



NSW Rivers Environmental Restoration Program

Final Report



Environment,
Climate Change
& Water



Australian Government
Water for the Future

NSW Rivers Environmental Restoration Program is jointly funded by the NSW Government and the Australian Government's Water for the Future initiative through the Water Smart Australia Program.

Cover photographs

Main photo: Piggery Lake within Yanga National Park. *Photo: L. Bezzina (DECCW).*

Smaller photos, left to right:

Aboriginal community members gathered in Balranald at the commencement of the RERP archaeological study to discuss the project's implementation, October 2009. *Photo: R. Williams (DECCW).*

Scientists Steve Jacobs (DECCW) and Syke Wassens (Charlies Sturt University) undertake a fish and frog survey following an environmental watering at Piggery Lake, Yanga National Park, March 2010. *Photo: J. Spencer (DECCW).*

Neroli Brennan of the Central West Catchment Management Authority talking to Macquarie Marsh landholders about soil health as part of a RERP-hosted field day which discussed holistic grazing practice, February 2010. *Photo: T. Hosking (DECCW).*

Construction workers building the road culvert as part of the Marebone Weir Fishway project, July 2010. *Photo: J. Weeraratne (State Water).*

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Abbreviations

ANU	Australian National University
DECCW	Department of Environment, Climate Change and Water NSW
DSS	Decision Support System
iCAM	Integrated Catchment Assessment and Management centre at the Australian National University (ANU)
IQQM	Integrated Quantity Quality Modelling
LiDAR	Light Detection and Ranging
NOW	NSW Office of Water
PCG	Plan Control Group
RERP	NSW Rivers Environmental Restoration Program
SAR	Synthetic Aperture Radar
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Australian Government)
STRC	Scientific Technical Review Committee
UNSW	University of New South Wales
WAL	Water Access Licence
WMA	Water Management Area
WRP	NSW Wetland Recovery Program

Foreword

Wetland systems are complex, demonstrating an interdependency of hydrological, ecological, physical, cultural, social, climatic and economic factors. Efforts to restore wetlands must therefore systematically address all of these factors in a coordinated and strategic manner. With this understanding, in September 2007, New South Wales in partnership with the Australian Government established the Rivers Environmental Restoration Program, with New South Wales contributing \$101.5 million and the Australian Government contributing \$79.62 million over the duration of the program.

This partnership has been an outstanding success with significant achievements. These include:

- new environmental water – over 108,000 megalitres of water entitlement purchased and available for environmental purposes
- new science – an increased understanding of complex wetland ecosystems culminating in the development of Decision Support Systems for the Lowbidgee, Macquarie Marshes, Narran Lakes and Gwydir Wetlands in support of the adaptive management of wetlands
- new regional infrastructure – the identification, development and construction of numerous infrastructure projects that improve the ability to deliver water to priority wetlands and support river health objectives
- new wetland protected areas – the purchase of four high conservation value strategic wetland properties covering over 14,000 hectares for inclusion in the national reserve system
- new local engagement – targeted engagement of landholders supporting high conservation value wetlands held on private land, resulting in management agreements for over 3200 hectares of wetland plus a major initiative in the Gwydir Wetlands to control water hyacinth over approximately 1000 hectares, and
- new connection with Aboriginal communities – significant progress in the understanding and reconnection of Aboriginal communities to culturally significant wetlands. This has included identifying over 1200 new sites of cultural significance and pioneering the development of access and use agreements between Aboriginal communities and landholders allowing for community access to culturally significant wetlands.

However, the value of the Rivers Environmental Restoration Program is greater than the significant individual project achievements. Critically, the program has demonstrated a template for future investment that is mindful of the complex economic, environmental and social interactions associated with water and river management.

This is a great program, with great learnings for the future.



LISA CORBYN
Director General
Department of Environment, Climate Change and Water NSW

Acknowledgments

The publication of the NSW Rivers Environmental Restoration Program (RERP) Final Report represents the culmination of the efforts of numerous individuals, across a range of disciplines and organisations, over a number of years.

In concluding the program, it is appropriate to recognise these contributions including those made by staff within the Department of Environment, Climate Change and Water NSW, NSW Office of Water, Industry & Investment NSW, State Water Corporation, NSW Treasury, NSW Department of Premier and Cabinet, the Central West and Border Rivers–Gwydir Catchment Management Authorities and the Australian Government Department of Sustainability, Environment, Water, Population and Communities.

The Department of Environment, Climate Change and Water NSW (DECCW) has led the delivery of RERP, which has been a collaboration between the Department's Climate Change, Policy and Programs Group; Parks and Wildlife Group; Environment Protection and Regulation Group; Country, Culture and Heritage Division and Scientific Services Division. Specifically, the contribution of DECCW's Senior Rivers and Wetland Conservation Officers across RERP-targeted valleys – Mike Maher, Daryl Albertson, Debbie Love, Peter Terrill, Paul Packard and James Maguire – are noteworthy, as are the contributions of Paul Childs, Gary Currey, Jennifer Spencer, Rachael Thomas, Li Wen, Yoshi Kobayashi and Sharon Bowen who successfully delivered significant projects within RERP.

It is also appropriate to recognise the effort, support and knowledge provided by landholders across RERP-targeted wetlands, who continue to support wetland values on both private and public land. Similarly, to recognise the contribution and enthusiastic engagement from Aboriginal communities associated with the Lowbidgee Floodplain and Lachlan Wetlands.

Finally, the broad RERP management group can be proud of their contribution, including RERP Program Manager Jeff Hillan, subprogram leaders Graeme Enders, Neil Saintilan/Joanne Ling, Janaka Weeraratne and Tim Hosking, as well as RERP Project Officer Clare D'Arcy.



DEREK RUTHERFORD
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Executive summary

This report presents the outcomes resulting from the \$181.12-million investment in wetland health made through the NSW Rivers Environmental Restoration Program (RERP). The completion of the program provides an opportunity to reflect upon its achievements and assess progress towards the program objective:

... arrest the decline of the most stressed and iconic rivers and wetlands in New South Wales through market-based water recovery focused on the voluntary acquisition and effective, active management of environmental water.

As suggested by the program aim, the primary focus of RERP was the purchase of Water Access Licences (WALs) from willing sellers. Consistent with this focus, approximately \$147.2 million of the overall RERP budget was spent on the purchase of WALs, or water infrastructure projects that led to water savings, for use on wetlands targeted by RERP. As a result of this investment, WALs representing over 108,000 megalitres are now being managed by the Department of Environment, Climate Change and Water NSW (DECCW).

Water allocated from these licences has been used to provide multiple environmental flows to the Gwydir Wetlands, Macquarie Marshes, Lowbidgee Floodplain and Lachlan Wetlands. It must be noted that these environmental flows occurred during a period of unprecedented drought and historic low or nil water allocations. The impact of these environmental flows cannot be underestimated in sustaining the resilience of core wetland areas and underpinning the rapid response by wetlands witnessed through 2010 and early 2011 as seasonal conditions and allocations improved.

\$147.2 million
(approximately 80%)
of the overall RERP
budget was spent on
the purchase of Water
Access Licences or
infrastructure projects
leading to water savings.



Aerial view of the Devils Creek regulator following the release of environmental water to Yanga National Park, Lowbidgee, August 2010.
Photo: J. Maguire (DECCW).

Significantly, RERP has concurrently supported investment in:

- management-focused science
- infrastructure to improve water management
- landholder and Aboriginal community engagement, and
- purchase of wetland properties.

Highlights from these investments include:

- development of hydrological and hydrodynamic models for the Gwydir Wetlands, Macquarie Marshes and Lowbidgee Floodplain, and Decision Support Systems (DSS) for these valleys and the Narran Lakes. These models will assist in the planning and management of environmental flows by predicting the duration, extent and depth of inundation at various water volumes while providing an indication of the likely ecological response of key species to watering events
- completion of multiple infrastructure projects across the Gwydir Wetlands, Macquarie Marshes, Narran Lakes, Lachlan Wetlands and Lowbidgee Floodplain that are already demonstrating their value in distributing environmental water to key wetland assets
- negotiation of 15 agreements with landholders who manage high conservation value wetlands on private land, covering over 3200 hectares, to improve management of these areas in support of their wetland values
- engagement of Aboriginal communities through the Lowbidgee Floodplain and Lower Lachlan to record the connection of Aboriginal people to wetlands, facilitate access to culturally significant wetlands and improve capacity and understanding to allow for greater engagement in wetland and water management, and
- purchase of high conservation value strategic wetland properties in the Lachlan (*Booligal Station* and part of the property *Geramy*), Macquarie Marshes (part of the property *Pillicawarrina*) and Gwydir Wetlands (*Old Dromana*) covering over 14,000 hectares for inclusion in the national reserve system.

The RERP Final Report discusses these outcomes and their significance relative to the program objective. The report concludes with a series of key learnings and recommendations that should guide future strategic investment in supporting wetland health.

1 Introduction

The NSW Rivers Environmental Restoration Program (RERP) is a \$181.12-million partnership between the NSW and Australian Governments and incorporating the NSW RiverBank program. The ambitious objective of the project is to:

... arrest the decline of the most stressed and iconic rivers and wetlands in New South Wales through market-based water recovery focused on the voluntary acquisition and effective, active management of environmental water.

NSW Riverbank was initiated in November 2005 with the NSW Government announcing the City and Country Environment Restoration Program, providing funding of \$439 million over five years to address specific and significant environmental challenges. The largest single component of the City and Country Environment Restoration Program was a \$105-million¹ contribution to the creation of NSW RiverBank, to buy and manage water for environmental benefits, and specifically to protect and restore ailing wetlands and river systems in New South Wales.

The establishment of NSW RiverBank led to the formation of RERP in September 2007 with the Australian Government, through its Water for the Future initiative – Water Smart Australia Program, providing \$71.77 million² in support of NSW RiverBank (\$101.5 million). Significantly, this investment allowed for the allocation of additional funds for water purchase (Subprogram I) and complimentary investment in:

- management-focused science (\$8.1 million through Subprogram II)
- infrastructure to improve water management (\$10.1 million through Subprogram III), and
- landholder and Aboriginal community engagement, and wetland purchase and protection (\$14.8 million through Subprogram IV).

RERP recognised the need for urgent action to address wetland decline resulting from flow regulation and floodplain development. It also recognised the opportunity to build on almost a decade of continuous effort and achievement in water reform.

At its inception, NSW RiverBank was the single largest government commitment to restore the health of priority wetlands in New South Wales and the first program to acquire water entitlements from willing sellers via the water market.

1 New South Wales contributed \$101.5 million to RERP with the balance of NSW RiverBank funds (\$3.5 million) allocated to Pipeline NSW.

2 The Australian Government contribution to RERP was increased by \$7.85 million to \$79.62 million to facilitate the purchase of the property *Old Dromana* in the Gwydir Wetlands, resulting in a final RERP budget of \$181.12 million.

It is estimated that the area flooded in the Macquarie Marshes has contracted by 40–50% in the 50 years between 1944 and 1993 (Kingsford and Thomas 1995), while the areas of semi-permanent wetland vegetation in the Gingham and Lower Gwydir watercourses have declined by an estimated 76% since the regulation of the Gwydir River in the 1970s (Bowen and Simpson 2009a). Similarly, it is estimated that 75% of the lower Murrumbidgee floodplain wetlands (Lowbidgee Floodplain) has been lost or degraded since the early 1900s to 1998 (Kingsford and Thomas 2004).

RERP set out to benefit five of the most important wetland areas in the NSW Murray–Darling Basin, with selection based on their conservation and cultural significance, and on the magnitude of the water supply risks posed to their values. The areas selected were:

- Narran Lakes
- Gwydir Wetlands
- Macquarie Marshes
- Lachlan Wetlands, and
- Lowbidgee Floodplain.

Figure 1 – Location of the wetlands targeted by RERP



2 RERP objectives

The following objectives are drawn from the original RERP proposal (NSW Government 2007).

Subprogram I – Acquisition and management of environmental water

The environmental and cultural objectives of this Subprogram are to:

- improve and protect the ecosystem function of wetlands and rivers, including the habitat for water-dependent biodiversity
- rehabilitate wetland habitat for significant water-dependent biota, including floodplain eucalyptus, water birds, frogs, reptiles and fish
- contribute to meeting the nation's international obligations with respect to wetlands and migratory birds, and
- improve water management decisions to reflect an understanding of the links between environmental water and Aboriginal cultural values.

Subprogram II – Enabling better use of environmental water

The aim is to maximise the benefit of environmental water by targeting the delivery of water to key ecological assets. The Subprogram will:

- identify the water requirements of targeted assets
- monitor the delivery of water
- monitor and report on the ecological responses in an adaptive management context, and
- develop Decision Support Systems for optimal management of environmental water.

Subprogram III – Better delivery of environmental water

This Subprogram aims to:

- optimise the environmental benefits gained through the application of environmental water through a range of feasibility studies and structural works
- improve the quality, quantity and timing of environmental flows
- optimise dam management, water release and delivery practices
- reinstate more natural flow regimes, including increasing the variability in flows and minimising the impacts of unseasonal flows
- identify cost efficient options for mitigating cold water pollution impacts
- facilitate the removal of in-stream barriers (e.g. chokes and weirs), to improve fish passage, habitat condition and flow efficiencies
- facilitate efficient delivery of environmental flows to high value environmental sites
- identify and achieve efficiency gains through real-time data acquisition, improved dam management practices and removal of in-stream barriers

- improve the functionality of ineffective fishways at key sites, using innovative low-cost designs
- improve operational flexibility to ensure greatest environmental benefit from environmental releases, including management of supplementary flows, and
- improve adaptive management capacity.

Subprogram IV – Partnerships for the management of environmental water on private land

This Subprogram aims to:

- ensure important wetlands on private land are protected and managed to maintain their environmental and cultural heritage values over the long term
- ensure important wetlands protected by conservation agreements have management plans that adequately cater for management and monitoring of conservation values
- engage wetland owners in grazing management practices that are sympathetic to biodiversity requirements
- ensure monitoring programs are in place to document changes in conservation values, and provide a basis for adaptive management, and
- facilitate opportunities for Aboriginal communities to undertake cultural activities in important wetlands.

Environmental water inundating river red gums at Yanga Creek Wetland (Yanga National Park), Lowbidgee, November 2010.
Photo: N. Jones (DECCW).



3 Methodology

3.1 Program delivery

RERP is governed by a funding agreement between the Department of Environment, Climate Change and Water NSW (DECCW), on behalf of the NSW Government, and the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC), on behalf of the Australian Government. The funding agreement outlines the obligations of the two parties including the Program's financial provisions, reporting requirements, objectives and activity plan.

The plan period commenced on 27 September 2007 and ends on 30 June 2011.

3.2 Governance

An inter-agency steering committee, or Plan Control Group (PCG), was established to coordinate RERP, set strategic direction and oversee and monitor the performance of the Program. Membership of the PCG includes:

- DECCW (Chair)
- NSW Office of Water (NOW)
- NSW Department of Premier and Cabinet, and
- NSW Treasury.

A representative from SEWPaC is an observer on the PCG. The PCG meets on a six-monthly basis, reviewing the progress of the program including the status of individual projects and the program budget. All public material is reviewed and endorsed by the PCG prior to release to ensure consistency of messages and appropriate content consistent with the RERP investment strategy.

A Program Manager employed by DECCW manages the day-to-day business of RERP. The Program Manager is responsible for the overall operation and performance of the program, consistent with the funding agreement and annual implementation plan. This includes liaising with project managers within each of the RERP Subprograms (Subprogram Leaders) and partner agencies, managing the budget, reporting, acting as Executive Officer to the PCG, being a member of the Subprogram Steering Committees and communicating with SEWPaC.

Subprogram Leaders are responsible for the day-to-day operation of each Subprogram within the parameters set by the annual implementation plan. Subprogram Leaders also coordinate Subprogram input to meet reporting requirements, ensure Subprogram progress is consistent with Subprogram budgets, coordinate Subprogram Steering Committees as well as providing leadership to Subprogram staff.

It is noteworthy to highlight the role of the NSW Environmental Trust, which oversees the delivery of NSW RiverBank (the NSW-funded component of RERP), and the Scientific Technical Review Committee (STRC) within Subprogram II. The STRC, a committee of independent scientists, provides input and guidance into the research being undertaken through RERP.

4 RERP results

4.1 Summary of RERP outcomes against Subprogram objectives

Subprogram I – Acquisition and management of environmental water	
Subprogram objectives	Summary of outcomes
<p>The environmental and cultural objectives of this Subprogram are to:</p> <ul style="list-style-type: none"> • improve and protect the ecosystem function of wetlands and rivers, including the habitat for water-dependent biodiversity • rehabilitate wetland habitat for significant water-dependent biota, including floodplain eucalyptus, water birds, frogs, reptiles and fish • contribute to meeting the nation’s international obligations with respect to wetlands and migratory birds, and • improve water management decisions to reflect an understanding of the links between environmental water and Aboriginal cultural values. 	<ul style="list-style-type: none"> • To January 2011, over 108,000 megalitres of Water Access Licences (WALs) have been purchased through RERP for application to targeted wetlands. • Water accumulating to these WALs has been used in conjunction with other sources of environmental water to undertake environmental waterings to targeted wetlands. • Watering events in these valleys have supported significant water-dependent biota and contributed the nation’s international obligations with respect to wetlands and migratory birds. • Watering events have occurred during a period of historic low rainfall and low water allocations. • Representatives of Aboriginal communities have been appointed to the Environmental Water Reference Groups (who provide recommendations on the use of environmental water).
Subprogram II – Enabling better use of environmental water	
Subprogram objectives	Summary of outcomes
<p>The aim is to maximise the benefit of environmental water by targeting the delivery of water to key ecological assets. The Subprogram will:</p> <ul style="list-style-type: none"> • identify the water requirements of targeted assets • monitor the delivery of water • monitor and report on the ecological responses in an adaptive management context, and • develop Decision Support Systems for optimal management of environmental water. 	<ul style="list-style-type: none"> • The water requirements of key ecological assets have been determined through inundation and vegetation mapping, ecological monitoring and extensive literature review. • Outcomes of environmental flows have been monitored in targeted valleys, working in collaboration with DECCW environmental water and asset managers. Information has been used for the adaptive management of wetland assets including supporting the threatened southern bell frog, river red gums and water birds. • Hydrological and hydrodynamic models for the Gwydir Wetlands, Macquarie Marshes and Lowbidgee Floodplain have been completed, providing a mechanism for predicting the likely movement of environmental water through targeted wetlands. • Decision Support Systems have been completed for Gwydir Wetlands, Macquarie Marshes, Lowbidgee Floodplain and Narran Lakes, allowing the prediction of the likely ecological response of key species to different watering scenarios.

Subprogram III – Better delivery of environmental water

Subprogram objectives

This Subprogram aims to:

- optimise the environmental benefits gained through the application of environmental water through a range of feasibility studies and structural works
- improve the quality, quantity and timing of environmental flows
- optimise dam management, water release and delivery practices
- reinstate more natural flow regimes, including increasing the variability in flows and minimising the impacts of unseasonal flows
- identify cost efficient options for mitigating cold water pollution impacts
- facilitate the removal of in-stream barriers (e.g. chokes and weirs), to improve fish passage, habitat condition and flow efficiencies
- facilitate efficient delivery of environmental flows to high value environmental sites
- identify and achieve efficiency gains through real-time data acquisition, improved dam management practices and removal of in-stream barriers
- improve the functionality of ineffective fishways at key sites, using innovative low-cost designs
- improve operational flexibility to ensure greatest environmental benefit from environmental releases, including management of supplementary flows, and
- improve adaptive management capacity.

Summary of outcomes

- Regulators have been constructed on the Muggabah and Merrimajeel creeks to control unseasonal flows and provide water at required times.
- A detailed concept design has been completed for works on Burrendong Dam to reduce cold water pollution (proving the feasibility of the floating curtain concept).
- Fishways have been constructed at Marebone and Tarabah weirs.
- Regulators have been constructed on the Yanco Creek system (Mollys Lagoon/Dry Lake and Gum Hole/Possum Creek) to enable the natural wetting and drying of these wetlands.
- Fishways have been designed for Lake Brewster, Tyreel Weir, Tyreel Regulator, Tareelaro Weir and Boolooroo Weir; some of these fishways will be constructed under State Water's dam construction offset program.
- The effectiveness of river system operations have been investigated in the Macquarie, Lachlan and Gwydir valleys, including the adequacy of the existing river gauging network and the accuracy of farm water meters.
- 'Bubblers' have been removed on Bulgeraga Creek and replaced with culverts to improve fish passage.
- 29 gauging stations have been installed to provide real-time information to assist in managing environmental flows.
- Ten regulating structures and ten floodways have been constructed and 40 pre-existing embankments have been breached on Yanga National Park to improve the distribution of environmental flows.
- Banks and channels have been removed to reinstate the flow of floodwater across the floodplain on *Pillicawarrina*.

Subprogram IV – Partnerships for the management of environmental water on private land

Subprogram objectives

This Subprogram aims to:

- ensure important wetlands on private land are protected and managed to maintain their environmental and cultural heritage values over the long term
- ensure important wetlands protected by conservation agreements have management plans that adequately cater for management and monitoring of conservation values
- engage wetland owners in grazing management practices that are sympathetic to biodiversity requirements
- ensure monitoring programs are in place to document changes in conservation values, and provide a basis for adaptive management, and
- facilitate opportunities for Aboriginal communities to undertake cultural activities in important wetlands.

Summary of outcomes

- Landholders whose properties contain high conservation value wetlands have been targeted for engagement with the program.
- 15 management agreements have been negotiated, covering over 3200 hectares of high conservation value wetlands, specifying land management objectives and monitoring requirements.
- Wetland management plans have been developed for properties in the Macquarie Marshes and Lachlan Wetlands.
- Subprogram IV staff have facilitated grazing management training opportunities for landholders whose properties contain high conservation value wetlands.
- Opportunities have been provided for Aboriginal communities in the Lowbidgee and Lower Lachlan to participate in various activities 'on country' including establishment of an access and use agreement.
- Four high conservation value wetland properties, covering over 14,000 hectares, have been purchased for inclusion in the national reserve system.

4.2 Macquarie Marshes

Purchase of Water Access Licences

At the end of January 2011, RERP had purchased 42,263 megalitres of general security and 140 megalitres of supplementary access entitlements. Combined with purchases under other State and Australian Government programs, the environment's share of available water has increased by over 60% compared with the 160,000-megalitre Environmental Contingency Allowance provided by the Water Sharing Plan for the Macquarie–Cudgong Regulated River Source 2004.

This significantly improves the ability of government to supply environmental water to core wetland assets and extend the scope of water allocated under the water sharing plan.

Monitoring of environmental flows

RERP has funded the purchase and installation of new river gauges at Oxley Break and *Pillicawarrina* which will improve knowledge about the delivery and distribution of environmental flows. Both the Oxley Break and *Pillicawarrina* gauging data can be accessed from the NSW Water Information website at http://waterinfo.nsw.gov.au/water.shtml?ppbm=SURFACE_WATER&rs&3&rskm_url.

Community engagement activities

A number of community events have been held to bring landholders, community members and agency staff together to share knowledge and experiences of the Macquarie Marshes. Events have included the 'Macquarie@Macquarie' workshop at Quambone in August 2009 which saw over 50 people discuss environmental water management, scientific research findings and land management issues.

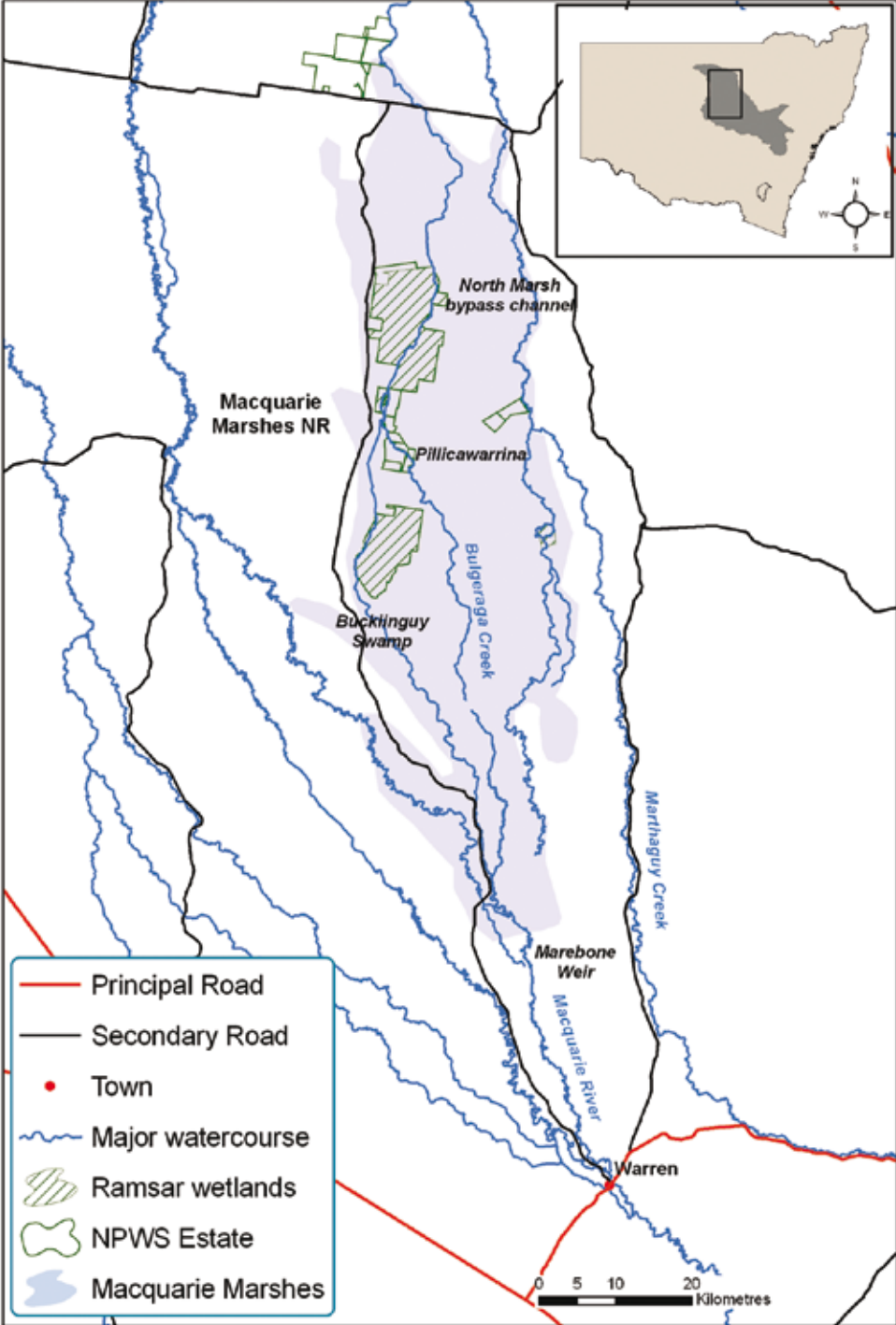
A holistic grazing workshop was also held in February 2010 with landholders discussing various grazing systems with agronomists. Discussion included the soil system, management of wetland species, stocking rates and grazing timing and duration. The workshop gave wetland managers a forum to share experience and hear new ideas for the sustainable grazing of high conservation value wetland systems.

Fish passage restoration

Work has commenced on a new fishway at Marebone Weir, 50 kilometres north of Warren³. Costing up to \$3.2 million, this fishway will improve the connectivity of fish communities in the Macquarie River and the Ramsar-listed Macquarie Marshes by allowing free movement of fish along an additional 214 kilometres of river (88 kilometres upstream and 126 kilometres downstream). This fishway will also include a carp trap.

³ Construction of the Marebone Weir Fishway is scheduled for completion by July 2011, following the recession of current high river flows.

Figure 2 – Map of the Macquarie Marshes





Above left: Marebone Fishway under construction, July 2010.

Photo: J. Weeraratne (State Water).

Above right: One of the existing 'bubblers' being replaced as part of the Bulgeraga Creek works, January 2010.

Photo: J. Weeraratne (State Water).

Fish passage restoration (continued)

The Macquarie Marshes have been identified as a major and possibly the most significant breeding and recruitment hot spot in the Murray–Darling Basin for European carp (Industry & Investment NSW 2010).

As a result of this RERP project, Industry & Investment NSW is taking responsibility for the management of the carp trap, for an initial period of two years, in an attempt to facilitate its commercial operation. This program is being undertaken in conjunction with the Central West Catchment Management Authority consistent with the carp strategy for the Macquarie Marshes (Industry & Investment NSW 2010).

Bulgeraga Creek is a major waterway of the Macquarie Marshes, downstream of Marebone Weir. On this creek there are numerous in-stream structures that impede fish passage. As part of RERP, State Water-owned structures along Bulgeraga Creek were assessed by a fish biologist to ascertain their impact on fish passage (Fishway Consulting Services 2010). As a result of this investigation, two priority 'bubbler' structures were replaced with culverts using RERP funding. The investigation also assessed and prioritised other structures in terms of their impact on fish passage and this work can be continued if further funding becomes available. Fish species that will benefit from these projects include golden perch, Murray cod, the threatened silver perch and other migratory native fish.

Burrendong Dam cold water pollution remediation

A numerical modelling study undertaken by Aurecon Consulting (Aurecon 2009) confirmed that an intake located 0–10 metres below the top water level would significantly reduce the incidence of cold water pollution from Burrendong Dam under a range of climate and management scenarios. Based on previous studies (including modelling) undertaken by State Water, a cost effective solution to achieve this is by the use of a floating 'curtain' device. Further studies (AMOG Consulting 2010a, 2010b) demonstrated the feasibility of the construction of a curtain that shrouds the lower levels of the outlet tower, forcing the release of warm water from shallower depths. The investigation also considered a range of management issues, including reducing the potential for seeding the water downstream with algae during algal blooms (cf. Ingleton *et al.* 2008). The preliminary estimate for these works is \$4 million, with the curtain having an expected 20-year lifespan. The AMOG Consulting studies were funded by RERP and State Water while the Aurecon Study was funded by RERP.



Case study – RERP investment in Pillicawarrina

In January 2009, RERP contributed approximately \$9.3 million to the \$10.5-million purchase of 2436 hectares of the western portion of the property *Pillicawarrina* (including the property's significant regulated water assets). The property, 117 kilometres north of Warren in Central West New South Wales, has been gazetted and added to the adjoining Macquarie Marshes Nature Reserve and is managed by DECCW Parks and Wildlife Group.

The purchase of *Pillicawarrina* was significant because it provided a number of strategic outcomes, including:

- purchasing 8658 megalitres of water entitlement for use by the environment and with a strategic delivery point in the heart of the Macquarie Marshes
- purchasing and restoring the principal floodplain that connects to the Ramsar-listed Macquarie Marshes Nature Reserve. This includes being able to restore the function of the floodplain and accommodate overland flow and natural processes such as fish passage and dispersal in a critical part of the Macquarie Marshes
- restoring key vegetation communities
- reducing potential irrigation within the Macquarie Marshes prohibited area, as defined by the 1996 Water Management Plan, which provides an appropriate buffer from irrigated agriculture around the Macquarie Marshes Nature Reserve, and
- helping link the north and south sections of the Macquarie Marshes Nature Reserve.

Above: Aerial view of *Pillicawarrina* showing the passage of environmental flows across the property following the breaching of levees and floodplain structures, October 2010.

Photo: J. Hillan (DECCW).

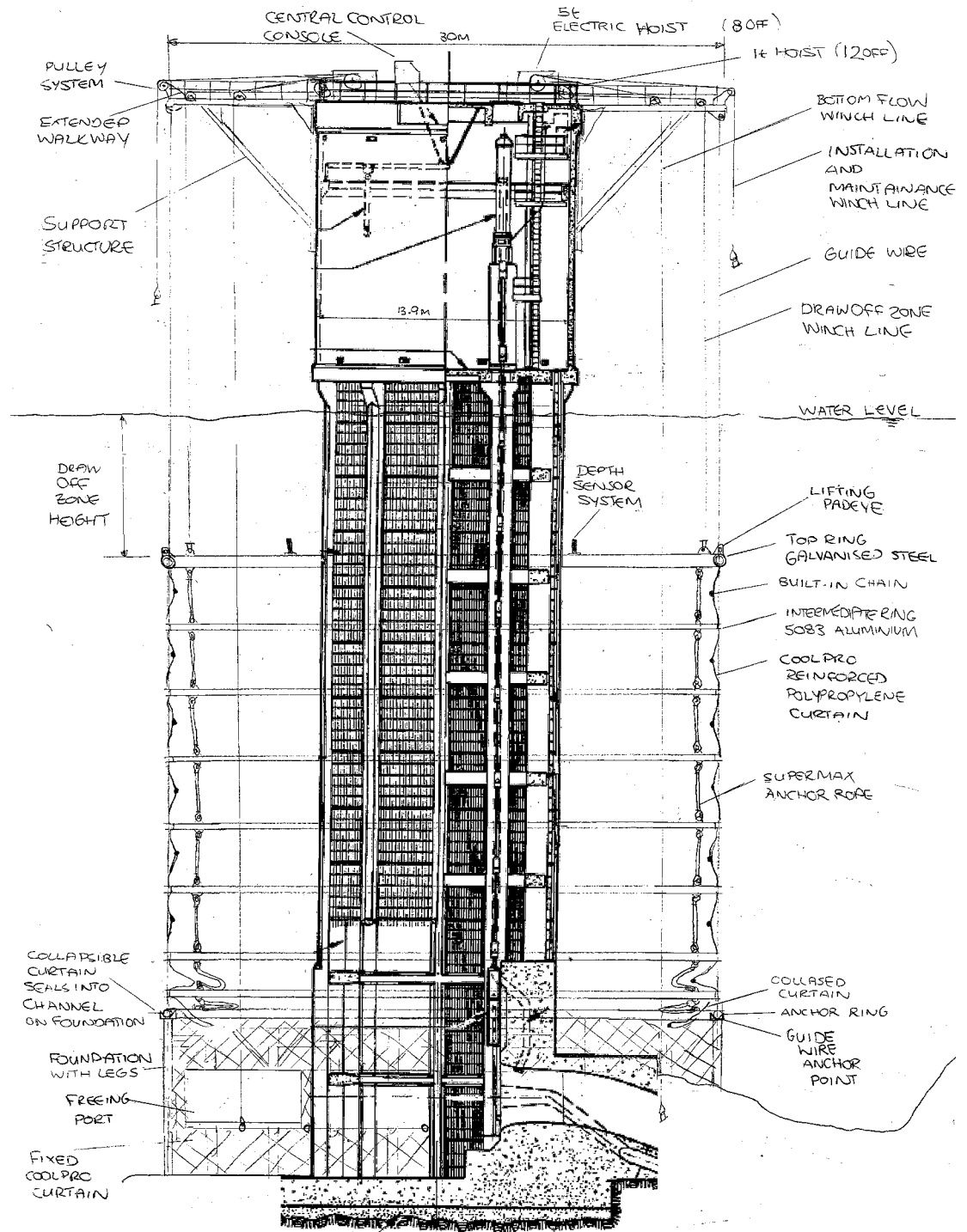
Since the purchase, RERP, in partnership with DECCW Parks and Wildlife Group, has invested over \$600,000 in the rehabilitation of the Pillicawarrina Floodplain. Completed works include removal of banks and channels to reinstate the flow of floodwater across the floodplain, the upgrade of culverts to enhance the passage of floodwaters and fish passage and the installation of a river gauge to improve real-time management and reporting of river flows. A seed bank study and revegetation strategy, including a monitoring program, has also been developed to guide further efforts to rehabilitate areas previously cleared. Modification of an in-stream structure, to ensure it is fish-friendly, will be completed when high river flows recede.

The works program on *Pillicawarrina* has been guided by RERP-funded geomorphic mapping, vegetation community mapping, inundation mapping, hydrodynamic modelling, engineering and environmental assessments. This has ensured works have been optimally placed while minimising the potential for any negative outcomes. Environmental flows through August to March 2011 have subsequently inundated the area and wetland species are now regenerating. It is expected that future inundation will result in significant restoration of the wetland ecology, demonstrating the regenerative potential of modified wetland environments.

While construction of the floating curtain is beyond the RERP timeframe, this innovative and cost effective solution to a key environmental issue (cold water pollution) could provide substantial benefits for the ecology downstream of Burrendong Dam.

The curtain design can apply to other large dams of a similar configuration.

Figure 3 – Concept plan of the floating curtain system relative to the Burrendong Dam outlet tower



Source: AMOG Consulting (2010a).

North Marsh bypass channel

The North Marsh bypass channel is used by State Water to supply stock and domestic water to landholders downstream of the Macquarie Marshes. RERP funded an investigation of options for providing a more reliable stock and domestic water supply to downstream landholders while also delivering water savings and environmental benefits (Integrated Resource Planning 2010). The investigation compares options for future works and provides a hydrological and ecological baseline upon which the outcomes of future works can be assessed.

Buckiinguy Swamp geomorphic study

Buckiinguy Swamp is a privately owned 500-hectare wetland in the southern Macquarie Marshes. Silt appears to be obstructing the flow of water into the northern parts of the wetland and diverting water away from the southern Macquarie Marshes. This RERP-funded study is defining the current state of the wetland, recording erosion and deposition of sediments over time and developing future management options.

Wilgara erosion control trial

A total grazing pressure trial has been established on the privately owned property *Wilgara* in the eastern part of the Macquarie Marshes. The trial will assist in determining the effect of stock and kangaroo exclusion in stabilising the bed and banks of shallow eroding channels. Baseline data collected in October 2009 and further monitoring upon the recession of current flood waters will provide an excellent comparison with future findings.

Results from the trial will have application to unstable channels on *Wilgara*, which includes 550 hectares of Ramsar-listed wetland, and other areas of the Macquarie Marshes where wetland plants are absent and bed and bank erosion is occurring.

Grazing management on privately owned wetlands

Four landholders in the Macquarie Marshes were successful in gaining incentives to improve the management of high conservation value wetland areas on their properties. The projects, which cover over 1480 hectares of river channels, wetlands and floodplains, are located on the properties *The Mole*, *Quilbone*, *South Roubaix* and *Cutbushes*. The projects include fencing for stock exclusion and controlled grazing, installation of alternate watering points and treatments to improve the biodiversity of native groundcover. Ten-year management agreements have been negotiated between landholders and DECCW, outlining respective obligations in support of the wetland values targeted by the project.



Above left (October 2009) and right (May 2010): Flood return channel, Wilgara Wetland. This channel has been surveyed to monitor stream change over time and investigate options for removing rock rubble structures in favour of solutions such as targeted revegetation and grazing management. This small trial site will be fenced and monitored as part of RERP outcomes.

Photos: T. Hosking (DECCW).

Research to better understand complex wetland ecosystems

A number of research projects have been completed to underpin the development of models and Decision Support Tools which are used to improve the management of environmental flows for wetlands in the Macquarie Valley:

- Vegetation community condition and extent mapping (funded under the NSW Wetland Recovery Program⁴) showed the extent of change in the period between 1991 to 2008 in the Macquarie Marshes and Floodplain (Bowen and Simpson 2009b, 2010a, in preparation b). This mapping provided fundamental data for delineating wetland assets, for use in the Decision Support System and for developing flow-inundation relationships for input into ecosystem response models. The vegetation condition and extent mapping continues to be used to provide vegetation community extents for monitoring vegetation response to environmental flows.
- Inundation mapping (funded under the NSW Wetland Recovery Program) for over 20 flood events (in 20 years) in the Macquarie Marshes (Thomas *et al.* 2010c) has provided fundamental data for determining the inundation frequency gradient of the floodplain, calibrating hydrodynamic and hydrological models and identifying wetland assets for use in the Decision Support System. Findings have also been used in developing flow-inundation relationships for input into ecosystem response models. The methods developed are also being used to determine inundation extent resulting from environmental flows.
- A drying trend using the long-term (1979–2006) spring inundation mapping was detected in the Macquarie Marshes (Bowen and Simpson 2009b, Thomas *et al.* in press). The drying trend corresponded spatially to the changes in flood-dependent vegetation communities mapped in 1991 compared with terrestrially dominated communities mapped in 2008 (Thomas *et al.* 2010a, 2010b). The study demonstrated the spatial response of flood-dependent vegetation communities to changes in inundation patterns over almost three decades.

⁴ The NSW Wetland Recovery Program (WRP) is a suite of projects that aim to restore the health of the Gwydir Wetlands and the Macquarie Marshes. The \$26.8-million WRP is jointly funded by the NSW Government and the Australian Government's Water for the Future initiative through the Water Smart Australia Program.



- The relationship of flood frequency to vegetation community distribution (mapped in 2008, Bowen and Simpson 2009b) was determined (Thomas *et al.* 2010b). Inundation zones supported vegetation communities according to their water requirements. Zones with a high frequency of flooding (every one to two years) supported semi-permanent wetland vegetation (e.g. common reed, water couch) and river red gum forest only. Terrestrial floodplain vegetation communities did not occur in these locations (Bowen and Simpson 2009b). Inundation zones with a very low frequency of flooding (every ten to twenty years) or no flooding were dominated by terrestrial vegetation, black box and coolibah woodlands. Zones with a moderate (every six to eight years in twenty) to low (ten to twenty years) flooding frequency supported about 15% of the river red gum woodland community which was in poor condition (Bowen and Simpson 2010a). Vegetation communities that had altered structure and composition more indicative of terrestrial landscapes (e.g. chenopod shrubland dominance), were distributed widely across the inundation gradient due to water requirements of the original vegetation community (e.g. common reed) not being met over the past twenty years (Thomas *et al.* 2010b).
- Studies of fish passage, location, assemblage structure and management of low-flow refugia were undertaken by the University of New South Wales (UNSW) in the Macquarie Marshes (Rayner *et al.* 2008a, 2008b, 2009).
- A groundwater study was undertaken to ascertain the extent to which groundwater might be contributing to soil moisture accessed by vegetation within the Macquarie Marshes during drought conditions. The study also sought to determine the extent of interaction between surface water and groundwater, as a guide to the hydrological modelling of the Macquarie Marshes. The study concluded that the groundwater was too deep, too saline and too isotopically distinct to be making a contribution to either surface water or plant water needs during prolonged dry conditions (Hollins *et al.* 2009).

Above: River red gums and common reeds in the northern Macquarie Marsh Nature Reserve inundated by excellent flows from the upper and mid-Macquarie catchment in late 2010, October 2010.

Photo: J. Hillan (DECCW).

Research to better understand complex wetland ecosystems (continued)

- A satellite-based remote sensing application was trialled that allows for the detection of water in the landscape otherwise obscured by vegetation structures and cloud cover (synthetic aperture radar [SAR]) (Milne *et al.* 2008). The trial, conducted during a small environmental flow event in 2008, demonstrated that SAR could be usefully applied to monitoring the distribution of water during environmental flow events. Following this trial, free access to SAR data, derived from the ALOS-PULSAR satellite, covering the entire Murray–Darling Basin, was negotiated with the Japanese Space Agency.
- The most detailed soil survey ever undertaken in the Macquarie Marshes was completed to document soil properties relevant to the hydrodynamic modelling of the wetland (Jenkins and James 2009). The survey focused on recording soil texture across the Macquarie Marshes to assist in determining the rate of water loss to the soil profile under dry conditions. The survey produced a soil map which provides insight into the geomorphic structure of the wetland. The spatial variability in infiltration rates mapped from the survey was incorporated into the hydrodynamic model for the Macquarie Marshes.
- The trophic dynamics and ecosystem function project demonstrated some important differences between the northern and southern sections of the Macquarie Marshes with respect to sources and sinks of nutrients. The southern marsh is often characterised as ecologically degraded when compared to the northern marsh. However, this project demonstrated that the southern marsh is an important source of nutrients that are subsequently redistributed to the northern marsh during environmental flows (Kobayashi *et al.* 2010). The project further demonstrated that the arrival of environmental water rapidly increases the availability of nutrients and carbon, leading to the successive emergence of bacteria, algae and invertebrates in floodplain waters, and providing the basis for the productivity and biodiversity of plant communities and higher-order wetland animals such as fish and waterbirds (Kobayashi *et al.* 2009).

Hydrodynamic and hydrological modelling tools

A hydrodynamic model (MIKEFLOOD-based⁵) representing water flow through the Macquarie Marshes has been completed, covering an area of 110,000 hectares. The model reproduces flow volumes and inundation extent to within an accuracy of 20% (DHI 2010), allowing water managers to model watering options considering available volumes and regulator operation.

The hydrodynamic model has also been used in the development of a Macquarie Marshes hydrology model (IQQM-based⁶) which provides the inputs required to extend the existing hydrology model into the wetlands. The hydrology model, developed in partnership with the NSW Office of Water,

⁵ MIKEFLOOD is software for flood modelling developed by DHI (www.mikebydhi.com).

⁶ IQQM is software designed for use as a basin-wide daily stream flow simulation model for water resource planning and management.

allows for the exploration of long-term hydrological variations resulting from climate change, amendments to water sharing plans and dam operation rules, at an individual wetland scale (now represented by 20 to 30 nodes of high ecological significance) at daily time-steps extending over periods of 100 years or more (MacDonald *et al.* 2011a).

Decision Support System

The development of a Decision Support System (DSS) for the Macquarie Marshes is the culmination of investment in science undertaken through RERP. This has allowed the integration of RERP scientific research with other complementary research into a single tool that can support a transparent and scientifically rigorous decision-making process. In particular, the DSS integrates ecosystem response models with hydrological models, allowing for the comparison of scenarios relating the volume and timing of water delivery to ecological outcomes.

The Macquarie Marshes EXCLAIM DSS (Fu *et al.* 2009), developed as a prototype under RERP in partnership with the Central West Catchment Management Authority, models the ecological implications of climate change scenarios using a water balance model of the Macquarie catchment and the water requirements information published by Rogers and Ralph (2010). The model has accurately hind-cast the probability of breeding success in the Macquarie Marshes, comparing model outputs with the data of Kingsford and Auld (2005). The Integrated Catchment Assessment and Management (iCAM) centre at the Australian National University (ANU) has subsequently developed the IBIS DSS for the Macquarie Marshes under RERP, which reports on 36 water management areas (storages) using IQQM as the contributing hydrological model (iCAM 2011a). IBIS is able to run hydrological time series ranging from an individual flow to over 100-year time series, and predict the likely ecological impacts of climate change or water resource development. The outputs of the DSS include changes to the hydrological characteristics of the water storages (extent and depth of inundation, duration of inundation, timing of inundation, rate of rise and fall). These outputs assist in the interpretation of the ecological implications of these conditions for important ecological components of the water storages, including the constituent vegetation and waterbird species that use the storage for breeding.

The DSS will assist water managers evaluate the long-term effect of rules governing sharing of water between environmental and consumptive users as well as exploring options for the delivery of available environmental water on an event basis.

Decision Support Systems allow the effects of climate change and water development on wetland health to be modelled over a range of time scales, from an individual flow to 100-year time series. These tools will improve water planning in the Macquarie, Gwydir, Narran and Lowbidgee catchments.

4.3 Gywdir Wetlands

Purchase of Water Access Licences

At the end of January 2011, RERP had purchased 14,902 megalitres of general security access and 441 megalitres of supplementary access entitlement. Combined with purchases under other government programs, the environment's share of water has increased by over 250% when compared with the existing 45,000-megalitre Environmental Contingency Allowance provided by the Water Sharing Plan for the Gywdir Regulated River Water Source 2002.

This significantly improves the ability of government to supply environmental water to core wetland assets and extend the scope of water allocated under the water sharing plan.

New Gywdir Wetlands State Conservation Area

In January 2010, RERP funded the \$10-million purchase of the 4292-hectare private property *Old Dromana* for inclusion in the national reserve system and management by DECCW Parks and Wildlife Group. This purchase secured the protection of what was the largest (600-hectare) privately owned portion of the Gywdir Wetlands Ramsar site. The property, of which 2000 hectares is wetland, supports:

- a remnant stand of marsh club-rush, which is currently under-represented in the NSW reserve system and is listed as a critically endangered ecological community under the NSW *Threatened Species Conservation Act 1995*
- the habitats of rare, endangered and vulnerable species and migratory birds listed under international treaties with China, Japan and the Republic of South Korea, and
- large areas of coolibah floodplain wetland (part of the Coolibah–Black Box Woodland endangered ecological community).

The property has been gazetted as the Gywdir Wetlands State Conservation Area.

Monitoring of environmental flows

A surface-water gauge was installed at the end of the Lower Gywdir watercourse to enable real-time monitoring of environmental flows reaching the Ramsar wetlands on *Old Dromana*.

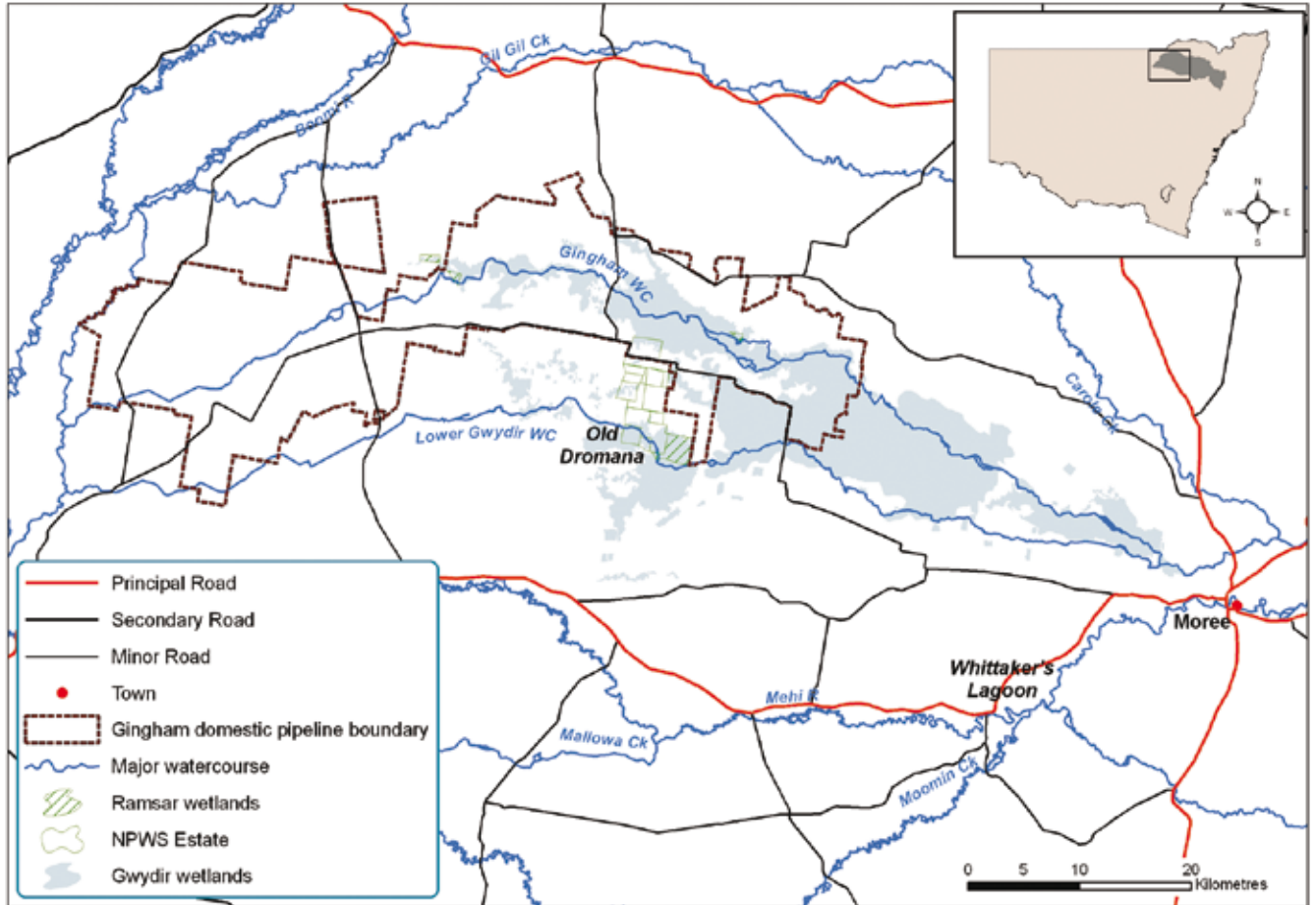
RERP also funded the upgrade of an existing river gauge in the Gingham watercourse, upstream of the Gingham Wetlands, to improve the monitoring of river flows to the Gywdir Wetlands.



Marsh club-rush
in flower on the
RERP-purchased
property *Old Dromana*.

Photo: D. Albertson (DECCW).

Figure 4 – Map of the Gwydir Wetlands



Managing water hyacinth in the Gingham watercourse

RERP has negotiated a partnership, in conjunction with local landholders and the Moree Plains Shire Council, to control water hyacinth across more than 1000 hectares of the Gingham section of the Gwydir Wetlands. Controlling this NSW-declared noxious weed will reduce competition for soil nutrients and water, improve water quality, revive native wetland vegetation and its associated habitat and allow environmental water to be used more efficiently.

Due to low flows during the 2009–10 summer season, control activities focused along the Gingham Channel. These control efforts resulted in minimal water hyacinth growth through the 2010–11 summer season with native wetland species able to establish more rapidly.

Weeds giving way to wetlands – Whittakers Lagoon benefitting from environmental water and now managed by North West Livestock Health and Pest Authority to achieve conservation outcomes under a project funded by RERP, January 2010.

Photo: J. Humphries (DECCW).



Conservation on private wetlands

Two incentive projects have been negotiated with landholders who manage high conservation value wetlands in the Gwydir. The projects, located on the properties *Belmont* and *Bunnor*, involve the sustainable grazing or exclusion of grazing from wetlands (100 hectares and 30 hectares respectively). After several dry seasons these wetlands have benefited from natural flows in spring and winter 2010 with their health now improving.

A further wetland conservation project has been negotiated with the North West Livestock Health and Pest Authority for the management of Whittakers Lagoon. As a result of the project, the 22-hectare floodplain billabong has been fenced to exclude grazing and boxthorn control has been undertaken. Whittakers Lagoon is an important and accessible community asset with its rehabilitation a positive demonstration of the restoration potential of wetlands in the highly developed Gwydir Valley.

In collaboration with adjacent landholders, DECCW has provided Whittakers Lagoon with a number of environmental waterings since 2008, which is assisting in its rehabilitation.

Ten-year management agreements have been negotiated between the landholders, North West Livestock Health and Pest Authority and DECCW for these projects, outlining the respective obligations of each party.

Community engagement activities

A number of extension events were held in the Gwydir Wetlands, including several field days on wetland plants and grazing management within wetlands. As a result of these activities, several wetland graziers are adjusting watering points, fencing layouts and amending their grazing practices in support of wetland values.

Macquarie/Gwydir/Lachlan Water Savings Project

RERP funded an investigation to assess the volume of potential water savings that could result from improved water metering and river practices in the Gwydir, Macquarie and Lachlan valleys (SKM 2010a).

Case study –Gingham domestic pipeline and Gingham Channel restoration

The completion of the NSW Wetland Recovery Program (WRP) and RERP-funded Gingham domestic pipeline represents the conclusion of a major infrastructure project and, significantly, it also provides the opportunity to rehabilitate the now redundant Gingham stock and domestic channel (constructed in the 1970s).

The \$2.9-million project involved the installation of 240 kilometres of pipe, 65 tanks and three pumping stations. It allows for the efficient delivery of water to households and has received support from landholders, with the establishment of a Private Irrigation District underway. This new pipeline will reduce existing water losses from evaporation and infiltration, with the resultant 958 megalitres of water savings allocated to a High Security water licence with Adaptive Environmental Water conditions for use on wetland assets within the Gwydir.

Complementing the pipeline project, RERP contributed \$235,000 towards the rehabilitation of Gingham Channel. The completed works, designed to limit the draining of wetlands and reduce channel bank erosion and sedimentation, are already showing their value.

The targeted restoration area within the Gingham watercourse includes Ramsar-listed wetlands and contains historical colonial waterbird breeding sites and critical habitat for other native species.

The undertaking of further restoration works will greatly benefit the wetlands and improve future water delivery into this system.

Below left: A trencher working on the RERP/WRP-funded Gingham domestic pipeline, October 2009. By reducing losses to evaporation and infiltration the project will result in savings equivalent to 958 megalitres of High Security water which will be used to water wetlands in the Gwydir.

Photo: N. Eigeland (NOW).

Below right: Wetlands on the property *Glendara* which are now benefiting as a result of the Gingham Channel restoration project, October 2010.

Photo: J. Hillan (DECCW).



Macquarie/Gwydir/Lachlan Water Savings Project (continued)

This study found that meters across the valleys tend to under-read and that the installation of new tamper-resistant meters may result in a redistribution of water between individual extractive users, and between extractive users and the environment. The study also found that:

- the installation of accurate meters is a cost effective way of achieving water savings
- better information helps operators reduce operational surplus, and
- reducing operational surplus is cost effective compared to the cost of purchasing entitlements but may have environmental impacts as a consequence of increased regulation of flows.

Fish passage solutions

RERP has funded the design of fishways at four major regulating structures at Tyreel Weir and Regulator, Boolooroo Weir and Tareelaro Weir (URS 2011). The resulting designs and business case present a 'shovel-ready' capital works opportunity. When constructed, these fishways will connect the Barwon River to Copeton Dam and provide free fish passage through 350 kilometres of river system.

State Water has subsequently committed funding to commence construction of Tyreel Weir Fishway as part of the fishway offset program for the Copeton Dam upgrade and is examining options to progress Boolooroo Weir Fishway.

Figure 5 – Locations of proposed fishways



Research to better understand complex wetland ecosystems

A number of research projects have been completed which underpin the development of models and decision support tools to improve the management of environmental flows for wetlands in the Gwydir Valley:

- Vegetation community condition and extent mapping (funded under the NSW Wetland Recovery Program) showed the extent of change in the period 1996 to 2008 in the Gwydir Wetlands and Floodplain (McCosker 2007, Bowen and Simpson 2009a, 2009c). This mapping provided fundamental data for delineating wetland assets for use in the Decision Support System, and for developing flow-inundation relationships for input into ecosystem response models. The vegetation condition and extent mapping continues to be used to provide vegetation community extents for monitoring vegetation response to environmental flows.
- Inundation mapping (funded under the NSW Wetland Recovery Program) for 30 flood events (in 20 years) in the Gwydir floodplain (Thomas *et al.* 2010d) provided fundamental data for determining the inundation frequency gradient of the floodplain, calibrating hydrodynamic (MIKEFLOOD) and hydrological (IQQM) models, delineating wetland assets for use in the Decision Support System, and for developing flow-inundation relationships for input into ecosystem response models. The method for detecting inundation is suitable for mapping flooding from environmental flows.
- The relationship between flood frequency and vegetation community distribution (mapped in 2008, Bowen and Simpson 2009c), was determined (Thomas *et al.* 2010b). Inundation zones supported vegetation communities according to their water requirements. Zones with a high frequency of flooding (every one to three years in twenty years) supported semi-permanent wetland vegetation (e.g. cumbungi and marsh club-rush). Terrestrial floodplain vegetation communities did not occur in these locations. Inundation zones with a very low frequency of flooding (every ten to fifteen years) or no flooding were dominated by coolibah woodlands and terrestrial vegetation (Bowen and Simpson 2009c, Thomas *et al.* 2010b).
- Waterbird and fish surveys (funded under the NSW Wetland Recovery Program) documented the location of historical waterbird colonies (Spencer 2010) and the status of waterbird and fish in the Gwydir system in 2007–08 (Spencer *et al.* 2010). Despite the lack of historical survey data documenting waterbirds and fish populations in the Gwydir Wetlands, at least 75 waterbird species and 12 native fish species have been recorded in the area.
- Fish studies conducted under RERP demonstrated that managed flows in the Gwydir Wetlands can influence the growth and condition of juvenile native fish in the Gwydir system (Heagney *et al.* 2009).



Delivery of a quad bike under the Water Hyacinth project to the Moree Plains Shire Weeds Officer, July 2009.

Photo: Moree Champion.

Research to better understand complex wetland ecosystems (continued)

- Fish surveys in the three major watercourses of the Gwydir Wetlands in 2009 revealed differences in fish assemblages among the channels were less obvious during autumn–winter than during previous spring and summer surveys. Overall, assemblages were dominated by the occurrence of four common native fish species, with alien species observed in only low numbers. This work also highlighted how the timing of flows can influence ecological responses, with spring–summer spawning activity and subsequent recruitment having a major influence on the structure of fish assemblages in dryland floodplain river systems (Wilson 2009, Wilson *et al.* 2010).
- To assist in the development of the Gwydir hydrodynamic model, a detailed soil survey was conducted of core wetland areas. The survey measured soil structural properties and the rate of infiltration under standing water. The study indicated that soils of the Gwydir Wetlands are remarkably uniform in texture and that a common rate-of-loss function could be used throughout the area covered by the hydrodynamic model (EASystems 2009).
- The trophic dynamics and ecosystem function project was able to trial a potentially significant new tool in the monitoring of environmental flows (Kelleway *et al.* 2010). The study explored the effect of an environmental flow in the Gwydir watercourse on in-stream ecological function (including the trophic structure of key biota), using the Gingham watercourse as a control. This ‘before-after-control-impact’ study demonstrated that even a modest environmental flow has the substantial benefit of decreasing competition between native fish and the invasive European carp (Kelleway *et al.* 2010).
- A longer term (‘palaeo’) study of ecological conditions was completed which provides a useful context for interpreting contemporary trends in the wetland ecosystem to inform thresholds of acceptable change in relation to flooding regime (Ralph *et al.* 2011). Results suggest that floods play a major role in the development of hydrological features within the Gwydir Wetlands, with lowland areas being filled and subsequently remaining as closed water bodies after the major flooding event of 1956 (Bernhardt *et al.* 2008).

Hydrodynamic and hydrological modelling tools

A hydrodynamic model (MIKEFLOOD-based) representing water flow through the Gwydir Wetlands has been completed, covering an area of 50,000 hectares. The model reproduces flow volumes and inundation extent to within an accuracy of 20% (Water Technologies 2010). The model allows environmental water managers to model watering options considering available volumes and the operation of regulating structures. In the coming 12 months the model will also be used to assist in identifying illegal floodplain structures. Previously there was no mechanism to test the hydraulic effects of artificial levee banks within the Gwydir Wetlands.

The hydrodynamic model has also been used in the development of a Gwydir hydrology model (IQQM-based), providing the inputs required to extend the existing hydrology model into the wetlands (now represented by 18 nodes of high ecological significance). Specifically, the hydrology model, developed in partnership with the NSW Office of Water (MacDonald *et al.* 2011b, Wen *et al.* 2010, Wen 2010), allows for the exploration of long-term hydrological variations resulting from climate change, amendments to water sharing plans and dam operation rules, at an individual wetland scale at daily time-steps extending over periods of 100 years or more.

Decision Support System

The development of a Decision Support System for the Gwydir Wetlands is the culmination of science investment undertaken through RERP. The development of the DSS has allowed for the integration of scientific research, undertaken through RERP as well as other complementary research, into a single tool that can support a transparent and scientifically rigorous decision-making process. In particular, the DSS integrates ecosystem response models with hydrological models, allowing for the comparison of scenarios relating the volume and timing of water delivery to ecological outcomes.

The DSS was developed by the iCAM group at ANU, using the same approach as adopted for the Macquarie Marshes (iCAM 2010). The Gwydir IBIS DSS represents hydrological conditions (extent and depth of inundation, timing and duration of inundation and the rate of rise and fall) for the 18 key wetland components (storages) identified in the hydrological and vegetation mapping (iCAM 2010). The Gwydir Ramsar sites are represented by discrete water storages. The DSS runs ecosystem response models within each storage which translates the hydrological inputs into ecological outcomes. The DSS can compare the ecological merits of hydrological inputs ranging from the individual flow event to a 100-year time-series.

This tool aims to assist water managers evaluate the long-term effect of rules governing sharing of water between environmental and consumptive users as well as exploring options for the delivery of available environmental water on an event basis. The tool will also be used to determine the vulnerability of the wetland to climate change and identify possible remediation strategies.



Above: Replanting (top) and fencing (bottom) on Dundomallee.

Photos: M. Graham (DECCW).

4.4 Lowbidgee Floodplain

Purchase of Water Access Licences

At the end of January 2011, RERP had purchased 19,739 megalitres of general security water entitlements and 5679 megalitres of supplementary access entitlement. Combined with the Australian Government's environmental water holdings (103 megalitres of high security; 102,953 megalitres of general security and 20,821 megalitres of supplementary access entitlement at the end of January 2011) this provides a total of 103 megalitres of high security; 119,605 megalitres of general security and 26,500 megalitres of supplementary access entitlement in addition to environmental water available under the Water Sharing Plan for the Murrumbidgee Regulated Water Source 2003.

This significantly improves the ability of government to supply environmental water to core wetland assets and extend the scope of water allocated under the water sharing plan.

Protecting and conserving wetlands on private land

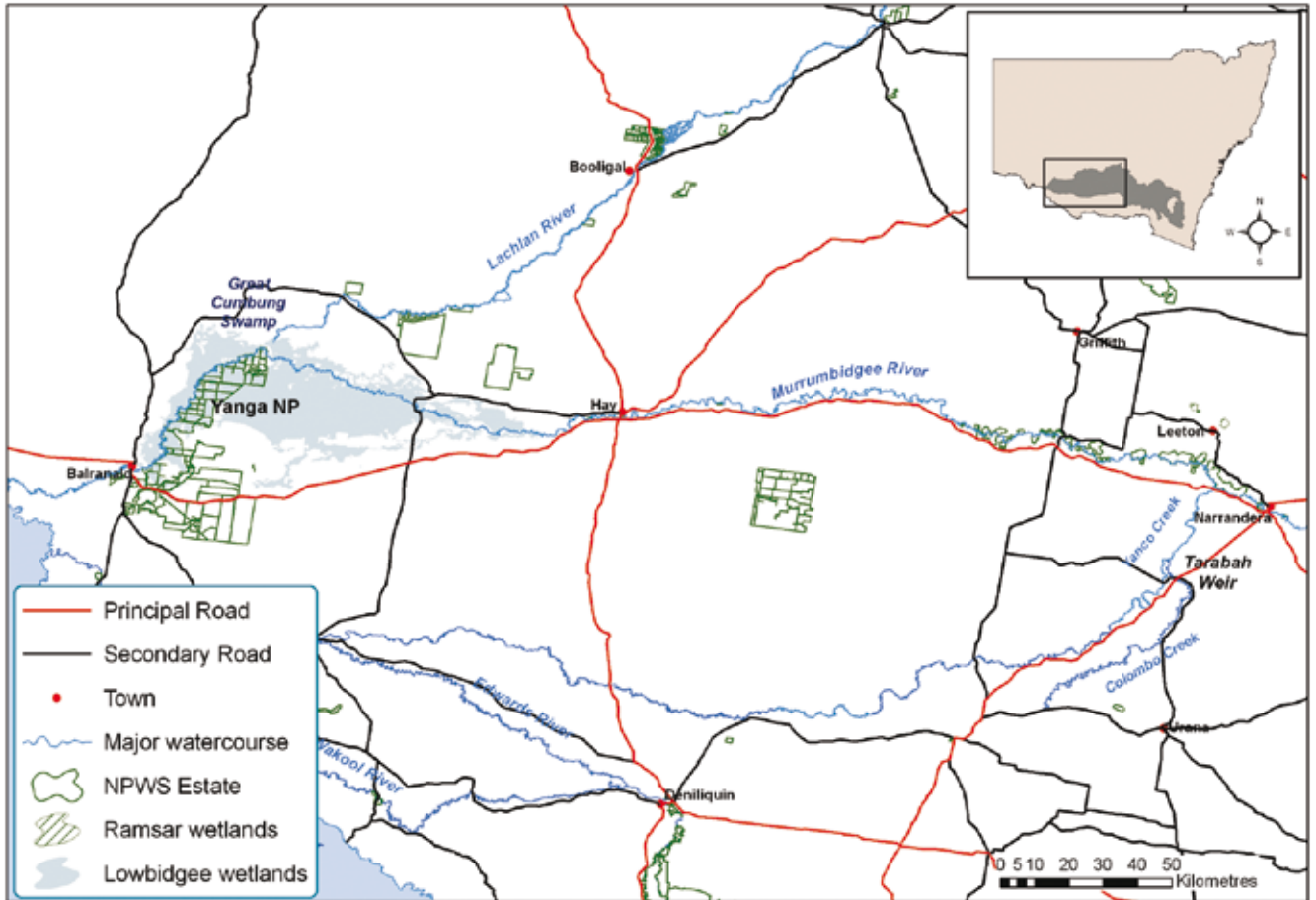
Incentives of \$64,000 have been provided to improve 650 hectares of wetlands on three private properties in the Lowbidgee Floodplain: *Dundomallee*, *Nap Nap Station* and *Talpee*. Projects include the fencing of wetland areas for grazing management, revegetation using endemic native species and minor earthworks to improve the effectiveness and efficiency of environmental water delivery to privately owned wetlands.

Ten-year management agreements have been negotiated between these landholders and DECCW outlining respective obligations in support of the wetland values targeted by the project.

Community engagement activities

RERP has held several community events, including a field day in Balranald in October 2009 to discuss 'biodiversity in the bush'. Landholders, community members and agency staff came together to share their enthusiasm for wetlands. Discussion included bird and water bug identification, the connection of Aboriginal people to local wetlands as well as examples of traditional usage of local plant species including basket weaving.

Figure 6 – Map of the Lowbidgee Floodplain



Yanco Creek projects

Currently, river regulation is causing adverse effects such as the death of river red gums and a decline in aquatic species within parts of the wetlands. Regulating structures have been constructed at Mollys Lagoon/Dry Lake and Gum Hole/Possum Creek Complex along Yanco Creek that allow for the reintroduction of a more appropriate drying and flooding regime and provide ecological benefits for these wetlands. The construction of these structures and future monitoring will provide a benchmark for the construction and operation of similar structures in other parts of the Yanco Creek and Murrumbidgee system. The other two projects that are part of this program are the removal of Wanganella Homestead Weir and Two Mile Weir.

All projects are being undertaken in collaboration with Water for Rivers⁷.

⁷ Water For Rivers is a public company established by the Australian, NSW and Victorian governments to recover 282 gigalitres of water for the Snowy and Murray rivers through investment in water efficiency infrastructure projects, innovation and technology, and, where appropriate, through acquisition of water entitlements.

Case study – RERP investment in Yanga National Park

Formerly a working property, *Yanga* was purchased by the NSW Government in 2005 for addition to the national reserve system. Located near the township of Balranald in south-western New South Wales, *Yanga* covers approximately 69,000 hectares of the Lower Murrumbidgee (Lowbidgee) River Floodplain (approximately 300,000 hectares).

The Lowbidgee Floodplain is listed in *A Directory of Important Wetlands in Australia* (Environment Australia 2001). It has supported some of the largest waterbird breeding colonies in Australia and is home to the State's largest known population of the endangered southern bell frog and approximately 22,000 hectares of river red gum forest and woodland (part of the largest continuous forest of this type outside the Murray Valley).

Flooding across the Lowbidgee Floodplain has been significantly reduced as a result of upstream water regulation and floodplain development (Kingsford 2003). Consequently, the condition of river red gum vegetation communities has declined over time, including on *Yanga* (McCosker 2008, Wen *et al.* 2009a, 2009b, Bowen and Simpson 2010d, Bowen and Childs in preparation).

In response, RERP, in partnership with DECCW Parks and Wildlife Group, undertook an assessment of the wetlands on *Yanga* resulting in the identification of 24 water management areas (WMA). An ecological character description of these areas was undertaken (Wen *et al.* 2009c) and an infrastructure program developed to allow for the effective management of small to moderate flows to support these areas.

The resulting \$1.6-million infrastructure program, funded by RERP, including the installation of 10 regulating structures, 10 floodways, and the breaching of 40 pre-existing embankments, has been completed and used to help distribute environmental flows.

Further information resulting from RERP, including a digital elevation model, hydrological and hydrodynamic models, inundation mapping, vegetation community mapping and a Decision Support System have helped refine WMA boundaries, define target areas and calculate water requirements. This information will assist in the development of *Yanga's* Wetland Management Plan and Plan of Management.

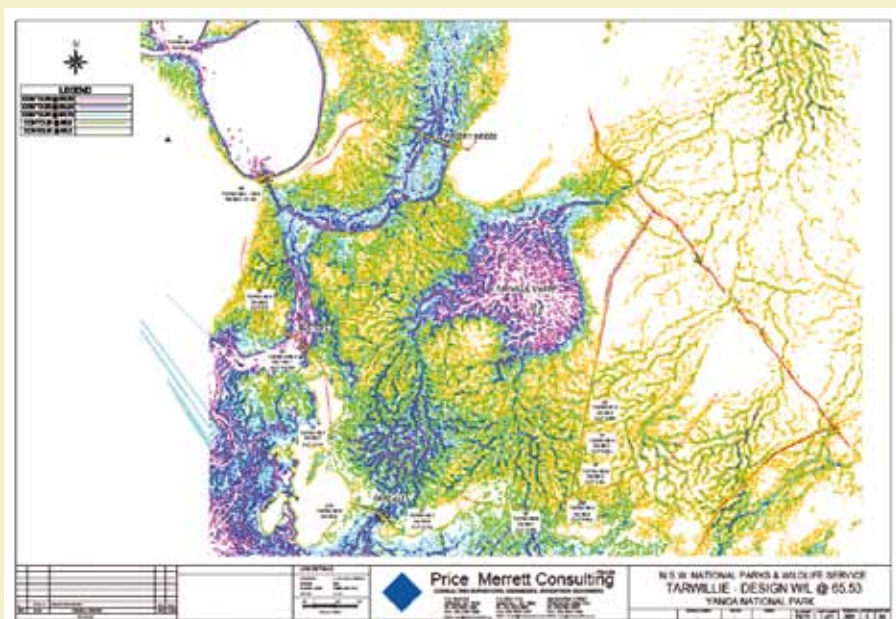
Several environmental waterings of the wetlands within *Yanga* have been undertaken since its purchase including water allocated under the Murrumbidgee Regulated River Water Sharing Plan and allocations accumulating to RERP and Australian Government licences. Over this period, approximately 220 gigalitres have been allocated to prioritised WMAs to maintain wetland habitat and river red gum forest health, support populations of the threatened southern bell frog and maintain egret nesting sites.

Significantly, improved rainfall through 2009–10 has resulted in a current watering event of approximately 120 gigalitres into *Yanga*, inundating some areas that have not received water since the late 1980s. An intensive biodiversity monitoring program is currently being undertaken by DECCW and CSIRO. Monitoring is also assisted by an extensive RERP-funded gauging network installed throughout *Yanga* by the NSW Office of Water (including six flow-metering stations, 17 height-only sites, 11 piezometer sites and one weather station).

Figure 7 – Elevation map of Tarwillie Swamp

The elevation map was used to inform the height at which levee banks should be breached to support egret breeding events.

Source: Price Merritt Consulting 2009.





Tarabah Weir Fishway under construction, July 2010.

Photo: J. Weeraratne (State Water).

Tarabah Weir Fishway

Yanco Creek has a range of native fish species typical of a lowland Murray–Darling stream. Species include three threatened species (the Murray cod, trout cod and silver perch) and important populations of freshwater catfish and Murray crayfish which are in decline across much of the Murray–Darling Basin. At a cost of \$0.9 million, RERP funded the installation of a vertical slot fishway at Tarabah Weir (near Leeton) which allows for the passage of these species.

Fostering Aboriginal connection to wetlands

With the assistance of RERP, 20 Aboriginal people have participated in a project to identify and record culturally significant sites across the Lowbidgee Floodplain to document the connection of Aboriginal communities to wetlands. Surveys were conducted on 13 properties and resulted in the identification of over 800 previously unrecorded Aboriginal archaeological sites, including burial sites, cooking mounds, hearths, modified (scarred) trees, mussel shell middens and areas where food, fibre and medicine plants were traditionally gathered (Martin 2010, Waters Consultancy 2009). Follow-up conservation and protection works have been undertaken where exposed Aboriginal ancestral burials were discovered. The project received strong landholder support and helped facilitate mutual understanding.

The oral histories of 10 Aboriginal people were also recorded, highlighting the deep connection of Aboriginal people to wetlands of the Lowbidgee Floodplain (Waters Consultancy 2011). A number of people have identified the reduction of culturally significant plant and animal species in and around the wetlands due to reduced flows. Others have highlighted stories of Aboriginal people working on various wetland properties, the lack of Aboriginal people participating in water management and the importance of revitalising the diversity of cultural and natural values through targeted watering. The oral histories will provide a lasting legacy of the significance of the Lowbidgee Floodplain to Aboriginal communities and will help ensure cultural knowledge is transferred to future generations.

As a result of the studies, 20 Aboriginal people have been trained in the recording of oral histories, archival and historical research skills and archaeological survey techniques to identify Aboriginal values across the wetland landscapes.

DECCW staff, Aboriginal community members and landholders discuss the Aboriginal cultural values of wetlands, August 2009.

Photo : R. Williams (DECCW).



Fostering Aboriginal connection to wetlands (continued)

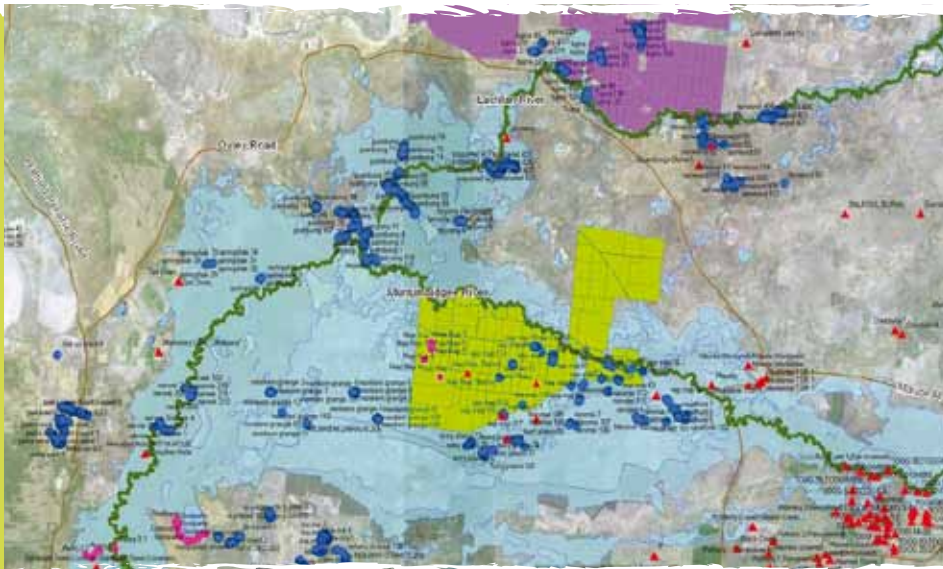
The Aboriginal Use and Values project also helped facilitate a number of negotiations to allow for Aboriginal community members to access culturally significant wetlands on private land. To date, one formal access and use agreement has been negotiated between the local Aboriginal community and a private landholder to allow access to a culturally significant wetland, with other agreements likely to follow.

The project, in conjunction with the Murrumbidgee Catchment Management Authority and Aboriginal Cultural Reference Group, is also facilitating the development of a process that will remove barriers to the effective use of the Murrumbidgee Cultural Access Licence. Under the Murrumbidgee Water Sharing Plan, 2150 megalitres have been allocated, and the process will seek to use the full allocation of this water on an annual basis in support of Aboriginal cultural values.

Research to better understand complex wetland ecosystems

A number of research projects have been completed to underpin the development of models and decision support tools to improve the management of environmental flows for wetlands in the Lowbidgee Floodplain:

- Inundation was detected from Landsat satellite imagery for 20 flood events between 1988 and 2006 in the Lowbidgee Floodplain (Thomas *et al.* 2010b) which included the application of an image calibration method developed by Sims (2008). Inundation maps provided fundamental data for determining the inundation frequency gradient of the floodplain, calibrating the hydrodynamic and hydrological models for Yanga National Park, delineating wetland assets for use in the Decision Support System, and for developing flow-inundation relationships for input into ecosystem response models. The method for detecting inundation continues to be used to provide inundation extents for flooding from environmental flows.
- Vegetation community condition and extent mapping of Yanga National Park and the Lowbidgee Floodplain (Bowen and Simpson 2010b, 2010c, 2010d, in preparation a) provided fundamental data for delineating wetland assets for use in the Decision Support System, and for developing flow-inundation relationships for input into ecosystem response models.



Map documenting Aboriginal cultural heritage sites in the Lowbidgee Floodplain; over 1200 previously unrecorded sites have been identified across the Lowbidgee Floodplain and lower Lachlan Wetlands.
Source: Martin 2010.

The vegetation condition and extent mapping continues to be used to provide vegetation community extents for monitoring vegetation response to environmental flows.

- The relationship of flood frequency to vegetation community distribution (mapped in 2005, McCosker 2008) was determined for Yanga National Park (Thomas *et al.* 2010b). Inundation zones supported vegetation communities according to their water requirements. Zones with a high frequency of flooding (every one to three years) supported swamps dominated by spike-rush and river red gum communities with spike-rush understorey. Terrestrial floodplain vegetation communities did not occur in these locations. Zones with a moderate frequency of flooding (every five to eight years in twenty) supported river red gum communities with lignum or terrestrial understorey of varying condition. Inundation zones with a very low frequency of flooding (flooding once or twice in twenty years) or no flooding were dominated by black box and lignum communities and terrestrial vegetation. Vegetation communities that had altered structure and composition more indicative of terrestrial landscapes (e.g. chenopod shrubland dominance) were distributed widely across the inundation gradient (Bowen and Simpson 2010b, Thomas *et al.* 2010b).
- In collaboration with Dr Skye Wassens of Charles Sturt University, waterbird, fish and frog surveys were undertaken to investigate the interaction and responses of species to environmental flows from 2008–10. This included an investigation into the relationships between the introduced European carp and native frog populations. This project has provided insights into species interactions, increased our knowledge of water requirements for wetland species, and provided real-time input into environmental flow management to sustain waterbird and frog breeding (Spencer and Wassens 2009, 2010). Faunal responses to flooding varied with wetland type, timing of flooding, volume of water entering the wetland, habitat complexity and flooding history. Waterbird abundance and diversity was very low during the 2008–09 season but their numbers increased in response to greater inundation during 2009–10 and small numbers of egrets and cormorants bred successfully. Overall, nine native fish species were detected and juvenile stages of all species were present, indicating floodplain habitats were important for native fish recruitment. Six frog species were detected in the Lowbidgee Wetlands and southern bell frogs were present at five out of fifteen wetland sites surveyed.

Environmental flows have been crucial for sustaining endangered populations of southern bell frogs in the Lowbidgee wetlands. Studies also show that alien fish populations need to be actively managed to ensure successful breeding.

Photo: L. Knowles (DECCW).



Research to better understand complex wetland ecosystems (continued)

- Investigations into the demographics and reproductive biology of the southern bell frog found that habitats for the endangered frog need water every one to two years to enable each generation to breed and maintain the wild populations. The extent of environmental flows also needs to be of sufficient duration to enable critical biological events such as anuran metamorphosis to occur during the spring and summer months (Hyne and Mann 2010).
- Historical vegetation condition mapping (McCosker 2008) was used to quantify the flood requirements of river red gum communities (Wen *et al.* 2009a, 2009b). The study found there was considerable variation in flood requirements between different community types, indicating soil moisture may be an appropriate variable to measuring in predicting river red gum health.
- Long-term aerial survey data (Kingsford and Porter 2009) was used to quantify the relative importance of climatic and hydrological factors on the waterbird population dynamics (Wen *et al.* 2011a). The study found a declining trend in waterbird abundance, and rainfall was slightly more important in most cases. In addition, temperature also affected waterbird abundance. The results support the practice of providing environmental water to sustain waterbird populations, particularly when coinciding with antecedent rainfall.
- Time-series analysis techniques were used to re-construct the natural river flows at various locations along the Murrumbidgee River for the past 100 years. The comparison between modelled natural and actual flow hydrographs clearly demonstrated the impacts of water resource development, and a turning point at around 1960, from when significant reductions (up to 75%) in annual flows occurred, was identified (Wen 2009).
- A new method, Standardised Flow Index (SFI) – adopted from the widely used meteorological drought index, SPI (standardised precipitation index) – was used to compute and investigate 'hydrological drought' in the Murrumbidgee River downstream of Wagga Wagga (Wen *et al.* accepted). The results revealed that upstream river regulation reduced water scarcity during drought at Wagga Wagga (downstream of the two major dams but immediately upstream of the major irrigation areas). However, the hydrological benefits of river regulation diminish as the river travels further downstream as greater extraction of water occurs. At Balranald, the end valley weir, hydrological drought progressively increased during the modelling period, and the impacts were greater during drier periods. The results of the study highlighted the importance of balancing the needs between upstream and downstream water users in river management.

- A detailed description of the ecological character of Yanga National Park has been completed. The study documents the key ecological components, the processes which sustain those values and the natural variability driven primarily by a variable hydrological regime. This information will inform the water requirement of wetlands and how wetlands may respond to varying watering regimes. The report also identifies threats to wetland health and recommends indicators for monitoring change in ecological character (Wen *et al.* 2009c).
- A detailed soil survey was conducted across Yanga National Park, including the properties of the soil relevant to the rate of water infiltration (EASystems 2008). The survey demonstrated important differences in the infiltration capacity of the soil in different water management areas, related to differences in soil textural properties. This provided a spatially explicit loss function that was included in the Yanga hydrodynamic model.
- The trophic dynamics and ecosystem function project has demonstrated that a diverse group of aquatic organisms use the Yanga Floodplain during environmental flow events, and that a complex ecosystem emerges with the arrival of environmental water: the successive emergence of bacteria, algae and invertebrates in floodplain waters which provide the basis for the productivity and biodiversity of plant communities and for higher-order wetland animals such as fish and waterbirds. Native grazing mammals (most notably kangaroos) during the dry phase help convert plant material into forms usable by aquatic organisms when the wetland floods (Iles *et al.* 2010a; see also Kobayashi *et al.* in press). However, connectivity to the river channel is primarily one-way, with few opportunities for mobile organisms, such as fish, to recruit back into the channel once the floodplain has been utilised (Iles *et al.* 2010b). Investigations of the types of food sources available determined that land use on the Lowbidgee Floodplain has reduced the quantity and nutritional value of resources available to aquatic species (Watkins *et al.* 2009).
- A longer term ('palaeo') study of ecological conditions can provide a useful context for interpreting contemporary trends in the wetland ecosystem to inform thresholds of acceptable change in relation to flooding regime (Ralph *et al.* 2011). In the Lowbidgee Wetlands, the results suggest that, in broad terms, despite over 150 years of agriculture in the region, the contemporary ecosystem is little changed from that which existed prior to the arrival of Europeans. Pre-European conditions are broadly similar to those prevalent today, particularly for floodplain vegetation. However, there is evidence that river red gum is more abundant today than it was prior to European settlement (Reid 2009, Reid and Capon 2009). Some areas of river red gum on less frequently inundated areas of the Yanga Floodplain are an artefact of extensive flooding in the 1970s and were for several decades artificially maintained as a forestry resource (Bowen and Simpson 2010c, Bowen and Childs in preparation).

Research to better understand complex wetland ecosystems (continued)

- Results of monitoring to determine the effect of the 2007–08 environmental water allocation on vegetation extent and the seed bank showed a clear and rapid response, with the emergence of rushes and the sprouting of ephemeral wetland vegetation. However, no differences in the composition of the seed bank could be detected before and after the flow. This indicates that the replenishment of the seed bank for most species requires a longer duration of flooding than that observed during 2007–08 (Reid and Capon 2009).

Hydrodynamic and hydrological modelling tools

A hydrodynamic model (MIKEFLOOD-based) representing water flow through Yanga National Park has been completed covering an area of 70,000 hectares. The model reproduces flow volumes and inundation extent to within an accuracy of 20% (SKM 2010b). The model allows environmental water and asset managers to determine the optimum volume and timing of water releases in support of key species.

The hydrodynamic model has been used to guide the construction of infrastructure on Yanga National Park, including the setting of levee bank heights within Tarwillie Swamp, a major egret rookery, to ensure sufficient water is retained within the swamp in support of egret breeding and river red gum health, while allowing surplus water to flow on to alternative environmental targets within the park.

The hydrodynamic model has also been used in the development of a Murrumbidgee hydrology model (IQQM-based), providing the inputs required to extend the existing hydrology model into the wetlands. Specifically, the hydrology model, developed in partnership with the NSW Office of Water, allows for exploration of long-term hydrological variations resulting from climate change, amendments to water sharing plans and dam operation rules, at an individual wetland scale at daily time-steps extending over periods of 100 years or more (Wen *et al.* 2011b).

Decision Support System

Development of a Decision Support System for the Lower Murrumbidgee wetlands has been completed, integrating the research undertaken through RERP as well as other complementary research into a single tool that can support a transparent and scientifically rigorous decision-making process. In particular, the DSS integrates the Lowbidgee ecosystem response model with the hydrological model, allowing for the comparison of scenarios relating the volume and timing of water delivery to ecological outcomes.

The development of a Decision Support System (EcoModeller-based) for the Lowbidgee Wetland was undertaken via collaboration between eWater and SKM (SKM/eWater 2011). The DSS uses an IQQM hydrological model to report on inundation extent and depth, timing and duration, and rate of rise and fall for 60 individual wetland components across Yanga National Park, the Lowbidgee Floodplain and the northern bank of the Murrumbidgee River. Ecological response models have been developed for key biota within the floodplain including target species identified in the Yanga National Park Environmental Watering Plan (egrets, river red gum, spike-rush and the southern bell frog). The DSS allows the comparison of watering strategies at a scale ranging from an individual flow to a 100-year series, and so can be used to assist with annual water planning or testing the implications of climate change over decadal time periods.

The Lowbidgee DSS, in conjunction with the CMA's RiverReach DSS, provide a comprehensive means of assessing water requirements for the entire Murrumbidgee system. This tool aims to assist water managers evaluate the long-term effect of rules governing sharing of water between environmental and consumptive users as well as exploring options for the delivery of available environmental water on an event basis.



Spike-rush in Yanga National Park, October 2009. Spike-rush is one of 11 species targeted by ecological response models in the Lowbidgee Decision Support System.
Photo: S. Simpson (DECCW).

4.5 Lachlan Wetlands

Purchase of Water Access Licences

At the end of January 2011, RERP had purchased 24,103 megalitres of general security and 1,000 megalitres of high security water access entitlements. Combined with purchases under the Australian Government's environmental water holdings (733 megalitres of high security and 81,671 megalitres of general security at the end of January 2011), the environment's share of the available water resource has increased considerably compared with the 20,000-megalitre Environmental Contingency Allowance and translucent flow rules (which provide mid-Lachlan flow targets for certain flow events) under the Water Sharing Plan for the Lachlan Regulated River Water Source 2004.

This significantly improves the ability of government to supply environmental water to core wetland assets and extend the scope of water allocated under the water sharing plan (noting the flow rule provisions of the Lachlan Water Sharing Plan have been suspended since July 2004 while the river is managed under critical water shortage conditions).

Purchase of *Geramy* for inclusion in the national reserve system

In July 2009, RERP funded the purchase of a 1463-hectare section of the property *Geramy*, securing 500 hectares of Lachlan Swamp. Of greater significance, the purchase secures the flow pathway for the delivery of environmental water to the adjacent Kalyarr State Conservation Area, which contains the 1214-hectare Lake Ita.

Lake Ita supports significant cultural and natural values, including river red gum and black box communities and crucial wetland habitats that are currently under-represented in the national reserve system. Research funded through RERP has demonstrated the viability of the seed bank within the bed of Lake Ita while a Lachlan Catchment Management Authority-funded project is examining infrastructure options that will assist in delivering small to moderate flows to the lake. The Lachlan Swamp component of *Geramy* is listed in *A Directory of Important Wetlands in Australia* (Environment Australia 2001).

At the time of publication, environmental flows were entering Lake Ita via *Geramy*, with an estimated 80% of the lake bed inundated (P. Packard 2011, pers. comm., 21 February). This is the first occasion since 1998 that Lake Ita has been inundated.

Muggabah and Merrimajeel regulators

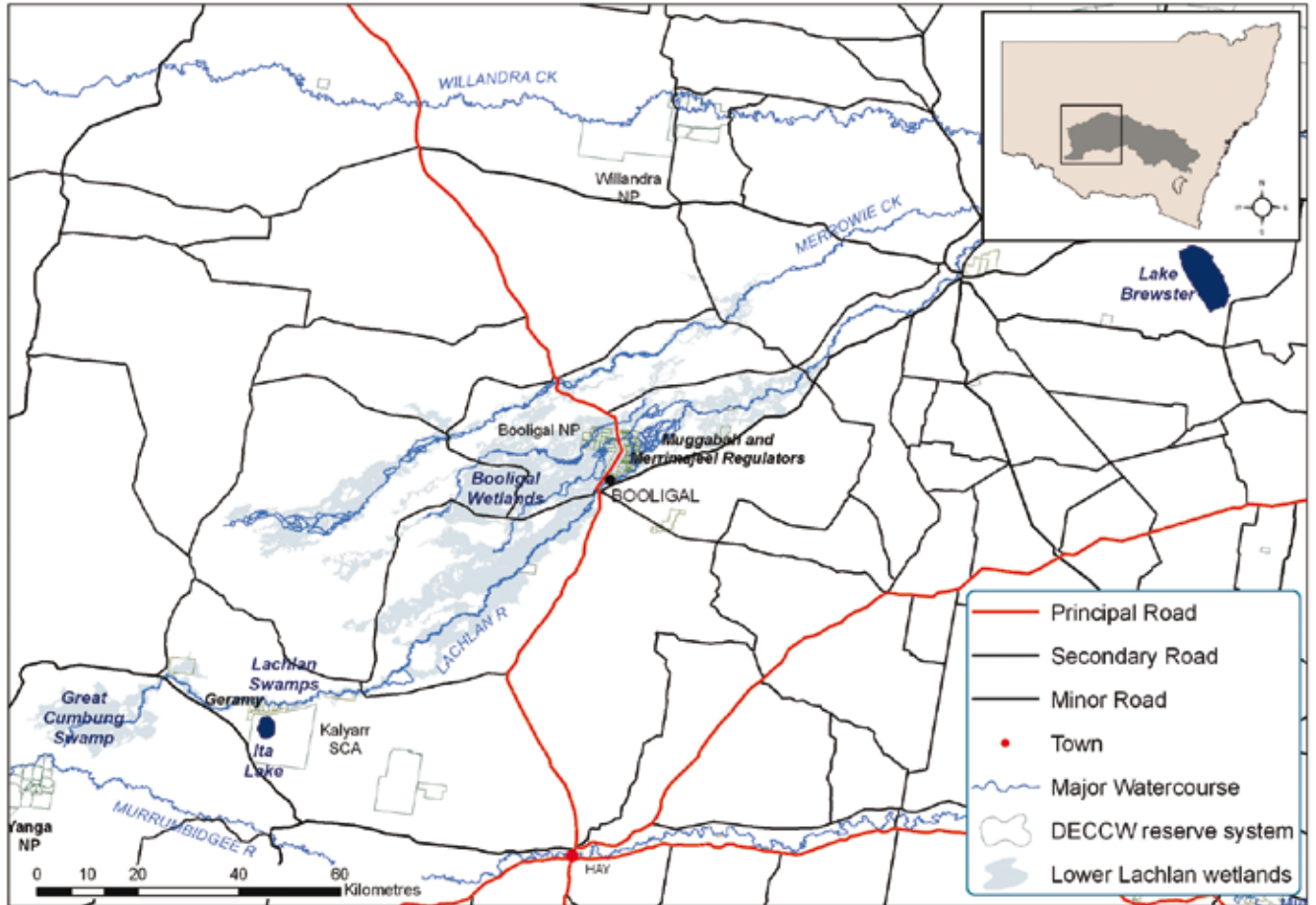
The completion of the RERP-funded \$1-million Muggabah and Merrimajeel regulators will re-establish more natural, intermittent flows in these creek systems (including Booligal Wetlands) and improve the efficiency of delivery of both environmental flows and domestic and stock replenishment flows. The regulators will:



The completed Muggabah Regulator, August 2010.

Top: L. Dixon (Gleeson Excavations).
Bottom: B. Lewis (State Water).

Figure 8 – Map of the Lachlan Wetlands



- ensure water intended for Booligal Wetlands or Murrumbidgee Swamp on Merrimajeel Creek is not diverted to the Muggabah Creek system, and
- prevent unseasonal flows entering these creek systems and assist in controlling vegetation chokes which impede the penetration of flows to the middle and lower reaches of the creeks.

Fostering Aboriginal connection to wetlands

A RERP-funded archaeological survey was conducted on a number of properties south of Booligal along the Lachlan River (Martin 2010, Waters Consultancy 2009). The survey, involving members of the Hay Aboriginal community, identified and recorded over 400 previously unrecorded archaeological sites in the survey area. Sites included burial grounds, cooking mounds, mussel shell middens, modified (scarred) trees, stone tool artefacts and areas where native bush foods and medicines were gathered. Some mound sites are extensive, stretching some 100 metres in length and over 1 metre in height. Wetland resources were collected and cooked in these mounds and then consumed by groups over many years.

Participants in the survey also included landholders who, together with the local Aboriginal community and the archaeologist, shared an interest in the regeneration and maintenance of these important wetland areas for future generations.

Case study – RERP investment in the Booligal Wetlands

Booligal Station, located near the township of Booligal, 80 kilometres north of Hay in south-western New South Wales, was purchased through RERP in April 2009 for inclusion in the national reserve system. The \$1.3-million purchase helped to secure a 2574-hectare portion of Booligal Wetlands. *Booligal Station* is now gazetted as a State Conservation Area.

The Booligal Wetlands are listed on the Register of the National Estate and in *A Directory of Important Wetlands in Australia* (Environment Australia 2001). The wetlands include one of the country's five major breeding sites for the straw-necked ibis (up to 80,000 pairs) during flood events and the largest breeding population of glossy ibis documented in Australia (4000 pairs). A number of threatened species have been recorded as well as a number of migratory species listed under various international agreements.

The riverine and wetland ecosystems on *Booligal Station* are significantly under-represented in the national reserve system and continue to be threatened by agricultural development.

The wetlands are also of high cultural significance and their acquisition will provide the opportunity for Aboriginal communities to reconnect to this area. The purchase is also complimented by the recent completion of the \$1-million RERP-funded Muggabah and Merrimajeel regulators which allow for more appropriate wetting and drying cycles to support the wetland values on Merrimajeel and Muggabah creeks and within the Booligal Wetlands.

Following good rainfall through winter and spring 2010, and subsequent flows into the Booligal Wetlands, a significant breeding event of straw-necked ibis, white ibis and glossy ibis has commenced on the *Booligal Station* portion of the Booligal Wetlands. This has subsequently expanded onto adjoining private properties. As flows into the wetland recede, environmental water (including RERP-purchased water) will be delivered to the wetland via the Merrimajeel Regulator to maintain inundation levels and so help ensure the success of this important breeding event.

Main photo: A creche of straw-necked ibis chicks on *Booligal Station*; most adult birds are away feeding during the day, December 2010. Inset: straw-necked ibis chick and eggs, December 2010.

Photos: P. McInnes (DECCW).



Improved grazing on privately owned Willandra Creek

A management agreement was negotiated with the owner of the property *Lignum Park* which resulted in the fencing of 856 hectares of creek line and floodplain wetlands on the property. The project involved the construction of 25 kilometres of fencing to enable the controlled grazing of high conservation value wetlands. A ten-year management agreement was negotiated between the landholder and DECCW outlining respective obligations in support of the area's wetland values.

Community engagement activities

RERP has held several community events in the Lachlan Catchment. This included a field day in Hillston in October 2009 to discuss 'biodiversity in the bush'. Landholders, community members and agency staff participated in discussions about improved wetland management. Discussion included bird and water bug identification, the connection of Aboriginal people to local wetlands as well as examples of traditional use of local plant species including basket weaving. The event helped build local knowledge and helped established a network of community members who support wetland values.

Lake Brewster Weir fish passage restoration

Lake Brewster Weir has been identified as the number-one ranked barrier to fish passage in the Lachlan Catchment, acting as a barrier to fish passage under all flow conditions (NSW Department of Primary Industries 2006). Local species, including several threatened species such as silver perch and Murray cod (that require migration to complete their life cycle) are negatively impacted.

RERP funded the development of designs for the construction of a new fishway at Lake Brewster Weir (Fishway Consulting Services and Industry & Investment NSW 2011), complimenting the recent installation of fishways at Buggan, Island Creek and Lake Cargelligo Weir (currently under construction by State Water). On completion, a Lake Brewster Weir fishway would open up approximately 235 kilometres of river to fish passage.

Research to better understand complex wetland ecosystems

A number of research projects have been completed to improve the use of environmental water and underpin the development of models and decision support tools to improve the management of environmental flows for Lachlan wetlands:

- Inundation was detected from Landsat satellite imagery for 21 flood events between 1988 and 2006 in the Great Cumbung Swamp (Thomas *et al.* 2010b) which included the application of an image calibration method developed by Sims (2008). Inundation maps provided fundamental data for determining the inundation frequency gradient of the floodplain and for developing flow-inundation relationships for input into ecosystem response models. The method for detecting inundation is suitable for mapping flooding from environmental flows.

The Lachlan Catchment Management Authority, Lachlan Riverine Working Group and NSW Office of Water are using this information to develop a range of hydrological and ecological modelling tools that aim to improve water management in the Lachlan Valley and important wetland environments including Booligal Wetlands.

- The relationship of flood frequency to vegetation community distribution (based on the best available mapping) was determined for the Great Cumbung Swamp (Thomas *et al.* 2010b). Inundation zones supported vegetation communities according to their water requirements. Zones with a high frequency of flooding (every one to three years) supported semi-permanent vegetation communities such as common reed and river red gum communities. Zones with a moderate frequency of flooding (every five to six years in twenty) supported river red gum communities, floodplain wetland vegetation (e.g. lignum) and floodplain vegetation (e.g. grasslands). Inundation zones with a very low frequency of flooding (flooding once or twice in twenty years) or no flooding were dominated by floodplain vegetation and floodplain wetland vegetation. River red gum communities also occurred in inundation zones of low frequency of flooding to no flooding in the past twenty years, leaving them vulnerable to death due to their water requirements not being met.
- Digital maps of vegetation extent and health of the Great Cumbung Swamp were completed (Bowen and Simpson in preparation c), forming an important component of the Lachlan Water Management Plan. The project also provides information on how vegetation communities change in condition, species composition and structure in response to specific environmental flow events and identifies priority habitat for protection through the delivery of environmental water.
- Investigations into trophic dynamics and ecosystem function highlight the critical importance of even small environmental flows during drought for the maintenance of aquatic ecosystem function and diversity (Kelleway *et al.* 2010, Kobayashi *et al.* 2007, 2010).
- Preliminary seed bank studies have indicated the viability of the seed bank in the bed of Lake Ita, suggesting its potential to regenerate following flooding (despite a lack of inundation since 1999). These findings, together with those from another study supported by the Lachlan Catchment Management Authority examining infrastructure options for the delivery of environmental water to the lake, indicate the rehabilitation potential of this wetland.
- A detailed description of the ecological character of the lower reaches of the Lachlan Floodplain (downstream of Corrong) has been completed. The study provides a documented understanding of the key ecological components, the processes which sustain those values, and the natural variability primarily driven by a variable hydrological regime (Capon *et al.* 2008).

4.6 Narran Lakes

Purchase of Water Access Licences

Purchasing water entitlement for the Narran Lakes has not been pursued by RERP due to delays in the completion of the water resource plans in Queensland catchments areas where nearly all the entitlements are held. The Australian Government has initiated a large-scale water purchase program in the Condamine–Balonne Catchment.

Monitoring of environmental flows

Three surface-water gauges have been installed at Wilby Wilby, Back Lake and Bundah to provide real-time information to assist in the management of river flows and bird breeding events. Rainfall, water quality and air and water temperature upstream within the Narran Lake Nature Reserve Ramsar site are recorded.

Narran River fish passage remediation

Fish sampling conducted by the University of New England in 2008 suggested that if native fish communities and the ecology of the sensitive Narran Floodplain are to be managed effectively, it is essential that the issue of fish passage and hydrological connectivity be addressed (Rolls and Wilson 2008).

RERP has funded a study to investigate the structures along the Narran River to assess low flow and fish passage performance. Non-binding agreements have been made with landholders as an indication of their support in case funds for on-ground works are available in the future. Landholder support is contingent in most cases on the provision of an alternative stock and domestic water supply.

Decision Support System

The Narran Ecosystem Project (Thoms *et al.* 2007) provided a prototype for RERP investment in science, i.e. using LiDAR to build hydrodynamic and hydrological models of the Narran Lakes, conducting studies into ecological responses to flows, and examining the palaeo-ecological history of the lakes.

RERP built on the Narran Ecosystem Project firstly by providing project management support to a series of Murray–Darling Basin Commission (MDBC) and Department of the Environment, Water, Heritage and the Arts (DEWHA) consultancy studies on the ecological outcomes of 2008 Narran flood and environmental flows. These studies documented the effects of flooding on fish, and vegetation responses, and the hydrological conditions associated with a substantial ibis breeding event (Jenkins *et al.* 2009, Kingsford *et al.* 2008, Rolls and Wilson 2008).

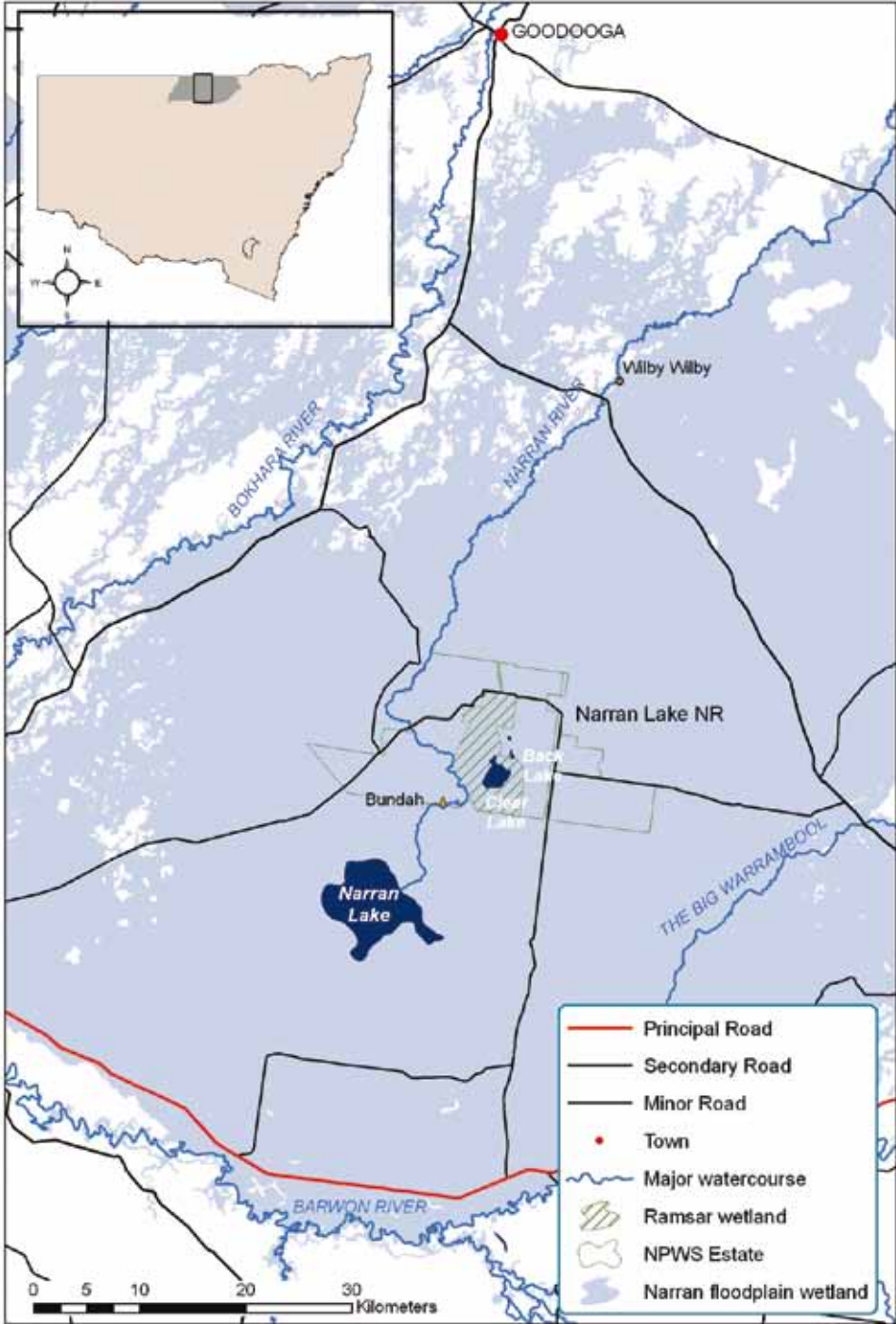


Back Lake Gauging Station, February 2010, recording rainfall, water quality and air and water temperature within Narran Lake Nature Reserve.

Data from the gauging station will be used to help monitor variables that are of significance in determining the success of water bird breeding events that occur on Back Lake.

Photo: P. Terrill (DECCW).

Figure 9 – Map of the Narran Lakes



Secondly, RERP developed a Decision Support System for the Narran Lakes which made the following contributions:

- Currently the DSS can interact with any hydrological model, providing it gives the correct spatial and data outputs. The model linkage provided is with IQQM.
- New and improved ecosystem response models were developed for Narran, in particular characterising ephemeral vegetation responses to flooding.
- The hydrological and ecosystem response models were integrated into the DSS.

The Narran Lakes DSS was developed by iCAM (2011b), and is one of the three IBIS DSS developed for the Ramsar-listed wetlands of the northern Murray–Darling Basin under RERP. The Narran DSS will allow Australian Government and state jurisdictions to test the ecological implications of water sharing plans developed by Queensland for the Condamine–Balonne system.

5 Key learnings

Key learnings resulting from RERP:

- The complex economic, physical, ecological and social interactions associated with water and river management necessitate a multi-disciplinary investment.
- Appropriately targeted and managed funding, directed at increasing the environment's share of available water resources, in combination with management science, water delivery and ecosystem restoration infrastructure, landholder engagement, engagement of Aboriginal communities and high conservation value wetland land purchase can produce significant progress towards wetland system recovery in a relatively short period of time.
- Concurrent, coordinated and strategic investment in increasing the environment's share of available water resources, in combination with management science, water delivery and ecosystem restoration infrastructure, landholder engagement, engagement of Aboriginal communities and high conservation value wetland land purchase creates synergies that provide returns considerably greater than the sum of their parts.
- The purchase of Water Access Licences from willing sellers is now recognised as a legitimate and effective mechanism to redress over-allocation in our river systems.
- Wetlands are complex systems and our scientific knowledge cannot yet encompass the breadth and scale of the physical and ecological interactions within them. Strategic, prioritised investment in research is required to develop our understanding and further improve tools for adaptive management. To ensure improved wetland health, research should produce outcomes that assist wetland/asset managers. Collaborative partnerships between researchers and wetland/asset managers are critical to improving wetland health.
- Infrastructure projects require considerable investment in design and approval processes before construction can commence. Investment must be made in the development of priority projects (design and approval) to ensure projects are sufficiently developed to allow for their completion during relatively short funding cycles.
- Landholders who manage high conservation value wetlands are integral to the success of government investment in environmental water and are receptive to respectful, collaborative approaches from government.
- Aboriginal communities maintain a deep connection to wetlands based on both traditional and contemporary interactions. Aboriginal communities maintain an eagerness to reconnect and engage in water and wetland management and to develop a better knowledge of cultural practices that have been lost or dispersed in the past 200 years.
- The purchase of high conservation value or strategic wetland properties for addition to the national reserve system is an important element in protecting core wetland areas.

- Given the scale and complexity of the challenge, cooperation between governments and within agencies is critical.
- Government and departmental structures and cultures are continuing to evolve to support the improvement of wetland health.
- Technologies to support wetland and river managers are rapidly developing, increasing the sophistication of adaptive management and our ability to effectively communicate the outcomes.



Regenerating black box trees in the Paika Reserve Wetland, located on *Dundomallee*, November 2010.
Photo: J. Maguire (DECCW).

6 Recommendations

While significant progress has been made towards arresting the decline of wetlands targeted by RERP, ongoing effort and investment is required. The following recommendations are provided to guide future investment in wetland management.

Recommendation 1 – Future investment priorities should be determined in consultation with wetland and environmental water managers to ensure investments are relevant and timely and that outcomes will be sustained in the medium term.

Recommendation 2 – Wetland and environmental water managers should be given support to develop investment strategies reflecting the differing needs of their area of responsibility.

Recommendation 3 – Future investment should recognise the complex economic, environmental and social interactions associated with water and river management. Investment should be made across the breadth of these areas in a strategic and coordinated manner to realise synergies.

Recommendation 4 – Managers of high conservation value wetlands on private land should be actively targeted to establish and maintain cooperative relationships that support wetland values. Engagement activities should be respectful of local knowledge and be flexible enough to cater for regional and personal differences.

Recommendation 5 – Further investment should be made to support the reconnection of Aboriginal communities to wetlands to realise cultural, socio-economic and environmental benefits. Aboriginal people should be actively engaged in these processes and this knowledge incorporated into environmental water management.

Recommendation 6 – Targeted purchase of high conservation value wetland properties remains a priority in some catchments. Processes should be implemented to:

- a. identify priority wetland properties
- b. increase the responsiveness of land acquisition processes, and
- c. amend acquisition processes so that properties of strategic significance (as opposed to simply containing high conservation wetland values) are recognised and valued.

Recommendation 7 – Monitoring methodologies should be standardised and resourced appropriately to inform adaptive management and justify government investment in wetland health.

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