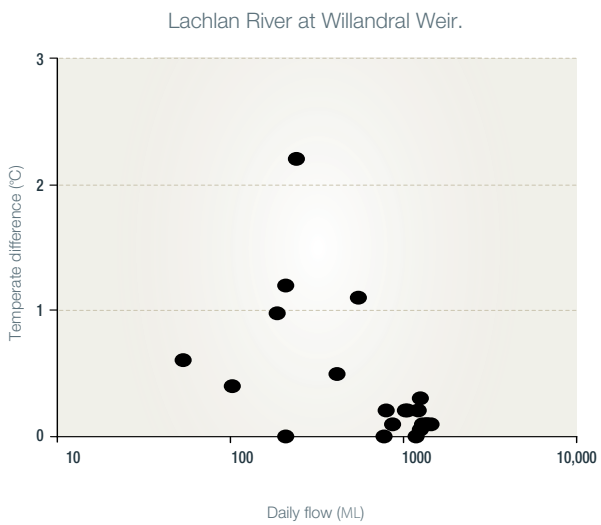


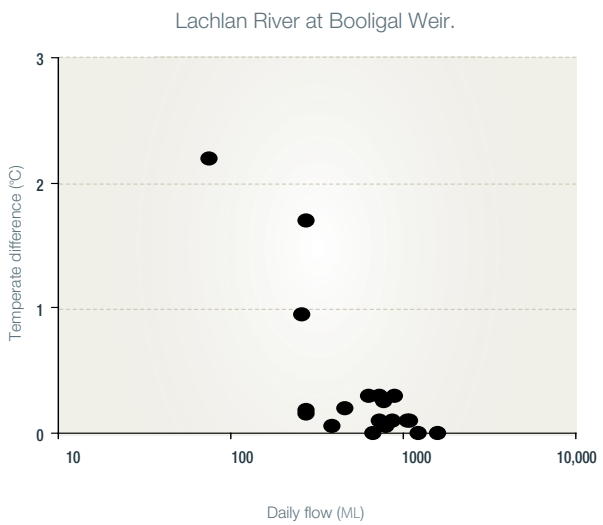
of water released in relation to the volume of water already in the river and the time of year, plus whether blooms were present in Lake Brewster. The study concluded that avoidance of using the first river pulse to fill the lakes may reduce the contribution of external nutrient loads, and made numerous recommendations regarding works within these lakes to improve the quality of water released. In consequence, State Water, the Lachlan Catchment Management Authority and other NSW agencies have undertaken numerous works to improve water quality, especially in Lake Brewster.

Under the Independent Pricing and Regulatory Tribunal (IPART) determination the management of algae and cold water pollution within the regulated section of the Lachlan and in off-river storages such as Lake Brewster is driven largely through the State Water Corporation's operating licence (DWE 2009a). The licence states that for the entire water source, 'The Approval Holder must undertake all quantity and quality monitoring as required by this approval consistent with appropriate quality assurance and quality control procedures, and national standards, or as required by the Minister.' The Approval Holder may include data of acceptable quality from other sources to meet the monitoring requirements of this approval. For Lake Brewster, 'The Approval Holder must undertake all quantity and quality monitoring as required by the Land and Water Management Plan for the Lake Brewster Water Efficiency Project' (www.water.nsw.gov.au).

The Lachlan River water quality objectives (www.environment.nsw.gov.au) sets a maximum cell count of 50,000 cells per millilitre, or biovolume of greater than 4 cubic millimetre per litre where a known toxin

FIGURE 18 Relationship between daily flow (logarithmic scale) and the vertical temperature difference in the Lachlan River at two sites, July 1998 - June 2000. Both relationships are statistically significant ($P < 0.05$; *Thurtell et al. 2003*).





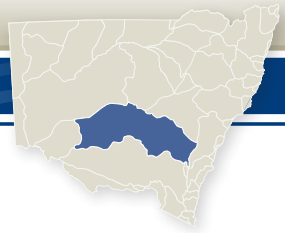
producer is dominant, or biovolume of greater than 10 cubic millimetre per litre for total cyanobacteria, or greater than 10 milligrams per litre of microcystin concentration, or when cyanobacterial scums are consistently present within recreational purposes. Water exceeding 6,500 cells per millilitre *Microcystis aeruginosa* or biovolume of greater than 0.6 cubic millimetres per litre limit may not be used for drinking except after full treatment incorporating filtration and activated carbon.

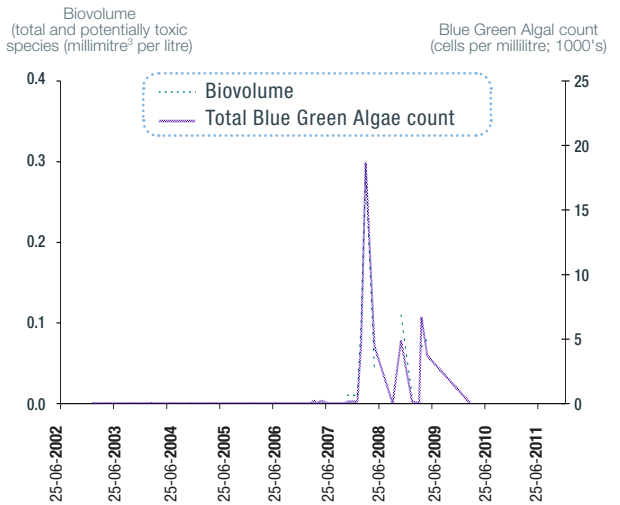
The results of algae monitoring from 2002 onwards are shown (Figure 19). These values do not take into account the type of algae in some totals and is necessarily cautious because the water could contain a high proportion of toxic algae. Only summary values are shown. Not surprisingly, algal counts reached moderately-high levels for recreation in the middle reaches of the Lachlan during the end of the drought in 2008, as seen at Forbes and Cowra (Figures 19A, 19B) This coincided with releases from Lake Brewster of about 1,000 megalitres per day (Figure 20A). Although the total count exceeded 58,492 cells per millilitre at Forbes, this value was driven by species considered to be non-toxic. Downstream of Lake Brewster, at Willandra Weir, values were even higher, reaching 2,401,380 cells per millilitre, but again driven by a non-toxic taxon, *Oscillatoria*. In January 2012, the highest blue-green levels were reached, with 431,409 cells per millilitre and 54 per cent of the biovolume potentially toxic. This coincided with releases from Lake Brewster of about 1,600 megalitres per day (Figure 20C). Most of the count (about 300,000 cells per millilitre) was dominated by a non-toxic taxon, *Aphanocapsa*. In the lower Lachlan, from Willandra Weir through to Hillston and Booligal weirs, algal levels increased in early 2011, and the patterns at Hillston and Booligal weirs generally reflect the algal levels at Willandra, suggesting that similar temperature and flow conditions were driving these values. The effect of Lake Brewster on these values within downstream weirs again was likely to be a driving factor with flows at the Lachlan River upstream suggesting a coinciding release from Lake Brewster in excess of 7,000 megalitres per day (Figure 20B).


Booligal Weir Pool.

Image courtesy of Darice Pepper

The NSW Office of Water supports State Water through routine algal monitoring and the monitoring of conductivity and through scientific investigations. The Australian and New Zealand Environment Conservation Council (ANZECC) threshold for drinking water is an electrical conductivity of 800 µS/cm. The ANZECC guidelines acknowledge that water salinity in the western lowlands can often reach 2,000 µS/cm. The NSW Water Quality objectives (used as a guide for developing water sharing plans) for the Lachlan recommend 125 to 2,200 µS/cm for aquatic organisms, noting that greater than 800 µS/cm causes a deterioration in taste (www.environment.nsw.gov.au).





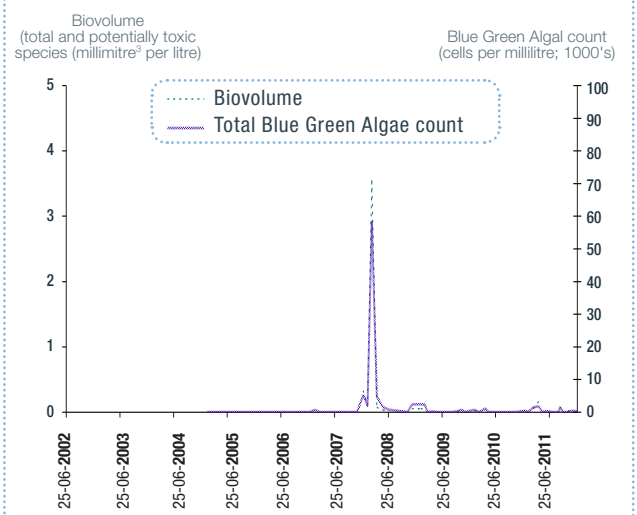
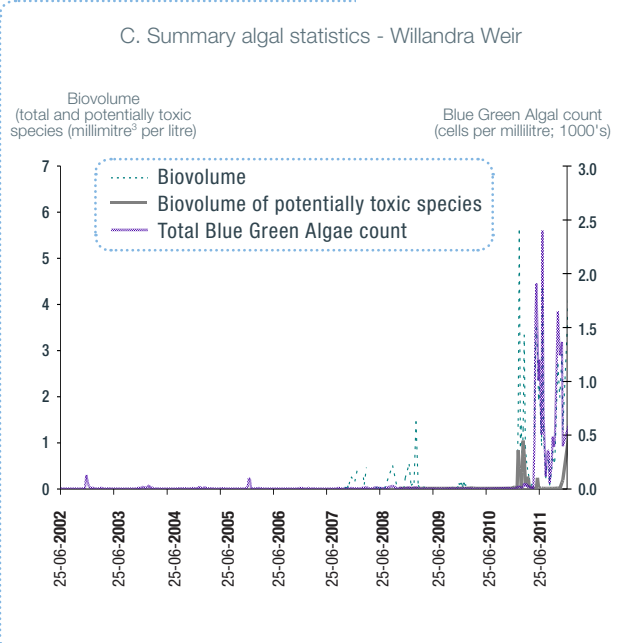
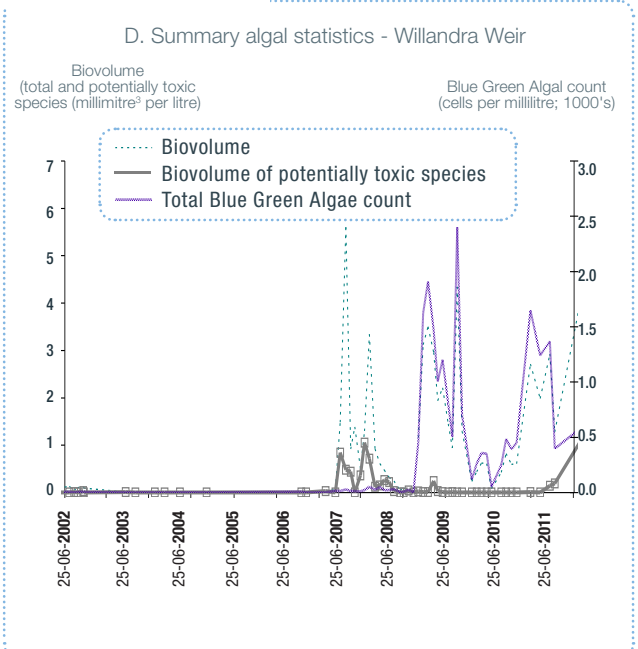
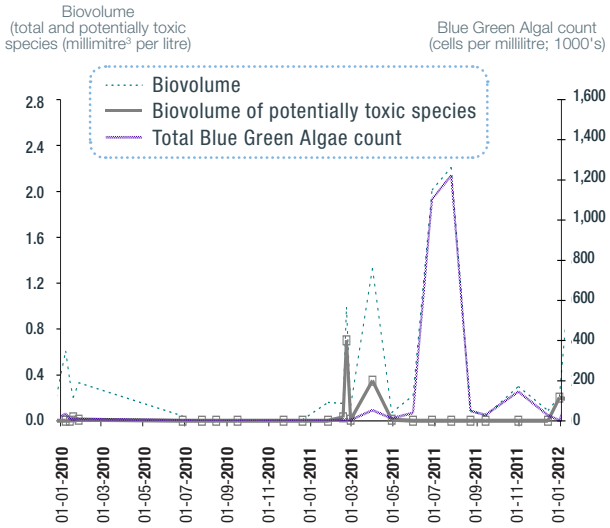


FIGURE 19 Cyanobacterial summary values for sampling sites in the Lachlan Valley, with total cell count and total biovolume.





E. Summary algal statistics - Lachlan River at Hillston Weir



F. Summary algal statistics - Lachlan River at Hillston Weir

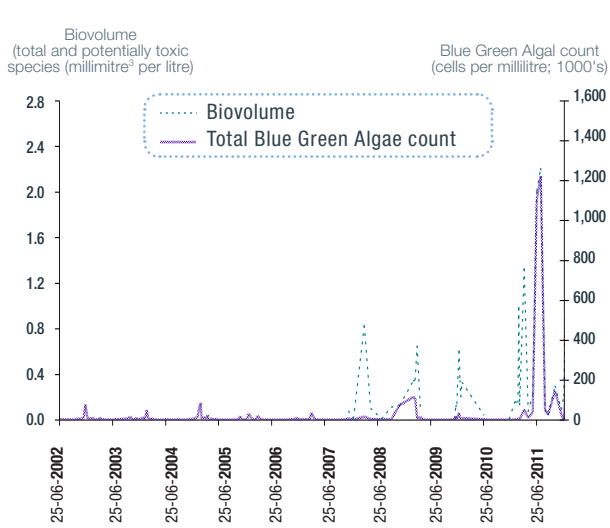
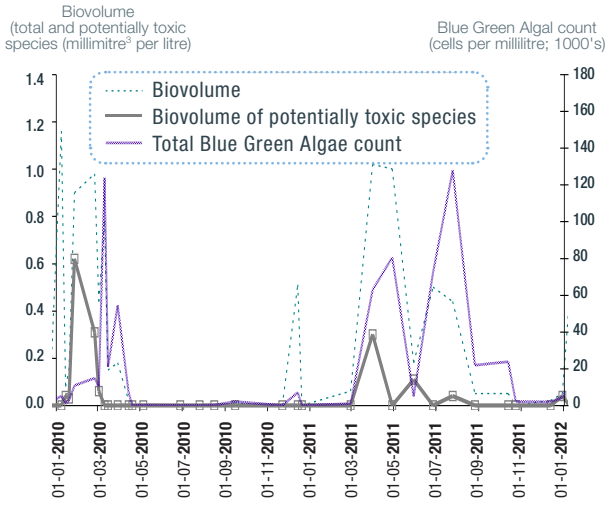
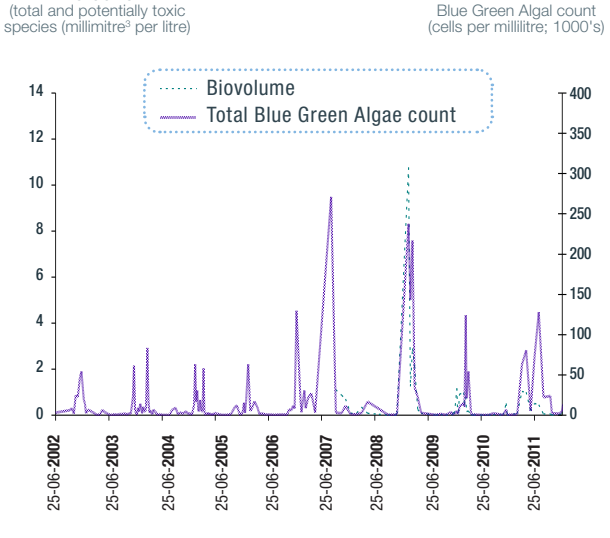


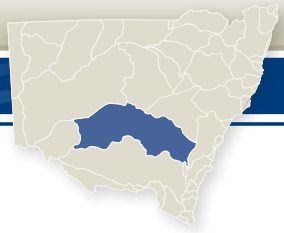
FIGURE 19 Cyanobacterial summary values for sampling sites in the Lachlan Valley, with total cell count and total biovolume.

G. Summary algal statistics - Lachlan River at Booligal Weir



H. Summary algal statistics - Lachlan River at Booligal Weir





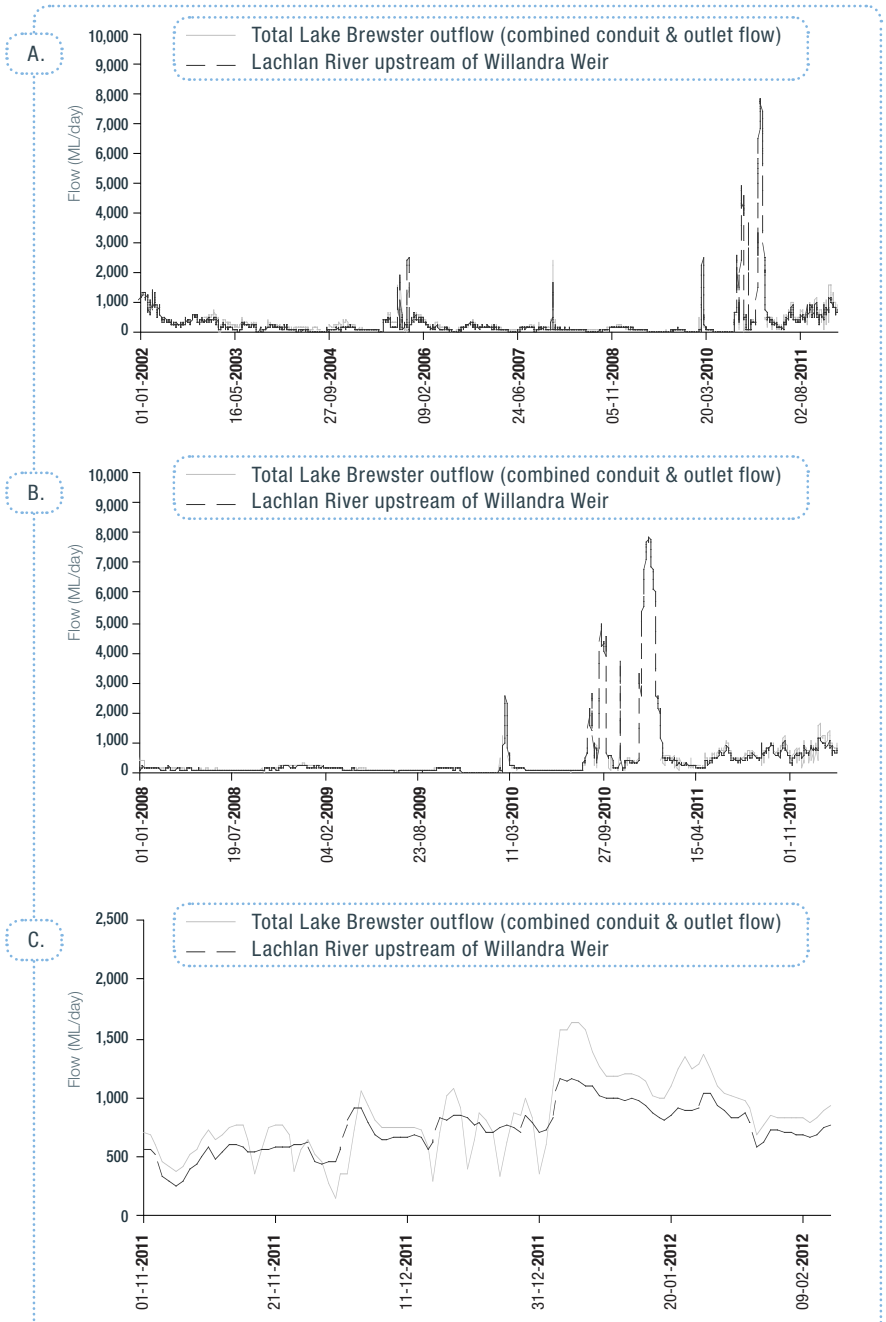


FIGURE 20

Daily flow release from Lake Brewster into the Lachlan River, shown at the junction of outlets, and also downstream at Willandra Weir, for: A. January 2002 - February 2012; B. January 2008 - February 2012; and C. November 2011 – February 2012. *(River Flow upstream of Willandra Weir is used as a surrogate for Lake Brewster outflow with some of the key flow peaks because of missing data.)*

Mitigation of cold water pollution

The State Water Corporation's operating licence (DWE 2009a) states that the Approval Holder must:

a) develop a water temperature monitoring program for Wyangala Dam within 12 months of issue of this approval in accordance with the Guidelines for Managing Cold Water Releases from High Priority Dams developed by the Cold Water Pollution Inter Agency Group

b) if required, develop and implement a cold water pollution monitoring program capable of measuring its performance against the operating protocol

c) submit the monitoring program to the Minister for approval

d) implement the monitoring program, if approved by the Minister

e) report the monitoring results in the Annual Compliance Report, taking into account the Guidelines for Managing Cold Water Releases from High Priority Dams

f) store and archive data for future use.

River pools as drought refugia

The results from the Lower Lachlan Drought Refugia Project in Booberoi, Lake Cargelligo, Willandra, Hillston

and Booligal weir pools showed as flows ceased and the river dried out, conditions within the remaining pools became hostile for native fish, with high surface temperatures and very low oxygen levels *(Pepper et al. 2010)*. The conditions deteriorated to such an extent that a fish kill was imminent; however, rainfall and a consequent flow in mid February 2010 disrupted the stratifications. The dissolved oxygen and temperature re-stratified after the flow event had dissipated.

Water quality monitoring showed that at most sites, electrical conductivity was increasing slightly over the summer, except at Booligal Weir pool, which had higher conductivities than the other sites and steeper increases as the weir pool dried out. Electrical conductivities decreased during the flow event. Nutrients and turbidity generally increased substantially during the flow event, and then declined as the flow event subsided.

Responses to the flow event included changes from toxic cyanobacteria to a mix of other non-toxic cyanobacteria, with flows producing conditions that were not conducive to blooms. These results may assist in the management of minimum flows and mitigation of blooms in the future.

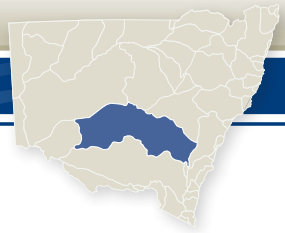
Water Sharing Plan for the Belubula Regulated River and Alluvial Water Source (in preparation)

Base river flows of at least 256 megalitres per day at Helensholme are probably required for the maintenance of river pools for fish and other aquatic species. Former river pools have been filled by sediments, and so maintaining fish communities within deep pools at lower flows is now more difficult than it might have been historically. The base flows that might be maintainable within the operating constraints of this only-marginally regulated river are much lower (about 10 to 20 megalitres per day). This is largely because of the limited effect of Carcoar Dam compared with the effects of uncontrolled tributary flows. It is likely that fish communities (including Murray cod (*Maccullochella peelii)*) will need to recolonise the lower reaches from Canowindra downstream after droughts such as that in 2009 when this part of the river dried up.

River base flows and groundwater-surface water interactions are critical to the maintenance of river pools operating as river refuges. Groundwater extraction probably contributed to the river's drying up in 2009. A study of river flows from 15 July 2008 to 1 July 2009, covering about 40 kilometres from the Needles downstream to Currans (10 kilometres downstream of Canowindra; SKM, 2010), suggested that groundwater pumping, predominantly near Canowindra, reduced stream flows by about 2,600 megalitres in 2009.

The Australian and New Zealand Environment Conservation Council (ANZECC) threshold for drinking water (800 µS/cm) is regularly exceeded in the Canowindra area. ANZECC guidelines acknowledge that water salinity in the western lowlands can often reach 2000 µS/cm. At nearby Lyndon (Figure 18), when the 2000 µS/cm threshold is exceeded, flows are usually below 0.6 metres (or 256 megalitres per day at Helensholme, which equates to about 300 megalitres per day at Canowindra). A height below 0.6 metres at Lyndon is associated with increased risk of high conductivity ('salinity'), which increases as flows decrease. This relationship suggests that saline input into the river upstream (largely the influence of tributary streams coming in from the south) has an increasing influence at low flows.

If the water quality requirements are eased for agriculture only, then the trends in Figure 21 are not a great concern. A salinity of 1,000 µS/cm typically equates to 670 milligrams per litre of total dissolved solids (TDS). Concerns for livestock health typically start at about 2,000

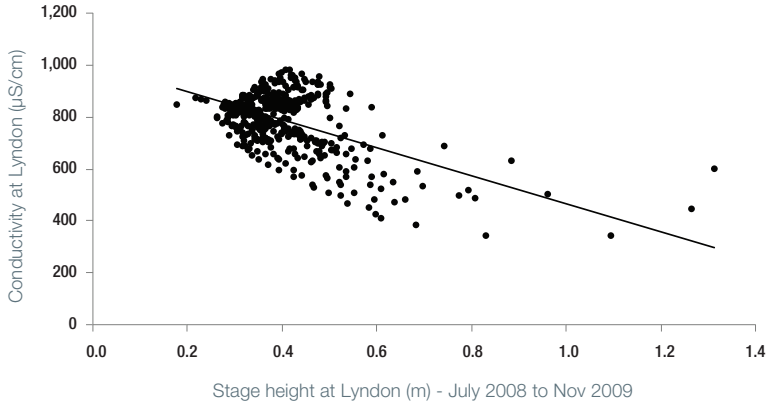


to 4,000 milligrams per litre TDS. Concerns for crops start at around 1,600 to 2,000 µS/cm, although lucerne's tolerance is lower.

There is little evidence that wetlands need a high level of attention for the determination of environmental flow rules, although land management in these areas could significantly improve river water quality. In the upper reaches (in areas such as Carcoar, Mandurama and Lyndhurst) there are numerous degraded swampy meadows (Figure 22) which have varying values, and some of these could significantly affect the water quality in the regulated stream, but are not likely to be significantly affected by regulated river flows. In particular, some of these swampy meadows interact with (mostly) southern tributaries in the middle reaches to contribute to a high salt load to the river. In the lower reaches (near Canowindra and downstream), where some floodplain development has occurred, there are few wetland features such as billabongs, and where these occur they are often highly degraded.

The results of this study (Driver and Michener 2010) relate primarily to the regulated sections of the Belubula River, but will also be relevant in the development of rules for groundwater and unregulated surface flows, which affect the regulated river flows.

FIGURE 21 Conductivity ('salinity') at the Lyndon gauge in relation to flow depth.



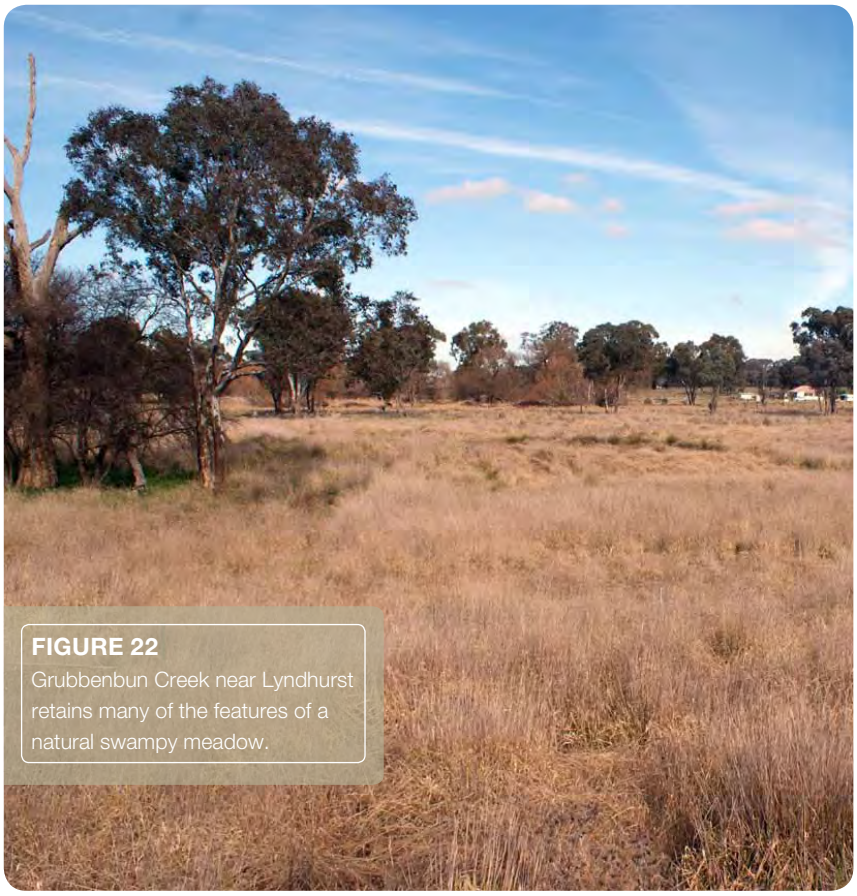


FIGURE 22
Grubbenbun Creek near Lyndhurst retains many of the features of a natural swampy meadow.

Image courtesy of Patrick Driver

There are likely to be only a few places in the lower reaches where moderate to high flows will break the channel to flood riparian areas. In these areas the possible existence of the endangered southern bell frog (*Litoria raniformis*) needs further investigation. Further upstream at the Needles (gauging station 412056, at the top end of the study area, Figure 23) and further upstream the flow requirements and existence of animals such as the Booroolong frog (*Litoria booroolongensis*), which could live between the river and the riparian zone, also needs further investigation.

A study that used LANDSAT data (1989-2005) to identify the relationships between geology, soils and terrain along the Belubula River and the degree of vegetation response to releases from Carcoar Dam (Fawcett et al. 2011; Figure 23) showed a progressive deterioration in vegetation condition as the catchment moved into drought.

FIGURE 23 Landscapes analysed in the study on Belubula River flow responses (Fawcett et al. 2011).

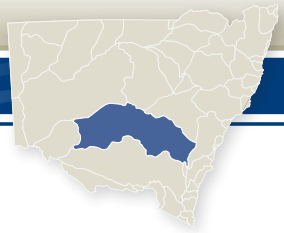


TABLE 1 River flows (in megalitres) investigated to assess vegetation response to flows (Fawcett et al. 2011).

Period	Location	Total	Minimum	Maximum	Mean
03-12-1989 to 03-10-1990	Belubula at the Needles (412056)	637,583	29	59,638	2,097
	Carcoar outflow	87,532	4	7,230	287
03-12-1989 to 03-10-1990	Belubula at the Needles (412056)	182,735	57	16,392	874
	Carcoar outflow	24,575	6	2,324	117
03-12-1989 to 03-10-1990	Belubula at the Needles (412056)	167,586	19	8,633	621
	Carcoar outflow	17,737	2	803	65

The Normalized Difference Vegetation Index (NDVI) is calculated from remote sensing data to assess the extent of vegetation in healthy, green condition. NDVI analyses were used to show the most responsive and the most constant river segments after flow releases from Carcoar Dam. Some sections responded greatly to changes in flow (Table 1), but not necessarily managed flows (because releases tend to coincide with higher rainfall). For example, the condition of vegetation in riparian sections just downstream of Flyers Creek clearly varied with flows, which is not surprising considering the creek's relatively flashy stream flows. Other riparian locations showed a high consistency in vegetation condition, mainly in the lower reaches. Generally the riparian areas in the lower reaches (that is, the alluvial plain) showed a decrease in response to flows from 1989 to 2000. The data showed generally no response after 1989-90 (perhaps because background wetness was already high), a strong positive response after 1993 and a negative response after releases during the relatively dry 2000 period. Alluvial areas most prone to decline in the response of vegetation condition to river flows tended to be underlain by fractured rock as opposed to alluvial sands.

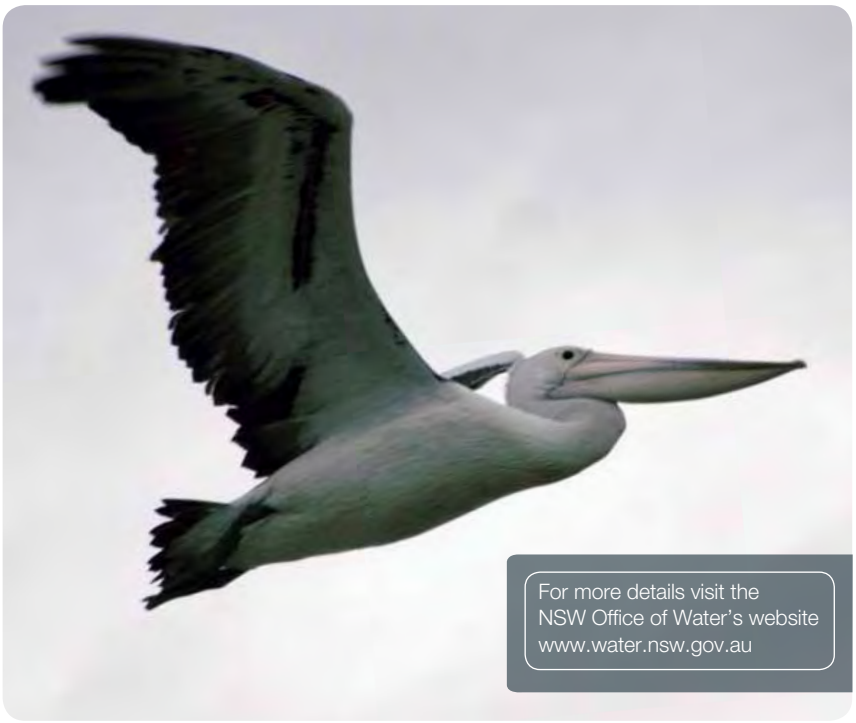


Image courtesy of Patrick Driver

For more details visit the NSW Office of Water's website www.water.nsw.gov.au

Maps of the limestone zone surrounding Canomodine Creek, a

tributary south of Cargo (Figure 24), show the progression of declining vegetation into drought in each of the three release periods and a dry year, 2005. Some areas (red ellipses) maintain a relatively consistent response for the first three periods before decreasing in 2005. The riparian area at the downstream end of each frame (blue ellipses) clearly shows the decreasing mean vegetation condition (NDVI).

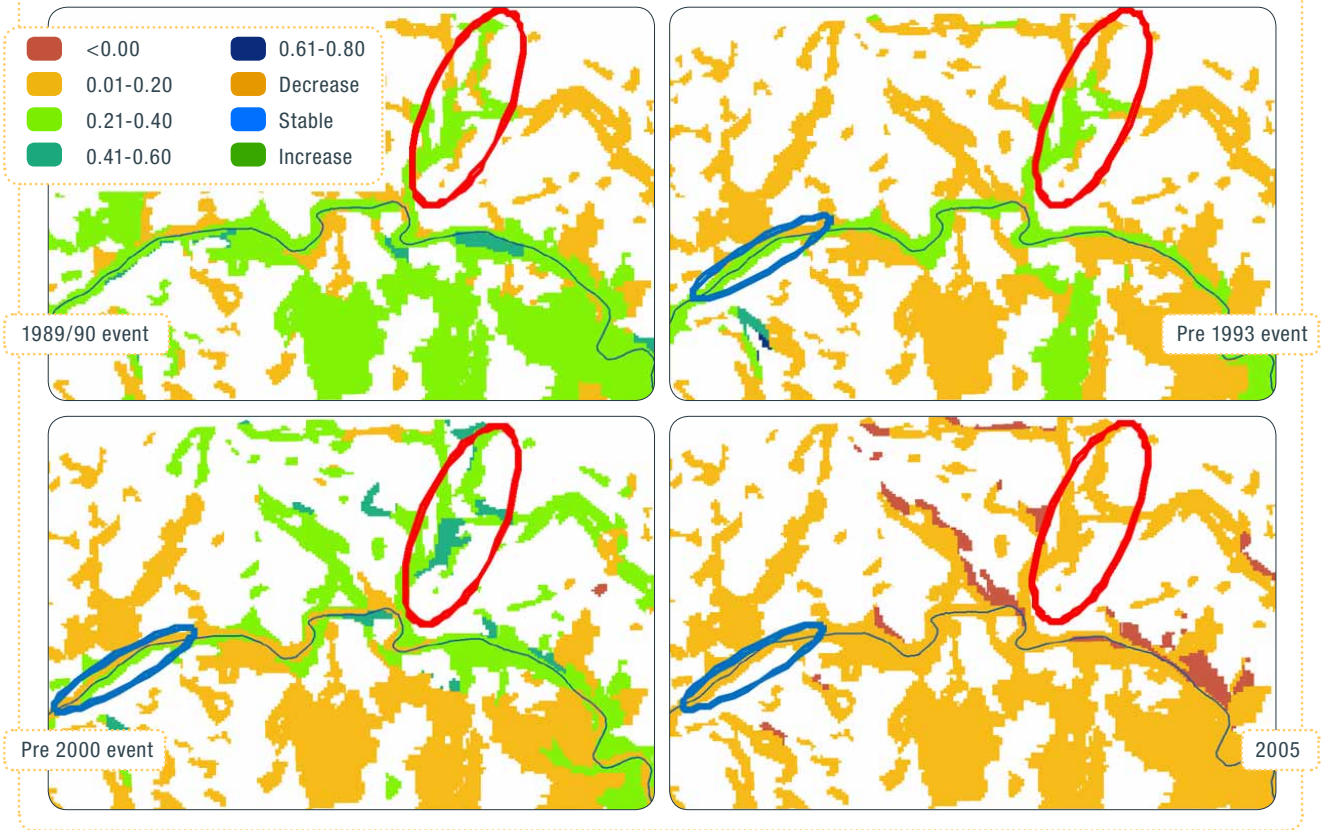
Unregulated rivers water sharing plans

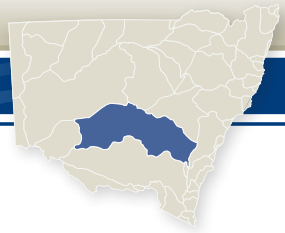
Water Sharing Plan for the Mandagery Creek Water Source

One key environmental objective was the protection of low flows at 2.6 megalitres per day at the Smithfield gauging station, within Zone 4. This rule was developed to protect connectivity between river pools. Since the plan commenced on 1 July 2004, this flow or greater has been achieved for 93 per cent of the time, and zero flows have occurred only 2 per cent of the time. The exceptions occurred for 10 days in late November to early December 2004, but otherwise during dry years in 2005 to 2010.

Further information on monitoring of unregulated river water sharing plans can be found at www.water.nsw.gov.au go to Water Management > Monitoring.

FIGURE 24 Mean NDVI in periods before flow releases within limestone area of Canomodine Creek (Fawcett et al. 2011).





Water Sharing Plan for Lachlan Unregulated and Alluvial Water Sources (in preparation)

Surface water investigations

With commencement of the plan in 2012, various studies across the NSW Government will inform on the effectiveness of the plan.

Upper Lachlan alluvium investigations

The upper Lachlan alluvial groundwater model developed by the NSW Office of Water and the National Water Commission produced nine predictive scenarios that combined three climate assumptions (wet, medium and dry) with three extraction regimes (no pumping, current development and full allocation). At full allocation the assigned extraction was not maintained for the duration of the model run, as the model predicted substantial localised drawdown leading to de-saturation of multiple model cells. De-saturated model cells affect any contained pumping bores by switching them off resulting in reduced total extraction volumes over the model run. Extraction in addition to current development would be unsustainable because the upper Lachlan alluvial aquifer already contains locally affected areas currently managed with specific rules. The sustainable extraction rate for the aquifer approximates current development.

In a drier future climate, small amounts are extracted from storage. The groundwater model suggests that the upper Lachlan aquifer may sustain extraction rates at current development with ongoing local impact management. This information was used to guide development of the groundwater sharing plans.

Groundwater sharing plans

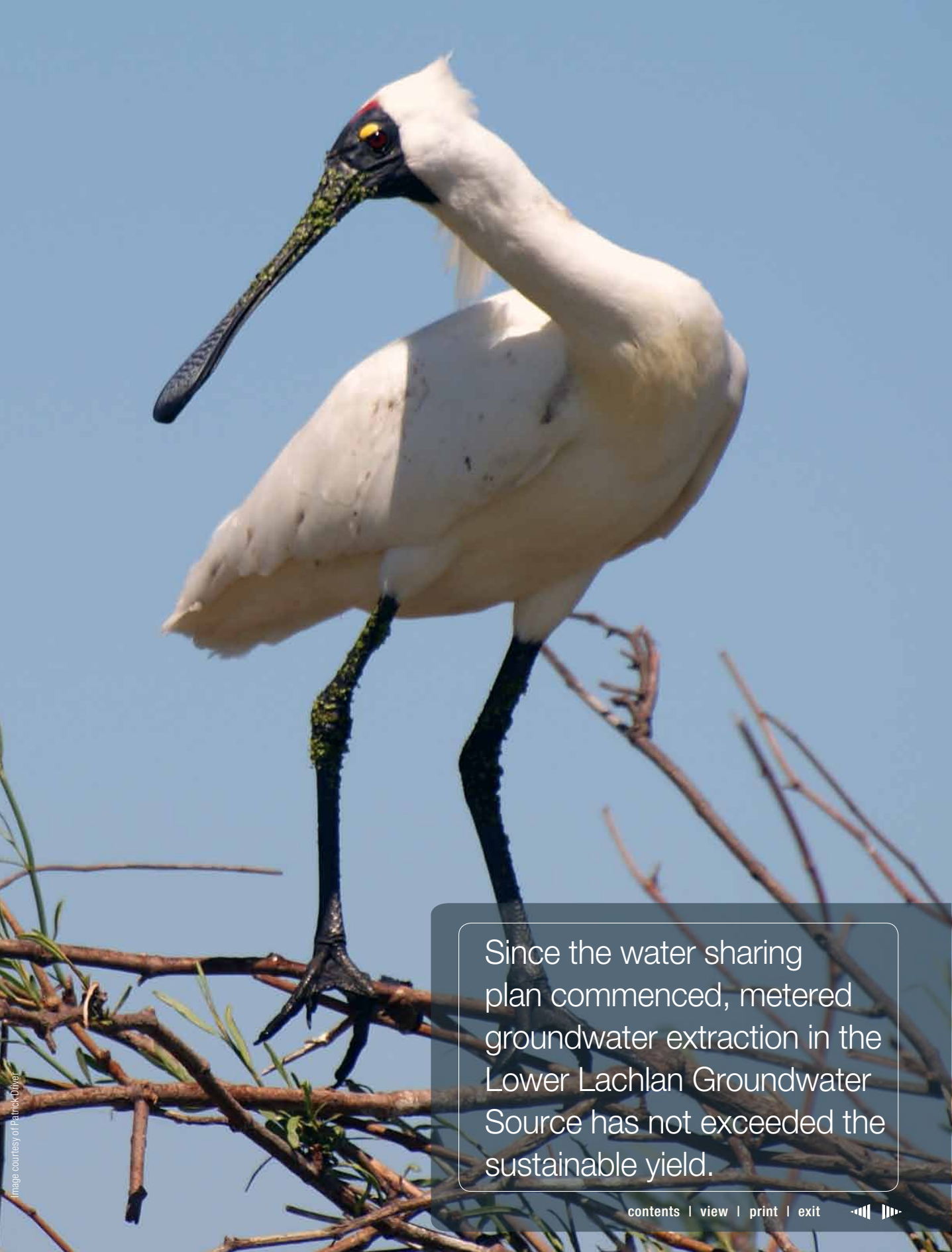
Groundwater modelling and calculations based on ecological monitoring measurements have provided sustainable extraction volumes which have been incorporated into the water sharing plans for each groundwater source in the Lachlan catchment.

Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources (in preparation)

The Draft Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources (scheduled for commencement in 2012) establishes the sustainable extraction volume for both the Upper Lachlan and Belubula alluvial groundwater sources. The sustainable extraction volume calculated by the upper Lachlan groundwater flow model is approximately equal to the long-term average annual extraction (activated groundwater) from both alluvial water sources: this is the extraction limit or sustainable yield. To date, maximum metered extraction volumes approximate the sustainable yield for the Upper Lachlan Alluvial Water Source but have exceeded the sustainable yield for the Belubula Alluvial Water Source.

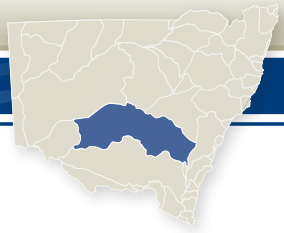
Water Sharing Plan for the Lower Lachlan Groundwater Source

Since the water sharing plan commenced, metered groundwater extraction in the Lower Lachlan Groundwater Source has not exceeded the sustainable yield. Monitoring suggests that groundwater levels are stable or in recovery. Recovery is particularly evident over the previous water year, when usage has reduced in response to wetter weather. No additional groundwater-dependent ecosystems have been identified in the Lower Lachlan Groundwater Source.



Since the water sharing plan commenced, metered groundwater extraction in the Lower Lachlan Groundwater Source has not exceeded the sustainable yield.

Image courtesy of Patrick Driver



Socio-economic monitoring

In 2005, the NSW Office of Water began a statewide project to monitor changes in the NSW irrigation industry following the introduction of water sharing plans. The project is designed to:

- monitor key social and economic changes at the farm and regional levels arising from water sharing plans
- provide data for the NSW Office of Water's review and evaluation of water sharing plans
- provide data for the Natural Resources Commission's review of water sharing plans
- provide a benchmark for other economic and social monitoring exercises in natural resource management.

The project was developed after extensive consultation with stakeholders, including the NSW Irrigator's Council and the Primary Industries and Economic Development Standing Committee of the NSW Natural Resources Advisory Council.

The project reports on changes in a number of identified social and economic indicators. The data are collected primarily in a 20-minute telephone survey of irrigators who respond to an invitation to participate. A sample size of approximately 10 per cent of the eligible irrigators is targeted for each survey. Additional customised data from the Australian Bureau of Statistics Agricultural Census are also used.

The first of the surveys, in 2006, targeted irrigators in areas where the first 31 water sharing plans were implemented in July 2004. These plans included all major regulated rivers in NSW, and represented approximately 80 per cent of the extractive water use in NSW. The 2006 survey collected baseline data reflecting the socio-economic conditions of farms in these areas.

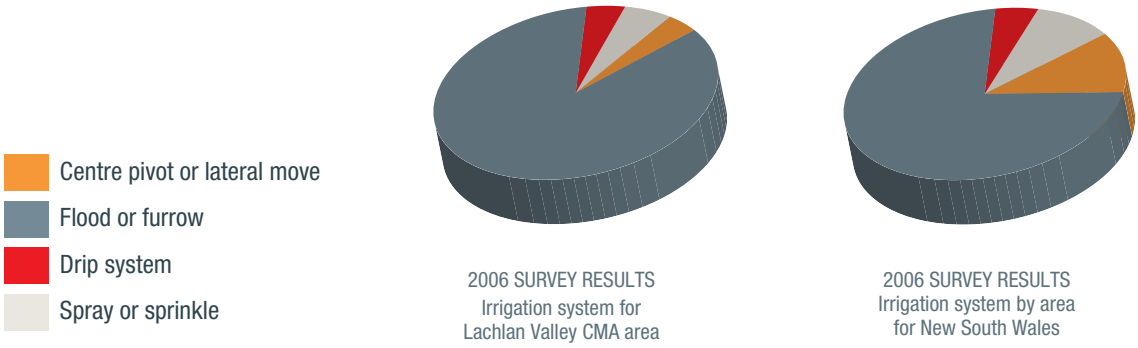
The 2009 baseline survey targeted irrigators in the remaining areas of the State, where water sharing plans were implemented after 2004 or are about to be implemented. This survey covered irrigators whose water sources are predominantly unregulated rivers or major inland groundwater systems. The combined data will provide a complete statewide baseline data set to be used in the reporting of plan performance against socio-economic indicators.

For reporting purposes the results of the irrigator surveys are tabulated by catchment management authority (CMA) area. The Lachlan Valley data are reported for the Lachlan CMA area for both surveys. The 2006 survey targeted water users in the Lachlan Regulated River and Mandagery Creek water sources. The 2009 survey covered irrigators in the Lower Lachlan Groundwater, Lachlan River Unregulated and Alluvial, and Belubula Regulated River water sources.

The 2006 survey results for the Lachlan Regulated River and the Mandagery Creek water sources showed:

- The median irrigation farm size was 346 hectares (25th to 75th percentile range, 49 to 1170 hectares). The statewide median farm size was 159 hectares (26 to 621 hectares)
- Flood or furrow irrigation systems were used on 85 per cent of the land irrigated (Figure 25). The statewide median was 73 per cent

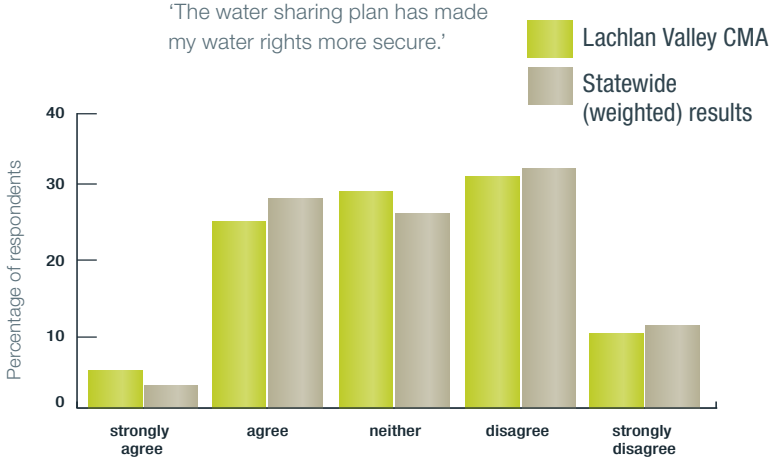
FIGURE 25 Proportion of irrigation systems used in the Lachlan Regulated River and Mandagery Creek Water Source and statewide.



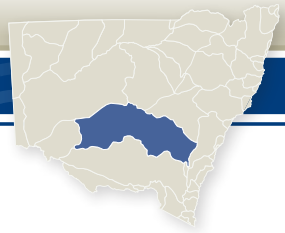
Source: 2006 Irrigators survey.

- Irrigators derived an average 28 per cent of total farm income from irrigated crops and pastures. This is less than the statewide average of 51 per cent
- 30 per cent of irrigators indicated that they had used their water entitlement as security for a loan. The statewide average was 30 per cent
- Figure 26 shows the irrigators' responses to the statement 'The water sharing plan has made my water rights more secure'
- 40 per cent of the irrigators employed non-family members on farm, and the percentage increased as entitlements increased. The statewide average was 52 per cent
- Full-time employment of family and non-family members per irrigation farm was 2.9 equivalent full-time (EFT) positions. The statewide average was 3.9 EFT positions
- The ratio of water per EFT employee was 236 megalitres per EFT. The statewide average was 164 megalitres per EFT
- Figure 27 shows the water users' response to the statement 'The water sharing plan has made a lot of difference to water use in this catchment.'

FIGURE 26 2006 response to the statement 'The water sharing plan has made my water rights more secure.'



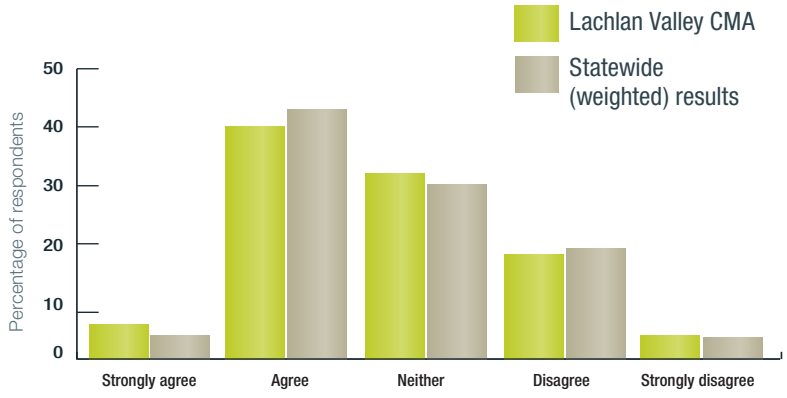
Source: 2006 Irrigators survey.



The 2009 survey included irrigators in the Lower Lachlan Groundwater, Lachlan River Unregulated and Alluvial, and the Belubula Regulated water sources within the Lachlan CMA and showed:

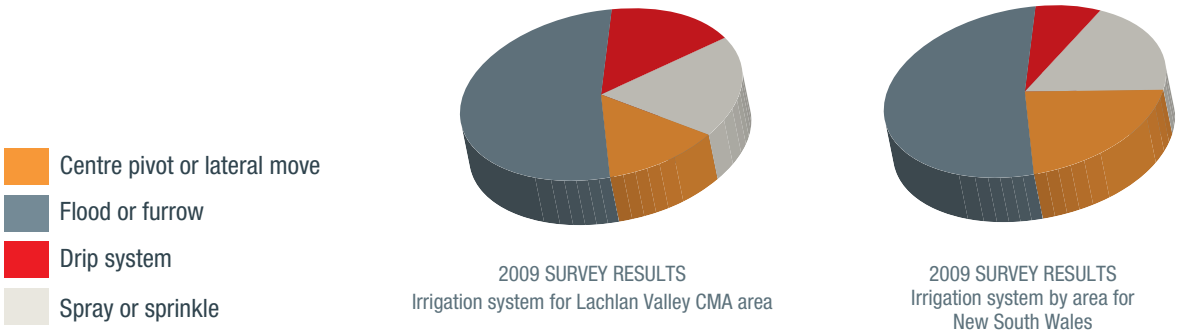
- The median irrigation farm size was 263 hectares (25th to 75th percentile, 68 to 790 hectares). The statewide median was 81 hectares, with the 25th to 75th percentile range of 28 to 81 hectares
- Flood or furrow irrigation systems were the dominant irrigation system in the Lower Lachlan Groundwater, the Lachlan River Unregulated and Alluvial, the Belubula Regulated water sources and the rest of NSW (Figure 28)
- Irrigators derived 33 per cent of total farm income from irrigated crops and pastures. The statewide average was 30 per cent
- 29 per cent of irrigators had used their water entitlement as security for a loan. The statewide average was 17 per cent
- Figure 29 shows the irrigators' responses to the statement 'The water sharing plan has made my water rights more secure'
- 61 per cent of irrigators employed non-family members on farm. The statewide average was 45 per cent
- Full-time employment of family and non-family members per irrigation farm was 2.2 EFT positions. The statewide average was 2.1 EFT positions

FIGURE 27 2006 response to the statement 'The water sharing plan has made a lot of difference to water use in this catchment.'



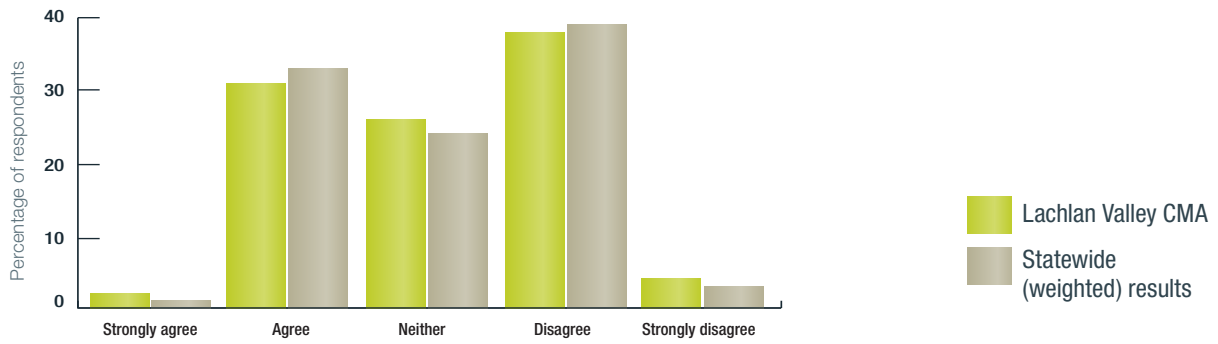
Source: 2006 Irrigators survey.

FIGURE 28 Proportion of irrigation systems used by area in the 2009 survey.



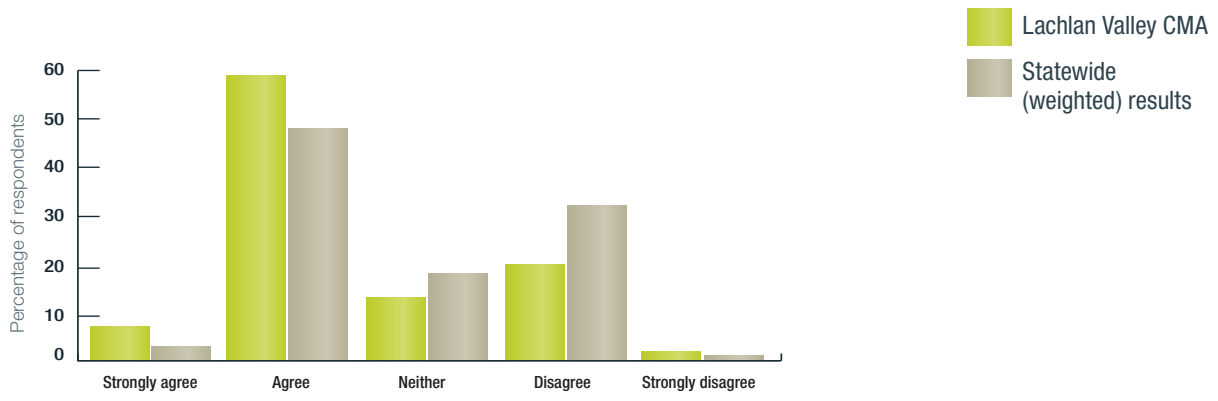
Source: 2009 Irrigators survey.

FIGURE 29 2009 response to the statement 'The water sharing plan has made my water rights more secure.'



Source: 2009 Irrigators survey.

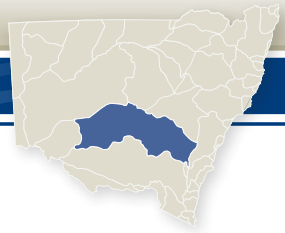
FIGURE 30 2009 response to the statement 'The water sharing plan has made or will make a lot of difference to water use in this catchment.'



Source: 2009 Irrigators survey.

- The ratio of water entitlement to EFT employee was 283 megalitres entitlement per EFT employee. The statewide ratio was 136 megalitres entitlement per EFT employee
- Figure 30 shows the water users' responses to the statement 'The water sharing plan has made or will make a lot of difference to water use in this catchment.'

Detailed reports of the 2006 and 2009 surveys are available at www.water.nsw.gov.au



monitoring plans for 2011-12

WHAT ECOLOGICAL MONITORING IS PLANNED FOR 2011-12?

Regulated rivers water sharing plans

The Lower Lachlan Drought Refugia Project was developed largely in response to the profound drought conditions during 2009-10. With the recent wetter weather this project has been scaled down, although some monitoring is are still occuring.

The NSW Office of Water continues to assess the effectiveness of environmental flow management and of the environmental flow rules within the water sharing plan. The NSW Office of Water, the Australian National University and the National Centre for Groundwater Research and Training are collaborating on the optimisation of environmental flow delivery and interactions among wetland plant responses, groundwater and surface water. In late 2011, this study was integrated into a broader collaboration on environmental flow management with Charles Sturt University, the Lachlan Riverine Working Group and the Lachlan Catchment Management Authority.

Event-based monitoring of environmental flows usually delivered to wetlands, and managed through the Lachlan Riverine Working Group, is now largely implemented by the Office of Environment and Heritage and reported through the working group (see www.lrwg.com.au).

Unregulated rivers water sharing plans

The Mandagery Creek Water Source will continue to be monitored with stream flow gauges to evaluate the effectiveness of cease-to-pump rules at protecting very low flows and of the daily flow sharing rules at protecting a proportion of flows for the environment.

Event-based monitoring within lowland unregulated sites such as within Merrimajeel, Muggabah (near Booligal) and Merrowie creeks is likely to continue under the Water Sharing Plan for the Lachlan Regulated River Water Source, largely under the Office of Environment and Heritage and as part of the broader Lachlan Riverine Working Group collaborations supported by the NSW Office of Water.

Water quality assessment will continue across a range of streams and especially within weir pools, including regulated and unregulated streams and, when warranted, significant wetlands such as Lake Cowal. Measurements include electrical conductivity to assess salinity risk, and data collected by the regional algal coordinating committees to assess the risk of toxic blue-green algae blooms.

Electrical conductivity is monitored in the Boorowa River at Prossers Crossing (site 412029), Belubula River at Needles (412056), Belubula River upstream of Canowindra (412195) and Mandagery Creek at Smithfield (412030). In lowland areas, it is measured at Cowra

(412002), Nanami (412057), Forbes (412004), Condobolin (412006), Lake Cargelligo Weir (412011), Willandra Weir (412038), Hillston Weir (412039), Booligal Weir (412005) and Four Mile Weir (Oxley; 412194).

Groundwater sharing plans

Monitoring projects under way in the Lower Lachlan Groundwater Source include:

- studies of recharge and environmental water using the groundwater flow model to predict recharge volume contributions
- work on temporal changes in groundwater chemistry due to groundwater development.

The NSW Office of Water will continue regional monitoring of groundwater levels and metered usage from production bores in the Lower Lachlan Groundwater Source. Specific projects on groundwater quality change in all aquifer units will continue but will be reviewed at the end of 2011-12.

Monitoring of surface water and groundwater to quantify stream–aquifer interactions will continue at the Lachlan River at Hillston, Forbes (Cottons Weir) and the Belubula River at Canowindra. The National Water Commission, with government partners that include the NSW Office of Water, the Office of Environment and Heritage and the Lachlan Catchment Management Authority, is undertaking a broadscale assessment of groundwater-dependent ecosystems (GDEs) through the National Atlas of Groundwater-Dependent Ecosystems project. The project is incorporating existing information on all GDE types (terrestrial, wetland, river base-flow, estuarine and subsurface). This includes identifying terrestrial, wetland and river base-flow GDEs across Australia; and resolving matters of scale and resolution. The project is also investigating the ability of remote sensing to detect ecosystems as small as 25 square metres.

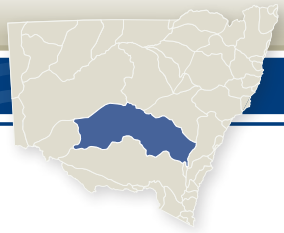
Image courtesy of Patrick Driver

For more details visit the NSW Office of Water's website www.water.nsw.gov.au

WHAT SOCIO-ECONOMIC MONITORING IS PLANNED FOR 2011-12?

The third of the planned irrigators' surveys was undertaken in 2010. This survey targeted the water users on the Lachlan Regulated River and Mandagery Creek Unregulated River water sources, who were first surveyed in 2006. This third survey was the first to collect data that could be used to report on changes since the implementation of the water sharing plans.

To assist in the socio-economic assessment of changes at the water sharing plan level, the NSW Office of Water will purchase customised agricultural census data from the Australian Bureau of Statistics, reported by water source areas.



WHAT'S PLANNED FOR FUTURE WATER SHARING PLANS?

Five additional water sharing plans covering the Lachlan Valley are currently being developed for:

- Lachlan River Unregulated and Alluvial Water Sources (including the Belubula Unregulated River and Alluvial Water Source)
- Murray-Darling Basin Fractured Rock Groundwater Sources (Central West Fractured Rock Groundwater Source, Orange Basalt Fractured Rock Groundwater Source)
- Murray-Darling Basin Porous Rock Groundwater Sources
- Young Granite Groundwater Source
- Belubula Regulated River Water Source.

FUTURE PRIORITY NEEDS FOR ECOLOGICAL MONITORING AND EVALUATION ACTIVITIES IN THE LACHLAN VALLEY

In accordance with *Macro Water Sharing Plans* – The approach for unregulated rivers. Report to assist community consultation, 2nd Edition" (DWE 2009b; available at www.water.nsw.gov.au) potentially high-priority water sources are those identified as being placed at high risk to instream environmental value by water extraction. During the development of the Water Sharing Plans for the Lachlan River Unregulated and Alluvial Water Sources, the Western Bland Creek and Mandagery Creek water sources were identified as potentially high-priority water sources.

Further refinement of monitoring locations within these water sources is guided by the relevance and reliability of the information likely to be gained (for example, for river pools that are stable; Driver et al., 2012). Future monitoring across such water sources to assess the performance of water sharing plans is likely to involve multiple NSW Government agencies such as the Lachlan Catchment Management Authority, the Office of Environment and Heritage, the NSW Office of Water and the fisheries research sections of the Department of Primary Industries.

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WANT MORE INFORMATION?

Further information on water sharing plans and socio-economic assessment is available at www.water.nsw.gov.au go to Water Management > Monitoring.

Image courtesy of Patrick Driver