DECEMBER 2009 | FINAL ASSESSMENT REPORT

RIVERINA BIOREGION REGIONAL FOREST ASSESSMENT
RIVER RED GUMS AND WOODLAND FORESTS

natural resources commission

Enquiries

Further information regarding this report can be found at **www.nrc.nsw.gov.au**

Enquiries can be directed to:

Bryce Wilde	Ph: **02 8227 4318** Email: bryce.wilde@nrc.nsw.gov.au
Daniel Hoenig (media enquiries)	Ph: **02 8227 4303** Email: daniel.hoenig@nrc.nsw.gov.au
By mail:	Forests Assessment Natural Resources Commission GPO Box 4206 Sydney NSW 2001
By fax:	**02 8227 4399**

This work is copyright. The *Copyright Act 1968* permits fair dealing for study, research, news reporting, criticism and review.
Selected passages, table or diagrams may be reproduced for such purposes provided acknowledgement of the source is included.

Printed on ENVI Coated paper, which is made from elemental chlorine-free pulp derived from sustainably-managed forests and non-controversial sources. It is Australian made and certified carbon neutral from an ISO 14001 accredited mill which utilises renewable energy sources.

All photographs are by the Natural Resources Commission unless otherwise acknowledged.

Document No. D09/4554
ISBN: 978 1 921050 54 1

Print management by e2e (www.e2em.com.au)
GIS services by Ecological Australia

Commissioner's foreword

The Riverina bioregion is a treasured part of Australia, with its winding rivers and floodplain forests, its rich agricultural land, and its cultural significance to Indigenous and non-Indigenous Australians. The region's floodplains, and the river red gum forests they have supported for thousands of years, are an integral part of the natural landscape and the social fabric of the region.

The large Central Murray river red gum forests were created by the Cadell fault that raises the land abruptly at Echuca, creating a natural dam and diverting the Murray River to the north and south. This 'choke' restricts the channel flow and frequently floods the otherwise flat landscape, creating the most extensive red gum stand in the world. These forests are thought to have supported the most densely populated Indigenous population in pre-European Australia. They continue to support a rich ecology, and significant economic and social values.

But the river red gum forests are in decline across the region. As we've built dams and weirs over the last 120 years and diverted river flows to irrigation, the natural flows and floods of the river have been progressively restricted. Without flooding, the red gum forests can't regenerate and support the ecology and forestry industries which depend on them. The impacts on communities, land use and the natural environment are predicted to get more severe under climate change.

To map a way forward, the NSW Government asked the Natural Resources Commission (NRC) to undertake this scientifically based assessment of the red gum and other woodland forests in the Riverina bioregion. This final assessment report provides the scientific platform to help everyone understand the forests, how they are changing, and what can be done to better manage them through the coming changes. Actively managing the forests through the changes is undoubtedly the best way to preserve what we all value about the forests.

The NRC has made its recommendations on future management of the forests in a separate, shorter recommendations report for ease of access. Reconciling the differing needs for the area has been a complicated yet inspiring task and we have sought to ensure that the requirements of the people who live and work in the area are thoroughly considered along with the views of those scientific experts and the broader community with whom we have engaged.

The assessment provides the scientific basis for Government to resolve the vexed issue of how the river red gum forests in the Riverina should be managed. Certainty on this crucial issue is fundamental so we can all work together to help the forests and the local communities that depend on them adapt to ongoing water scarcity and the potential impacts of climate change.

The timing of this assessment is also important. There is a unique opportunity for governments to use the pending Murray-Darling Basin Plan to rebalance the use of water resources across the Basin and create sustainable futures for the river red gum forests and the communities that love them. To survive, the forests need to be flooded and actively managed to help them transition to a drier future. Industries and local communities need the same degree of support to make a similarly challenging transition. This report provides the scientific and information base to guide a process of change, and the NRC's recommendations report proposes how this should begin.

I would like to thank all those who contributed so enthusiastically to the assessment, including the NRC's staff, technical panel members, stakeholder groups, consultants, government agencies, and members of the public who made submissions and attended public hearings.

Sincerely,

John Williams

Commissioner

Contents

Contents

Contents

Chapter 1

Introduction and approach

1.1 Overview

The NSW Government asked the Natural Resources Commission (NRC) to assess the river red gum and woodland forests in the Riverina bioregion in NSW so that Government can then make a forest agreement "to determine conservation outcomes and a sustainable future for the forests, the forestry industry and local communities". The terms of reference are included in **Appendix 1**.

The NRC completed a preliminary assessment report on 30 September 2009 and called for submissions to the NRC on how Government can best promote conservation outcomes and a sustainable future for these forests, the forest industries and local communities in the region.

The NRC also consulted key stakeholders and experts and held public forums in October 2009 to seek input and gain a richer picture of the breadth and depth of values people place on the forests. This report takes the input from public submissions and consultation into consideration.

The purposes of this final assessment report are to:

- draw together the best available science and knowledge on the river red gum and woodland forests of the Riverina bioregion
- outline what we know about the values of the forests and their current management
- draw out the key issues to underpin recommendations to the Government on their future management.

This report does not make specific recommendations to Government on the future of the forests. These are covered in an accompanying recommendations report. Also available is an accompanying A3 Map Book.

1.2 Terms of reference

The NRC was required to report by 21 December 2009[1] on the river red gum and woodland forests in the Riverina bioregion in NSW, and separately on the south-western cypress forests by 30 April 2010. The terms of reference (**Appendix 1**) require the NRC to:

1. assess the environment and heritage values (including Indigenous heritage), economic and social values, ecologically sustainable forest management, timber resources, and otherwise meet the assessment requirements of the Environment Protection and *Biodiversity Conservation Act 1999* (Cth) as determined in discussion with DEWHA
2. recommend conservation, protection, economic and ecological sustainable use of public land in the bioregion
3. recommend water management and flooding requirements to sustain the forests and identified values and uses under the range of projected impacts of climate change.

This assessment report deals substantially with term of reference 1. The NRC will also undertake an assessment on the cypress forests in south-western NSW. It is anticipated that this report will be available in mid-2010.

An accompanying recommendations report addresses terms of reference 2 and 3. Together these documents report on the full terms of reference, and present recommendations to Government on the future management and uses of the river red gum and woodland forests in the Riverina bioregion.

[1]The NSW Premier granted an extension to 21 December 2009 from the original date in the Terms of Reference which required the NRC to report by 30 November 2009.

1.3 What does this report indicate about the forests?

This assessment report presents the best available science and knowledge on the current health, uses and values of the forests, together with the predicted implications of climate variability and climate change, and the consequent impacts on changes in water availability and flooding regimes. The report also proposes goals and principles to guide river red gum floodplain ecosystem management in a water-scarce future.

The Riverina bioregion is characterised by rivers with extreme hydrological variability and extensive regulation. The construction of dams and weirs over the last 120 years and diversion of river flows for irrigation have resulted in highly modified ecosystems. In addition, there has been a dramatic decline in average inflows to the Murray system in the last 15 years compared to the long-term average.

River regulation, over-allocation of water resources and persistent drought are responsible for the observed decline in the red river gum forests and the industries and social systems they support.

The health of red river gum forest ecosystems is driven by river flows and flooding regimes. As such, many of the river red gum forests are under high stress, and in some cases are transitioning to alternative states. Their future health, and the industries and communities they support, will depend on whether the forests stands can be artificially flooded and how they are managed. However, even with ambitious water reforms there will not be enough water to restore all the red river gum forests to health.

Climate change is a significant threat to biodiversity, ecosystem function and ecosystem resilience in the bioregion. Climate change is likely to cause landscape-scale changes, markedly different hydrological regimes and the further transformation of ecosystems. The choice ahead is therefore whether to let this decline take its course, or act to manage the forests to create new, more sustainable ecological, economic and social futures.

Future management of these floodplain ecosystems needs to be attuned to meeting the diverse values of conservation, commercial production, cultural and social use in an increasingly dynamic water-scarce future. Accordingly, current tenure, models and management strategies need to be able to actively and adaptively manage the emerging challenges. There is a range of institutions, tenures and management models available to manage the red gum forests.

Future management of river red gum forests under all forms of tenure must also address the ecosystem as a whole. In many cases, we will need to rethink our current approach to forest management. Depending on the management objectives, targeted and active management interventions across all tenures can achieve outcomes with a greater degree of control and certainty than naturally occurring processes or passive approaches. Ecological thinning may provide a useful tool to enhance conservation and/or production outcomes.

The river red gum forests play a role in the regional economy and support a number of forest industries that are dependent on them for timber. Reduced quality of timber supply is already impacting upon local forest industries. Timber growth rates have declined significantly as a result of reduced flood inundation and draughts. As a consequence, sustainable long-term timber yields are expected to be reduced by 70 per cent. Timber quality is dropping as tree health declines with drought stress. While the forestry industry on public land in the Riverina makes a relatively small contribution to the economy at a state or regional level, it is a significant employer and basis of social capital for a number of towns in the region.

The forests have important cultural significance particularly to their Traditional Owners. Indigenous communities value the forests for the ability to visit special places, and continue practices such as hunting, fishing, collecting foods and telling stories. Like environmental flows, cultural water flows are also highly valued by Indigenous communities. Improving the protection of special and sacred sites and improving compliance with provisions for protecting these sites is important to Indigenous communities.

Non-Indigenous people also have a strong cultural connection to the forests. This is particularly so for community members who work, and enjoy a variety of recreational activities, in the forests.

Several towns within the region have close ties to the timber industry through the employment and local expenditure it provides, and some are more sensitive to changes in the timber industry than others. All towns in the region are already being impacted by the effects of drought and water reforms. The capacity of the region's communities to reinvent themselves will however depend on maintaining economic and social diversity, and investing in human and physical capital. A sustainable future for the region will depend on regional development focused on less-water-dependent industries.

1.4 What is a regional forest assessment?

NSW forest agreements are formal agreements between the NSW Ministers for Environment and Primary Industries setting out how forests in particular regions will be managed by the Department of Environment, Climate Change and Water (DECCW) as part of the NSW reserve system or by Forests NSW as State Forests.

The NSW Ministers may only negotiate a forest agreement following a 'regional forest assessment' by the NRC, which must include an assessment of:

1. environment and heritage values (including Indigenous heritage)
2. economic and social values
3. ecologically sustainable forest management
4. timber resources.

NSW forest agreements must contain certain minimum provisions and are intended to frame an Integrated Forestry Operations Approval (IFOA) under which Forests NSW then carries out harvesting operations. An IFOA describes the forestry operations permitted in the area covered, and the conditions imposed[2] (*Forestry and National Parks Estate Act 1998* (NSW)). The agreements must also meet the assessment requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

[2] The approval may contain the terms of a licence under the *Protection of the Environment Operations Act 1997*, *Threatened Species Conservation Act 1995* and *Fisheries Management Act 1994*. Enforcement of the licences rests with DECCW or Department of Industry and Investment – Fisheries.

A stand of healthy River red gum forest – photo courtesy of DII

1.5 Analytical framework for this assessment

The NRC developed an analytical framework for undertaking this assessment and making its recommendations to Government. The NRC's broad approach was to:

- characterise the biophysical, historical and institutional context for the forests, and the current condition of these floodplain ecosystems
- characterise the cultural, heritage, environmental, social and economic values the forests currently support
- project how the forests and associated ecosystems and socio-economic systems, and hence values, may change under future climate-change projections, water management regimes, and possible forest management regimes
- draw out the implications for the NRC's recommendations on uses and management arrangements.

Figure 1.1 depicts the broad approach across six steps and a number of sub-steps.

Step 1 – Map forest locations and explain landscape context – Chapters 2 and 3

The river red gum and cypress forests coexist in some parts of the region and are distinct landscape types in others. The NRC defined which forests to assess first within the Riverina bioregion, and which to assess later as the South-Western Cypress State Forests.

Step 2 – Document historic management and current extent, condition and values – Chapters 2, 3, 4, 5 and 6

The river red gum forests have been managed and modified over a lengthy period. Documenting the baseline of how historic Indigenous and European management has shaped forest extent and condition and resultant values satisfies term of reference 1(a) at a broad scale using existing information and expert opinion. Public consultation on the preliminary assessment report has generated finer-scale information on forest uses and values.

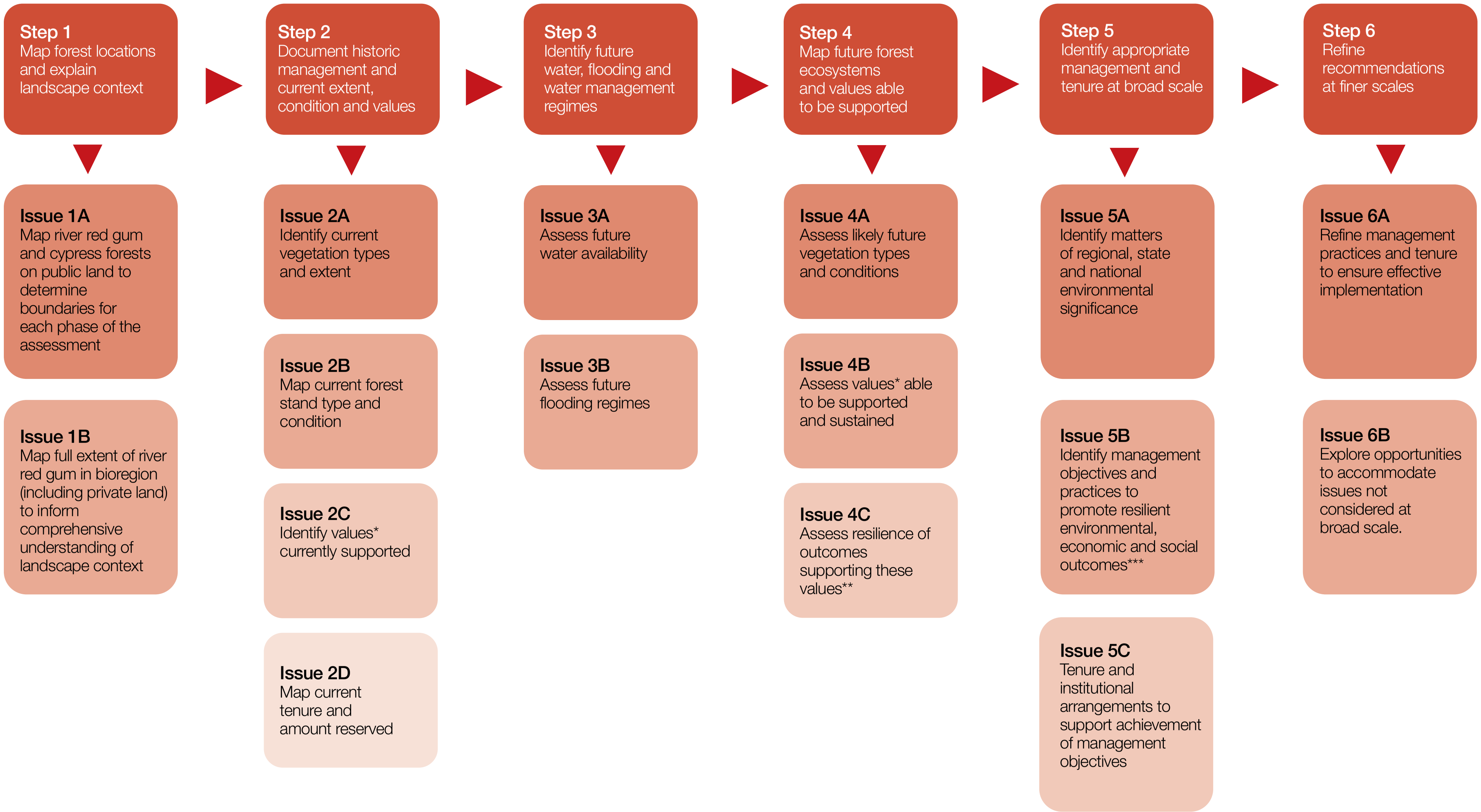
Step 3 – Identify likely future water, flooding and water management regimes – Chapters 7 and 8

Climate variability and climate change is projected to reduce rainfall, river flow and flooding. Basin-wide and local water management will differentially affect flooding timing, frequency and duration, and hence forest health. This step defined the 'future water scenarios' considered within the assessment and anticipated how this might affect flooding patterns in particular forest groups.

Step 4 – Map future forest ecosystems and values able to be supported – Chapters 9 and 10 and recommendations report

Based on likely future flooding patterns, possible changes to vegetation types and ecosystems were characterised and mapped, and changes to the values they are likely to support were described. Nationally agreed criteria for reserve systems plus more recent work on resilience of socio-ecological systems will be used to nominate parameters to describe and gauge the resilience of particular environmental, economic and social outcomes and values. The NRC attempted to identify likely tipping points beyond which further changes in a parameter (say flooding frequency) will cause a step change in the vegetation types (say from river red gum forest to open river red gum woodland or box woodland) and the values and uses that that vegetation type is able to support. The NRC's approach to resilience was informed by recent work which explores how this concept might be incorporated into land use and sustainability decision-making (for example, Cork, 2009; Fischer et al., 2009, Walker et al., 2009).

Figure 1.1: The NRC's analytical framework for assessment and recommendations for the river red gum forests of the NSW Riverina bioregion



* Environmental heritage (including indigenous heritage), economic and social values will be considered
** Regard will be given to nationally agreed criteria for a comprehensive, adequate and representative reserve system and to other complimentary methodologies for protection conservation values
*** Regard will be given to appropriate forest management practices to promote long term productivity and health and to international or governmental obligations, agreements or arrangements

Step 5 – Identify appropriate management and tenure at broad scale – Chapter 11 and recommendations report

This step determined the most appropriate mix of landscape management objectives, practices and tenure options to achieve conservation outcomes, protection of matters of national environmental significance and a sustainable future for the forests, forestry industry and local communities. High priority environmental values were identified and mapped at an appropriate scale, to address the *EPBC Act* requirements in term of reference 1(b). Potential synergies and trade-offs between environmental, economic and social outcomes and values were then identified and mapped at a coarse scale to identify preferred management regimes and principles to promote resilient outcomes. Preferred management regimes were used to recommend a relatively broad-scale mosaic of tenure and associated management arrangements.

Step 6 – Refine recommendations at finer scales – recommendations report

Through engagement, consultation, and finer-scale assessment (local/site scale), the NRC refined its recommendations, and refined management practices within different forest zones. Where existing knowledge allowed, the NRC recommended appropriate management priorities for the forests and tenures for many of the 83 individual State Forests containing river red gum forests.

Forest inspection by the NRC and stakeholders

1.6 Consultation during this assessment

As part of the analytical approach described above, the NRC undertook a variety of consultations with a diverse range of groups and individuals who have interests in the river red gum forests of the Riverina bioregion.

The NRC met with a cross-section of interested parties, took tours of the region, held public forums and received formal submissions.

The consultation activities helped the NRC see the forest from a diversity of perspectives and values, develop an appreciation of the specific issues of communities and industries, and better understand the local and regional context of the assessment.

Appendix 6 outlines the consultation process in greater detail.

1.6.1 NRC tours of the river red gum forests in the Riverina

To better understand the issues facing the river red gum forests in the Riverina and the communities which rely on them, the NRC visited the region nine times and visited 50 State Forests between August and November 2009.

The local Indigenous communities, forest industries, local government, state agencies and community representatives generously gave their time and expertise to help the NRC understand the issues concerning the river red gum forests. The NRC:

- observed silvicultural practices, and mill operations, including timber processing for high-value timber veneers
- met with Indigenous people, who shared their stories and history
- visited sites of environmental and cultural significance and observed the close connections between the forests and the communities that rely on them
- visited Yanga National Park and saw the contrast of healthy river red gum forests with non-flooded areas of drought-stressed trees
- visited interpretative centres on the history and heritage values of the rivers and their floodplain forests
- visited areas important for tourism and the recreation of locals.

1.7 Overview of submissions

The NRC received 5,534 submissions, of which 259 were unique The remainder were form letters or emails. **Appendix 6** contains a list of organisations that provided submissions.

The NRC reviewed and considered every submission during the preparation of this assessment report and the recommendations report.

Individuals, interest groups and organisations representing a broad cross-section of the community made submissions to the assessment. Several submissions provided detailed information including technical reports to support opinions or proposals.

The submissions covered a broad range of views and recommendations in response to the main findings of the preliminary assessment report – that the river red gum forest ecosystems are experiencing, and will continue to face, unprecedented levels of long-term change associated with a water-scarce future.

Many submissions called for greater consideration of forest ecology, impacts of timber industry operations and impacts of water allocation on desired conservation outcomes. Others called for more attention to the social, economic and community interests of local people.

Most submissions acknowledged that the forests were under stress and recognised that changes were needed to protect them for the future. Overall, they agreed on the fundamental importance of environmental watering for the future of the forests, with most calling for greater water security and for efficient use of that water.

Many of the submissions provided detail on the values that the forests support and how these should be conserved or managed in the future. In particular, submissions detailed the biodiversity values of the forests and the cultural, social and economic values of the forests for regional communities. All submissions demonstrated the high value of these forests to the region, the state and for all Australians.

The submissions varied in how forest values might be maintained into the future, with many focused on either conservation or production values. The submissions ranged from strong support for new national parks, perhaps jointly managed with the traditional owners, through to equally strong support for maintenance of the current situation – management by Forests NSW – and protection of forest industries and their communities. A few submissions argued for a balance across both conservation and forestry – national parks or reserves in high-value conservation areas and continued forest industries elsewhere.

Conserving forest ecosystems in national parks

A significant number of submissions called for approaches to prioritise the environmental values of the forests – requesting preservation of all, or at least the most ecologically significant, river red gum forests, in national parks. Some called for linking conservation reserves across the landscape and conserving high-value forests in national parks, providing environmental flows to these forests, controlling total grazing pressure and ending logging activities.

Advocates for this approach argued that the intrinsic ecological values of the river red gum forests outweighed the benefits from timber production. In particular, proponents wanted national parks for preservation of forest ecosystems currently under-represented in the national reserve system and for protection of habitat for threatened species.

The supporters of future national park management of the river red gum forests were focused on the precautionary principle – wanting protection of the forests in light of the implications for biodiversity of predicted climate change impacts. They argued that, as well as their inherent ecological values, the forests are important for carbon sequestration and as east-west conservation corridors for adaptation to climate change.

Most proponents for the conservation of the river red gum forests in national parks did not discuss the specifics of their management (including issues surrounding fire and pest management). The submissions focused on current management practices only with respect to cessation of production activities due to both known and potential impacts on biodiversity. Water management was not addressed in detail. Proponents did request more comprehensive landscape-scale conservation strategies for the region.

Support for continued forestry management

An equally substantial number of submissions strongly opposed a 'lock-up' style of forest conservation (in national parks) and argued for continued forestry management. Proponents argued that current timber industry practices are ecologically sound and the current health of the forests – excluding the impacts of the recent drought – are evidence of past sustainable management, balancing environmental and social values with timber production.

These submissions argued that, until the current drought, the health of the forests was maintained and thinning operations were able to sustain tree regeneration and growth rates. They further added that State Forests are well maintained, provide employment and control feral animals, minimise spread of weeds and actively manage fire risk. They cited examples of other national parks where they believe tourism, pests and fire risk are not managed in the best interests of local communities and they suggested that the success of a preservation approach should be demonstrated before 'locking-up' other forests.

Some submissions called for reform of forest management by Government and separation of the management of public land from commercial interests.

Long-term security for industry and communities

Submissions focused on the value the forests hold for local and regional communities and the interdependence of local towns on forest related industries – including forestry, service industries and recreation. They argued strongly for continued government support for these industries – both in allowing continued activity but also investment in research, development, training and infrastructure – to underpin the regional economy and the viability of local towns.

Many proponents argued for long-term security for the forest industries in the bioregion, even if a reduction in sustainable yield is agreed. They want support for high-quality forestry enterprises, to reduce reliance on lower-value or less well-managed activities and to encourage investment in their industries and towns, including forestry-related tourism. While firewood is considered a lower-value timber industry, some submissions discussed pragmatic and equity issues – firewood collection is an important source of income and a cheap fuel source for lower socio-economic groups.

Local business owners stressed that they invest heavily in the local community – they have invested in infrastructure for their future and will not be viable if their industry is cut back. Submissions from industry and local shires described the heavy reliance of businesses and communities on the income and future viability of the forest industries. Concerns were raised about the viability of community services such as schools, health services and clubs, should forestry decline.

Proponents discussed the need to support individuals, businesses and communities impacted by possible transfers to national park management. Most acknowledged the need to support local communities that are dependent on forestry-related income and with a strong social and cultural relationship to the forests – although views differed on how this might be done.

Consideration of Indigenous communities

A significant number of submissions argued for greater recognition of the importance of river red gum forests to Indigenous people and many argued for a much greater role for traditional owners in forest management. There were requests for transfer of ownership to, and/or joint management of the forests by, the traditional owners. Many viewed this as an important step in future sustainable management of the forests for a range of values.

Environmental water allocations

Many proponents stated their belief that water purchased by Government will support healthy river red gum forests and forestry in the region once the current drought is over. They requested secure environmental water allocations for the forests.

Additional science and adaptive management

Many submissions requested more information – both in the report and in future research – on the environmental values of the forests and on the impact of timber production activities on forest ecology.

Most submissions agreed that the future is uncertain and an adaptive approach will be important.

1.8 Structure of this report

This assessment report presents the available science and information on the current health, uses and values of the forests, and how climate variability and climate change is likely to affect them. This report underpins the NRC's separate recommendations report. The structure of the report is as follows:

Chapter 2 – Biophysical and historical context – describes an evolving landscape with a history of forest use and management. The distribution of river red gum forests and woodlands are considered in terms of eight water management units.

Chapter 3 – Institutional context – describes the institutional arrangements under which the forests are managed and governed, and discusses cross-jurisdictional and governance issues for future management.

Chapter 4 – Current forest extent, condition and environmental values – describes the environmental values and the current extent, health and functioning of red gum forest ecosystems.

Chapter 5 – Economic and social values – examines the socio-economic values and uses of the forests at a local and regional scale.

Chapter 6 – Cultural and heritage values – describes the Indigenous and non-Indigenous cultural and heritage values derived from the forests, and discusses possibilities for joint management.

Chapter 7 – Climate variability and predictions for future climate change – outlines the current understanding of climate variability and climate change in south-eastern Australia and the implications for planning under uncertainty.

Chapter 8 – River regulation and water reforms in a drying climate – describes the effects of river regulation in the Murray-Darling Basin, the water reforms required to save the river red gum forests, and predicts the impacts of changes in future water availability for forests in each water management unit.

Chapter 9 – Implications of water scarcity for environmental values – predicts the likely impacts, in the context of altered flooding regimes, on the environmental values of the forests.

Chapter 10 – Implications of water scarcity for economic and social values – predicts the likely social and economic impacts of a changing and variable climate on the bioregion, and discusses possible alternatives for the timber industry under a water-scarce future as well as approaches for building adaptive capacity in the region's communities.

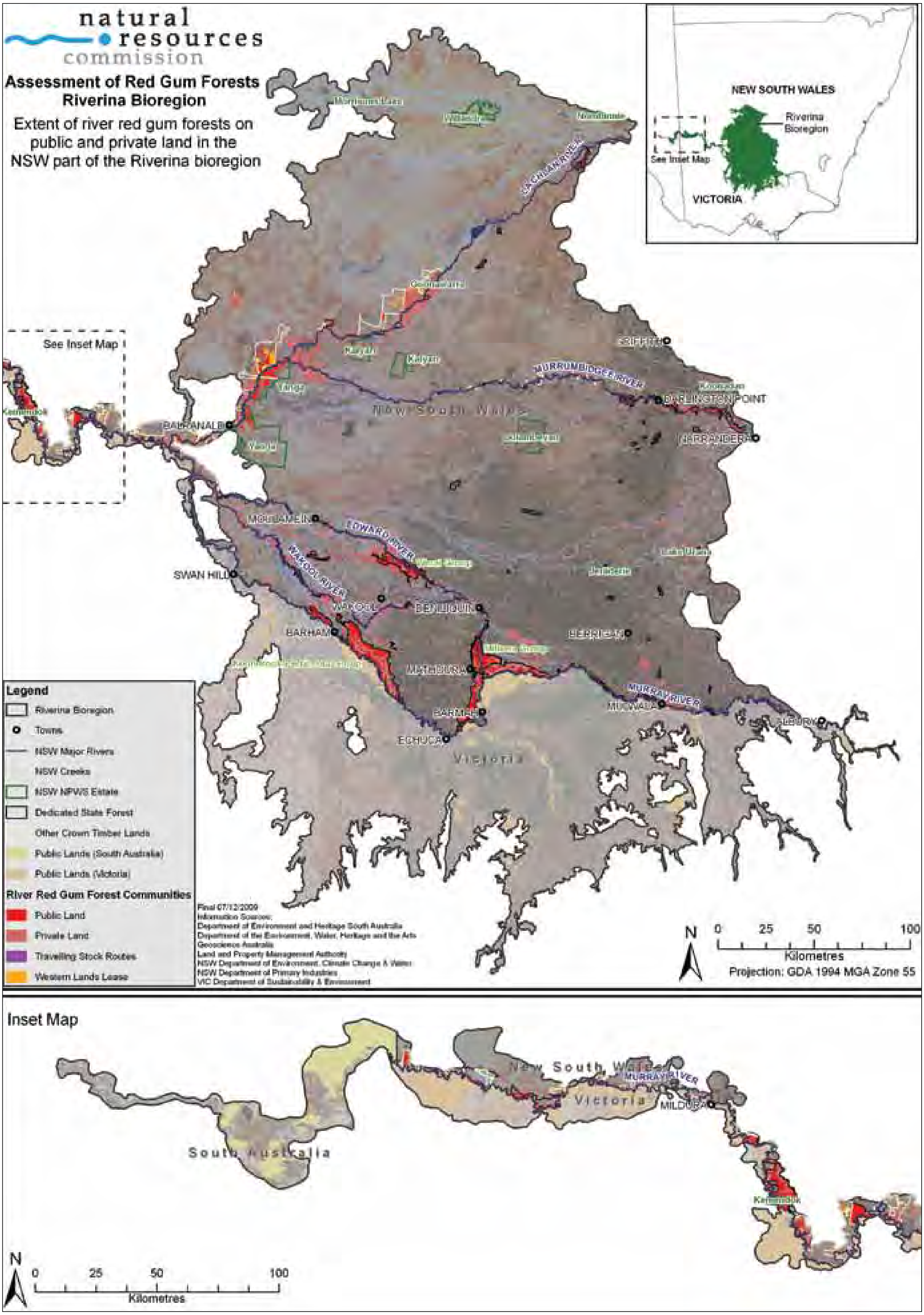
Chapter 11 – Managing red gum floodplain ecosystems – proposes a set of principles for the future management of red gum floodplain ecosystems across a dynamic socio-ecological landscape.

Historic Murray River flood levels near Moama

Chapter 2

Biophysical and historical context

Figure 2.1: Extent of river red gum forests on public and private land in the NSW part of the Riverina bioregion



2.1 Overview

The Riverina bioregion is an area of about 9.7 million hectares across south-west NSW, northern Victoria and north-east South Australia. Major river catchments in the NSW portion of the bioregion include the Murray, Murrumbidgee and Lachlan. Vast floodplains have developed in these catchments as a result of water moving across the landscape and depositing sediment and nutrients.

There are approximately 401,000 hectares of river red gum forests in the NSW portion of the bioregion **(Figure 2.1)**. These forests are associated with most of the major channels and floodplains in the bioregion. Their health and productivity is sensitive to flooding regimes and, in some cases, access to groundwater. Changes to flows as a result of river regulation have significantly altered the characteristics of river red gum forest communities and in many places they are under extreme stress.

The river red gum forests play a key role in maintaining ecosystem processes in the catchments of the bioregion. These processes include water and nutrient cycling, habitat provision and support of economic production and other human uses. Understanding that role is fundamental to maximising the values and uses of river red gum forests in the Riverina bioregion.

This chapter provides an overview of:

- the biophysical attributes of the bioregion at the landscape scale
- the evolution of the landscape and the history of use and management of the Riverina's red gum forests.

Key findings of this chapter are:

- The river red gum forests of the Riverina bioregion are influenced by their geomorphic setting, hydrological setting and the human interventions that have shaped the forests over time. These are highly modified ecosystems and their future depends on how we manage them.
- The Riverina bioregion is characterised by rivers with extreme hydrological variability and extensive regulation. This results in red gum floodplain ecosystems which are dynamic in nature. The frequency, extent, timing and duration of floods determines the floodplain, which in turn determines where the red gum ecosystems develop and persist. When the river moves as a result of geomorphic processes, or where flooding changes when we build dams and weirs, the forests move and change structure.
- The river red gum forests are an important component of a much broader and dynamic river floodplain ecosystem. They are potentially the main primary producers in the river floodplain ecosystems, supporting and driving other ecosystem processes.

2.2 The Riverina bioregion

2.2.1 Location, land use and climate of the Riverina bioregion

The Riverina bioregion covers parts of south-west NSW, central-north Victoria and South Australia **(Figure 2.1 and 2.2)**. It covers an area of about 9.7 million hectares, of which 7 million hectares (72 per cent) lies in NSW (Thackway and Cresswell, 1995). The remainder occurs in Victoria (2.5 million hectares) and South Australia (0.2 million hectares).

The major river catchments in the NSW portion of the bioregion include the Murray, Murrumbidgee and Lachlan. In the Victorian portion, the major catchments are of the Upper Murray, Kiewa, Ovens, Broken, Goulburn, Campaspe, Loddon and Avoca rivers.

In NSW, the Riverina bioregion extends from near Ivanhoe in the Murray Darling Depression bioregion south to the Murray River, and from Narrandera in the east to the South Australian border in the west. The towns of Hay, Coleambally, Deniliquin, Leeton, Hillston, Booligal and Wentworth are within its boundaries. Other major towns of Griffith, Ivanhoe, Narrandera and Albury lie just outside its boundary.

The bioregion consists of six subregions (**Figure 2.2**), which are based on finer differences in biophysical attributes:

- Lachlan River
- Murrumbidgee
- Murray Fans
- Victorian Riverina
- Robinvale Plains
- Murray Scroll Belt (Morgan and Terrey, 1992, cited in NSW NPWS, 2003).

Approximately 50 per cent of the bioregion has been cleared for agriculture. Grazing on native pastures is the dominant land use in the area (Eardley, 1999). There are also large areas of irrigated rice and horticultural crops within the region. In general, ongoing water shortages and rising salinity are threatening agriculture and remnant vegetation.

The Riverina bioregion is characterised by a semi-arid climate with hot summers and cool winters. Seasonal temperatures vary little across the bioregion, although in the north both summer and winter temperatures tend to be higher (Stern et al., 2000). Rainfall currently occurs mainly in May and September and annual rainfall tends to increase from west to east and from north to south.

2.2.2 Landforms and soils

The landforms of the Riverina bioregion are dominated by river channels, floodplains, backplains, swamps, lakes and lunettes that are all of Quaternary age (less than 1.8 million years old). The region covers the alluvial fans of the Lachlan, Murrumbidgee and Murray rivers west of the Great Dividing Range and down the Murray River (NSW NPWS, 2003). The catchments of the Edward and Wakool rivers and their floodplains are also in the bioregion.

The characteristics of each alluvial fan differ slightly due to the variation in river discharge. The Lachlan fan is predominantly clay due to its smaller river discharge and therefore its reduced capacity to transport sand. The other two fans are similar except that the Murray River is more confined and has more active anabranch channels where it is forced to flow around the north-south Cadell Fault near Echuca. During flood events the different rivers can cross the fan surfaces and enter the channel of another system (DEWHA, 2009).

Figure 2.2: Subregions of the Riverina bioregion

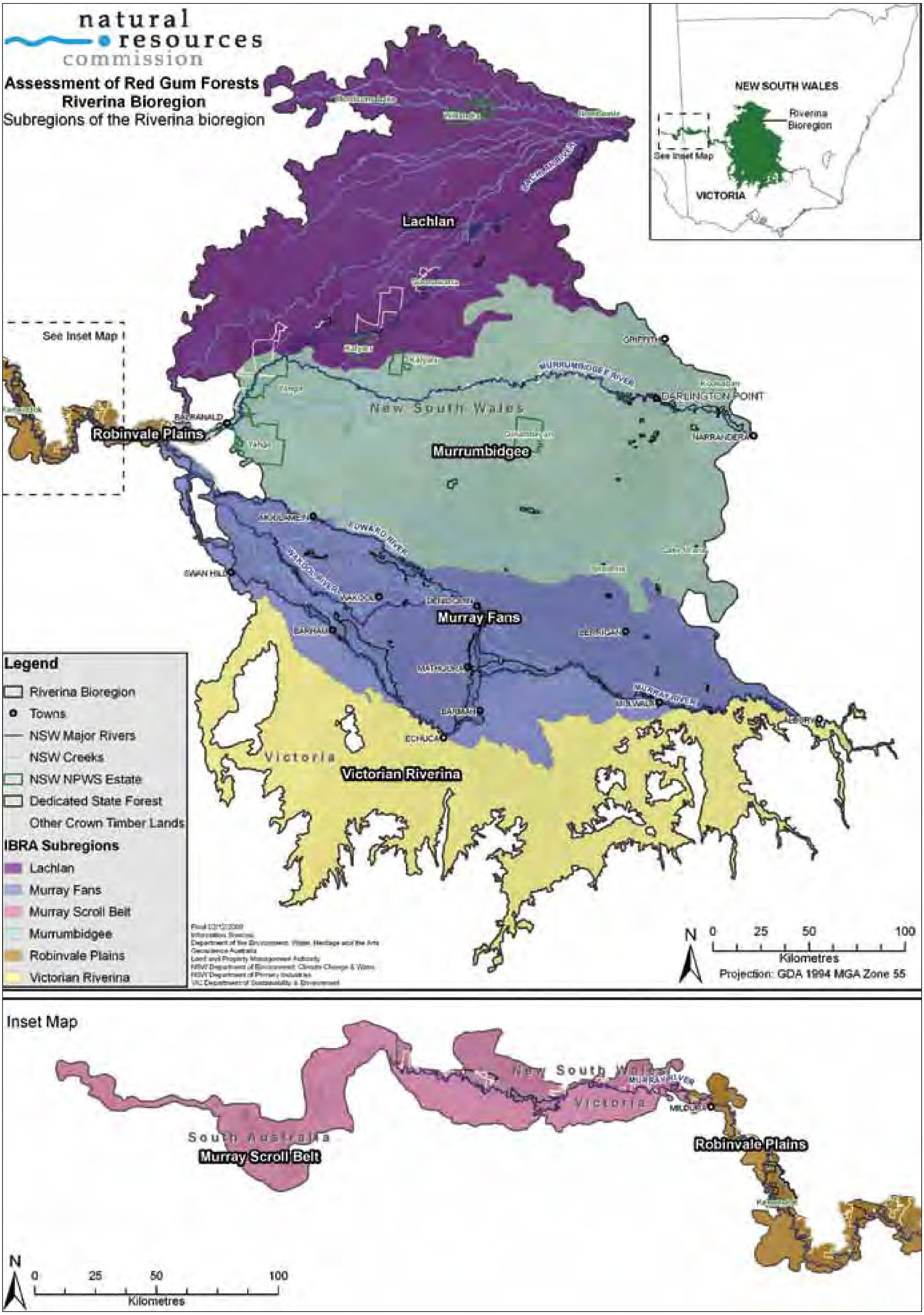


Table 2.1: River Red Gum Forest area in the Riverina bioregion

River Red Gum Forest	Area (ha)	Area (%)
Dedicated State Forests	128,000	31.9
National Parks Estate	27,400	6.8
Other Crown Timber Lands	18,400	4.6
Travelling Stock Routes	8,600	2.1
Western Land Leases	17,600	4.4
Private Land	210,500	50.1
Total	401,000	

Source: Mapping from Binns and DECCW (unpublished data), Benson et al., (2006)

Soils of the bioregion reflect past patterns of sedimentation and the current flooding regime. Sandy soils are found in belts along the older stream channels and their associated levees, dunes and lunettes. Modern river channels consist mostly of sandy soils and more saline heavy grey and brown clays towards the outer perimeter of the floodplains on the higher rarely flooded terraces (NSW NPWS, 2003). The red-brown and grey clays in the bioregion support native grassland and woodland communities. Calcareous, sandy soils, which tend to be a feature of adjacent bioregions, are also present in the Riverina bioregion (NSW NPWS, 2003).

2.2.3 Geological resources of the Riverina bioregion

The Riverina bioregion contains a range of known mineral resources including mineral sands, gypsum, bentonite and coal **(Figure 2.3)**. It also has the potential for further discoveries of these commodities, gas (coal seam methane and conventional gas), gold and base metals and geothermal energy (hot dry rock). In addition, geosequestration potential has been identified in the area (Whitehead, A, NSW Department of Industry and Investment, pers. comm., 2009).

2.3 River red gum forest ecosystems in the Riverina bioregion

2.3.1 Location of red gum forests

The river red gum (*Eucalyptus camaldulensis*) is the most widely distributed of all eucalypts in Australia (Keith, 2004). It is a fast growing tree that reaches to 45 metres at maturity with a large dense crown. Individual trees can live for up to 500 years. Forests dominated by river red gum are found along watercourses throughout Australia. They occur along the middle and lower reaches of the Murray and Murrumbidgee river floodplains, the lower Lachlan and Darling rivers, and smaller rivers of the northern Darling floodplains (Keith, 2004). They extend north along tributaries of the Darling into southern Queensland and south along the Murray and its tributaries into Victoria and South Australia and are only absent from the humid eastern seaboard, the western sandy deserts and Nullarbor Plain, and the south-west of Western Australia (Keith, 2004).

The largest river red gum forests in Australia occur in the Riverina bioregion. There are approximately 401,000 hectares of river red gum forests in the NSW portion. Of this:

- around 50 per cent is located in private land
- around 32 per cent is located within State Forests
- almost 7 per cent is located in national parks
- around 4 per cent is located within Western Lands Leases
- around 4 per cent is located in other crown timber lands
- around 2 per cent is located in travelling stock routes **(Table 2.1)**.

These figures do not include river red gum/box types, of which there is an additional 162,000 hectares in the NSW Riverina, where 22,700 hectares (14 per cent) is in State Forest.

The majority of river red gum on public land is found within three areas along the Murray and Edward rivers. Namely, in the Millewa, Koondrook-Perricoota, Campbells Island and Werai forests which together form the NSW Central Murray State forests (**Figure 2.4**). The high ecological values of the Central Murray State forests have been recognised in their listing as Ramsar Wetlands of International Importance. Important stands are also located along the Murrumbidgee, Wakool and Lachlan rivers, and Upper and Lower Murray River.

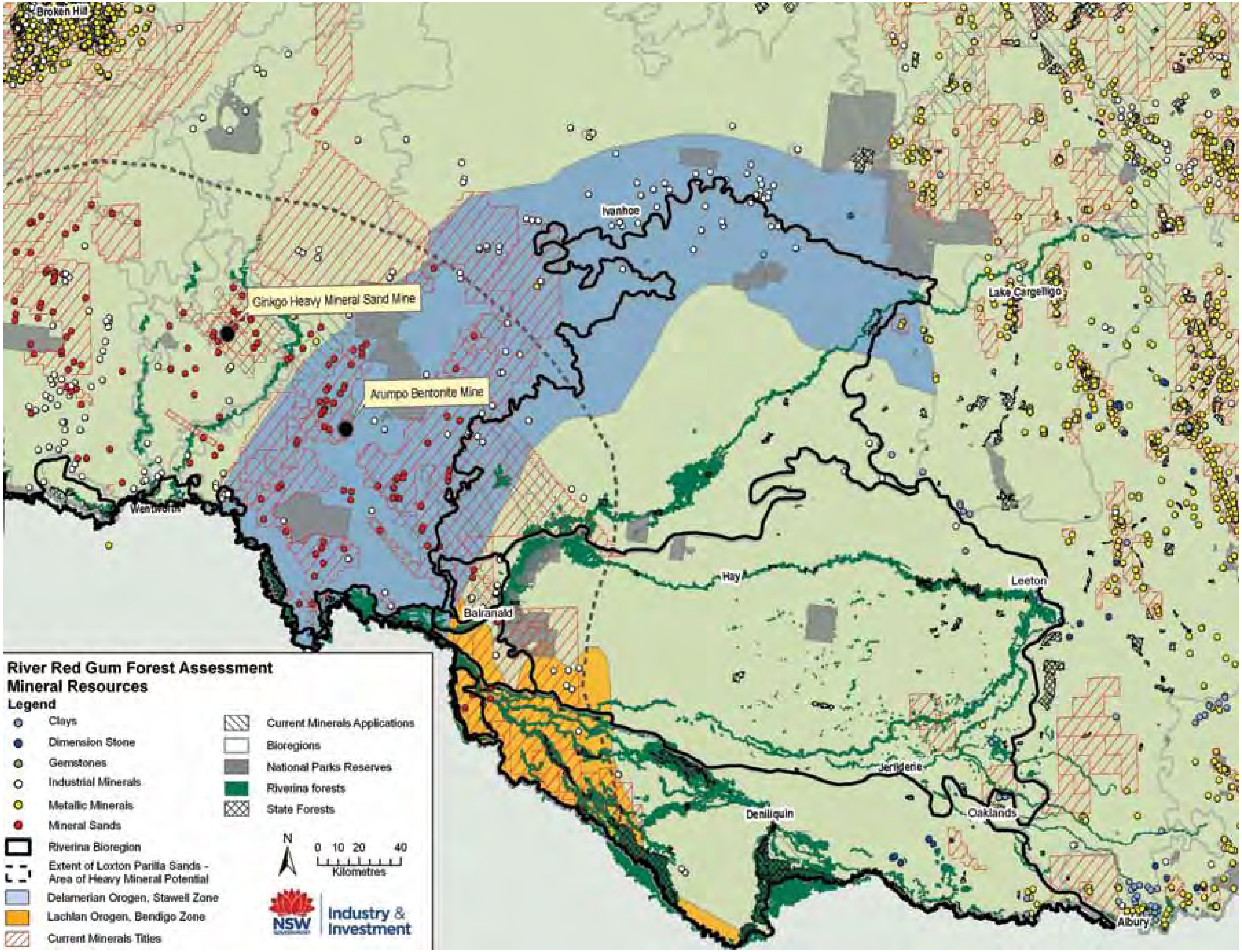
The river red gum forests of the Riverina bioregion are associated with most of the major channels and floodplains of the Lachlan, Murrumbidgee and Murray catchments (**Figure 2.1**). Red gum forest dominates areas in the floodplain that receive regular delivery of in-channel water and over-bank flooding.

2.3.2 Function of red gum forests in the landscape

River red gum forests function as an important component of the broader floodplain ecosystem. For example, they produce organic carbon and other nutrients in the form of forest litter which is distributed across the floodplain in flooding events. River red gum forests are potentially the key primary drivers of ecosystem processes in the floodplain (Hillman, T, pers. comm., 2009).

Flooding processes influence both the location and role of the red gum forests in the floodplain and then back to the river ecosystem. In its most simplistic nature, flooding results in water being delivered from the river channel to the floodplain. Biotic resources, such as leaf litter produced by river red

Figure 2.3: Known mineral resources in the Riverina bioregion (NSW Department of Industry and Investment)



gums, are returned to the river channel. This process maintains and supports the diversity and resilience of river floodplain ecosystems, its channel, wetlands and forests.

Chapter 4 further describes the environmental values of river red gum forests.

2.4 Landscape evolution

2.4.1 Geologic and geomorphic events influencing the Riverina bioregion

The physical form of the Riverina bioregion today is a product of geologic and geomorphic processes in the Quaternary period (1.8 million years ago to the present). During this period there have been climatic variations, fluctuations in sea level, and tectonic activity that has fundamentally shaped the bioregion. Although geologic processes (and to a lesser extent geomorphic processes) operate at timescales beyond the capability of humans to directly observe them, the physical form of the Riverina bioregion is dynamic and changing.

The key geologic and geomorphic events influencing the Riverina bioregion have been:

- Displacement along the Cadell Fault some 25,000 years ago forced the west-flowing Murray River north through the Edward River system and south through an ancestral channel of the Goulburn River. These major changes to the physical form of the landscape led to a greater frequency and duration of flooding, which in turn created the river red gum forests observed in the present day Millewa, Koondrook-Perricoota and Werai forests. Uplift of the Cadell Fault ultimately changed the course, pattern and character of the central Murray River over approximately 500 kilometres of its length (Rutherfurd, 1990).

- Movement of the main course of the Murray River from Green Gully (approximately 20 kilometres north of Echuca) to a new course, from Picnic Point in a southerly direction into the ancestral course of the Goulburn River. This change in course occurred approximately 500 to 600 years ago (Stone, 2006, cited in GHD, 2009a).

The geological and geomorphic processes that have shaped the Riverina bioregion have created a mosaic of geomorphic forms upon which a variety of vegetation communities are located. Examination of Quaternary geologic and geomorphic processes shows the physical form of the region has changed over time, leading to subsequent changes in vegetation distribution.

For example, the Barmah-Millewa river red gum forests have developed as a result of interaction between ancient river and floodplain forms and Quaternary geologic and geomorphic processes, in particular the uplift of the Cadell Fault. Movement along the Cadell Fault diverted the Murray River through elevated sandhills to create what is now known as the Barmah Choke because of its relatively small flow capacity (compared with the Murray River channel in other locations). The Barmah Choke constricts flow, causes the upstream floodplain to be frequently inundated, and therefore creates the hydrologic conditions suitable for the development of the extensive floodplain forests found nowhere else.

The intermittent flooding of the Murray River, the Edward River and associated creeks and channels contributes greatly to soil moisture. This provides environmental conditions that are conducive to the establishment and growth of the river red gums. Accordingly, climate conditions in the upstream catchment for the Murray River and its tributaries are of much greater importance to the site than local rainfall.

2.4.2 Hydrological setting of the Riverina bioregion

The vegetation and ecology of the Riverina bioregion has evolved over time in response to water availability.

Australian rivers have the most variable flow regimes in the world. As shown in **Tables 2.2** and **2.3**, the Murray River in particular has a highly variable annual flow and a relatively low average discharge by comparison with similar size catchments worldwide. Understanding and managing flows in this context presents a considerable challenge.

Mean annual rainfall of the Riverina bioregion varies from 238 mm to 617 mm. The region's low rainfall and relatively high average temperatures result in a mean annual rainfall deficit (evaporation in excess of rainfall) of 1,075 mm.

Table 2.2: Flow variability of some major rivers (ABS, 2008)

Country	River	Ratio of maximum and minimum annual flows
Switzerland	Rhine	1.9
China	Yangtze	2.0
Sudan	White Nile	2.4
USA	Potomac	3.9
South Africa	Orange	16.9
Australia	Murray	15.5
Australia	Hunter	54.3
Australia	Darling	4705.2

Figure 2.4: NSW Central Murray State Forests Ramsar site

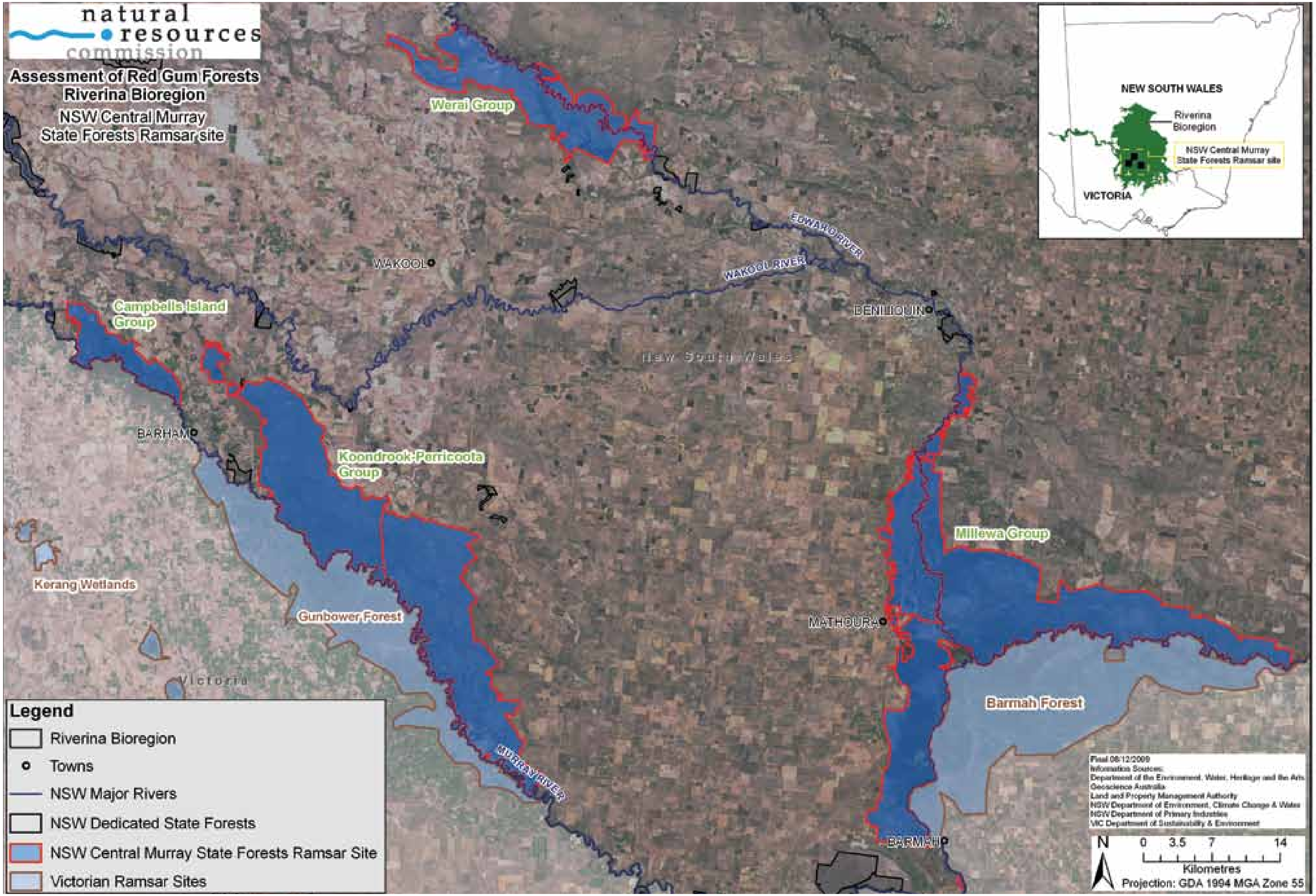


Table 2.3: Murray River average discharge compared to other rivers worldwide (MDBC, 2005)

River system	Length (km)	Catchment (km2)	Mean discharge (ML/sec)
Murray-Darling, Australia	3,780	1,060,000	0.4
Nelson, North America	2,575	1,072,000	2.0
Indus, Asia	2,900	1,166,000	5.0
Danube, Europe	2,850	816,000	7.0
Ganges-Brahmaputra, Asia	2,897	1,621,000	38.0
Zambesi, Africa	3,500	1,330,000	7.0
Tocantins, South America	2,699	906,000	10.0
Tigris-Euphrates, Middle East	2,800	1,114,000	1.0

The significant rainfall deficit means that floodwater contributions are needed to support the soil moisture requirements of forests and wetlands (Leslie, 2001).

Another important component of the hydrologic setting is the extent of regulation of the river systems. Many dams and weirs have been constructed on the river systems over the last 80 years. The average annual flow on the Murrumbidgee River has increased from approximately 3,900 GL/year (NSW DLWC, 2004) to approximately 4,400 GL/year because of diversions from the Snowy River (CSIRO, 2008b). Current average surface water availability in the Lachlan River is 1,139 GL/year, of which 321 GL/year goes to consumptive use (CSIRO, 2008c). The effect of river regulation on flooding of the various forest stands is described further in **Chapter 8**.

Groundwater is the third important component of the hydrologic setting, including groundwater-surface water linkages. The use of groundwater is a key part of survival of certain ecosystems in the bioregion, termed groundwater-dependent ecosystems (Sinclair Knight Merz, 2001). In general, groundwater-dependent ecosystems are a poorly understood part of the freshwater environment. Typically, areas of groundwater dependent river red gum forests access the shallow unsaturated zone. Some stands of forests in the Riverina bioregion may be maintained in good health by interactions with groundwater rather than through direct flooding (see **Chapter 8** for further explanation). Generally the recharge of groundwater systems is largely influenced by stream and flooding conditions, therefore altered flooding frequency impacts on groundwater recharge (Overton, I, CSIRO, pers. comm., 2009).

The hydrological setting of the bioregion is also likely to transform in the future due to climate change. The expected changes and implications for the forests are further described in **Chapter 8**.

2.4.3 Influence of geomorphic and hydrological setting on river red gum forests

Geomorphic setting has a fundamental influence on the distribution of river red gum forests. The geomorphology provides the physical template on which vegetation communities are located, and strongly influences other processes important to vegetation distribution, including soil characteristics and wetting and drying regimes.

Soil characteristics, shaped by geomorphic and hydrological processes, influence the distribution of vegetation communities. River red gum forests are found on alluvial sediments, Moira grasslands and marshes on water-retentive clay soils in the lowest parts of the landscape, and woodlands (river red gum and box communities) on sand dunes and the surrounding Riverina Plain.

River red gum is physiologically dependent upon floodwaters to maintain sufficient soil moisture to sustain metabolism, growth and reproduction processes. The distribution, species composition and silvicultural 'quality' of river red gum forests is constrained by the extent, frequency, timing and duration of floods (Roberts and Marston, 2000; Benson et al., 2006; Di Stefano, 2001).

The relationships between geomorphic setting, vegetation associations and flood regimes are shown in **Figure 2.5**.

2.4.4 Influence of human interventions on the forests

Along with geological and geomorphological processes, human interventions have also driven landscape evolution and the extent of river red gum forests.

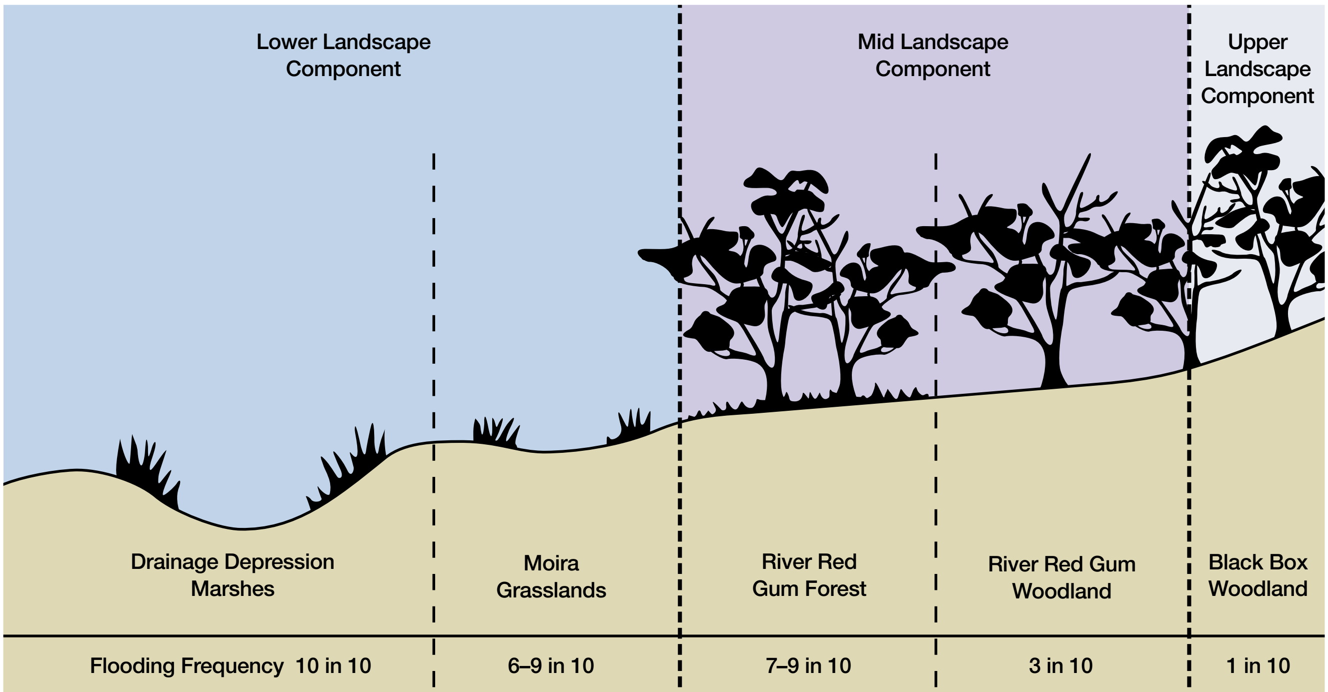
Indigenous use and management

Indigenous people have been continuously present in the Murray-Darling Basin for at least 40,000 years (Hope, 1995).

In the Riverina bioregion, the rivers and wetlands provided an abundant variety of food resources for Indigenous people (Pardoe, 1998). The warmer, drier months were more productive, but in the colder months people would disperse into smaller groups keeping away from main water bodies when the river was in flood (Beveridge, 1889; Kneebone, 1992). Meetings of larger groups were organised to coincide with the availability of more food. Some ceremonies were designed to perpetuate particular food species, while totemic restrictions helped to manage over-exploitation (Hagen, 1997). In this way, culture, climatic and hydrological cycles, and livelihoods were interwoven for Indigenous people.

Research suggests that Indigenous people in the Riverina also actively managed the landscape to secure more sustainable livelihoods (Atkinson, 2005). An example of this type of

Figure 2.5: Indicative vegetation associations, geomorphic setting and flood regime (adapted from MDBC, 2007a)



management is the use of fire. Recollections from 1841 to 1851 reported in Curr (1965, as cited in Atkinson, 2005) suggest that fire was used by the Yorta Yorta for hunting, regeneration, track clearing and as a defence against Europeans to dissuade them from entering the land. The relationship between the deliberate use of fire and vegetation structure is contested (for example, Benson & Redpath, 1997; Bowman, 1998; Esplin et al., 2003; Jurskis, 2009). It is difficult to draw conclusions about the linkages between the use of fire and forest structure at the time of European settlement (Bren, 1990; Donovan, 1997; Yates and Hobbs, 1997; Lunt and Morgan, 2002; Fensham, 2003).

European use and management

Since the **1800s**, forest management has changed from unrestricted use of the resource to support settlement and early industry, through a period of formal forest management and river regulation, to a more recent focus on State Forest planning and management for the sustainable use of commercial timber resources and the protection of environmental values.

In the period **up to 1900**, river red gum forests were used to support European settlement and early industry. There was little control of forest use or management during most of this period. Widespread grazing of domestic stock (sheep and cattle), and ringbarking was carried out to open up pastures.

Major flooding in the **early 1870s** resulted in a significant change to forest structure, as a thick understorey of natural regeneration developed in newly cleared areas, and larger trees continued to be removed through timber cutting and ringbarking.

Grazing was formalised towards the **end of the 1800s** by granting leases across the forests, and the first attempt to allocate forests to product classes was undertaken through designation of timber reserves and appointment of forest rangers.

Dense new forests were generated over extensive areas in the Central Murray, after flood events between the **1840s** and the **1970s** (Curr, 1883).

From **1900 to 1980** formalisation of public forest management and levels of river regulation increased. The *Forestry Act 1916* (NSW) was enacted, timber reserves were designated as State Forest, and timber cutting and apiary use were regulated.

River regulation, which was to have a profound impact on the long-term health of the river red gum forests, began in the **1920s**, as summarised in **Box 2.1**. In response to changes in flooding regimes, river red gum seedlings invaded the grass plains, and regeneration developed into full forest cover on areas that were previously native grass plains, for example, the Moira State Forest.

Redbank weir on the Murrumbidgee river

Box 2.1: History of river regulation in the Southern Murray-Darling Basin

Murrumbidgee catchment: In the Murrumbidgee system, 14 large regulating structures have been built (Murray, 2008), including the Burrinjuck Dam (completed in 1928 and which provides water for summer irrigation). Two dams, including the Blowering Dam, were built on the Tumut River, a major tributary of the Murrumbidgee, in the 1960s as part of the Snowy Mountains Scheme, generating a major expansion of irrigation in the Murray and Murrumbidgee systems.

Murray catchment: River regulation of the Murray River itself commenced with the completion of Hume Weir in 1936, and the construction of small regulators in the Millewa Forests to prevent loss of regulated flows.

In 1966, the first diversion of water was made from the Snowy River to the Murray River.

Lachlan catchment: The Lachlan River is also heavily regulated, beginning with the construction of the Lake Cargelligo Weir in 1902. There are 10 dams and 323 weirs in the Lachlan catchment (Kingsford and Thomas, 2004).

Goulburn Broken catchment (Vic): The first stage of Eildon Weir on the Goulburn River was completed in 1929 and a series of enlargements were completed in 1955.

Construction of Dartmouth Storage at the confluence of the Mitta Mitta and Dart rivers was completed in 1979.

The introduction of 'Improved Utilisation Harvesting' in **1947** was designed to regenerate older stands whilst thinning younger stands, as selective logging of mature forests between **1910** and **1945** had left many defective trees that impeded regeneration.

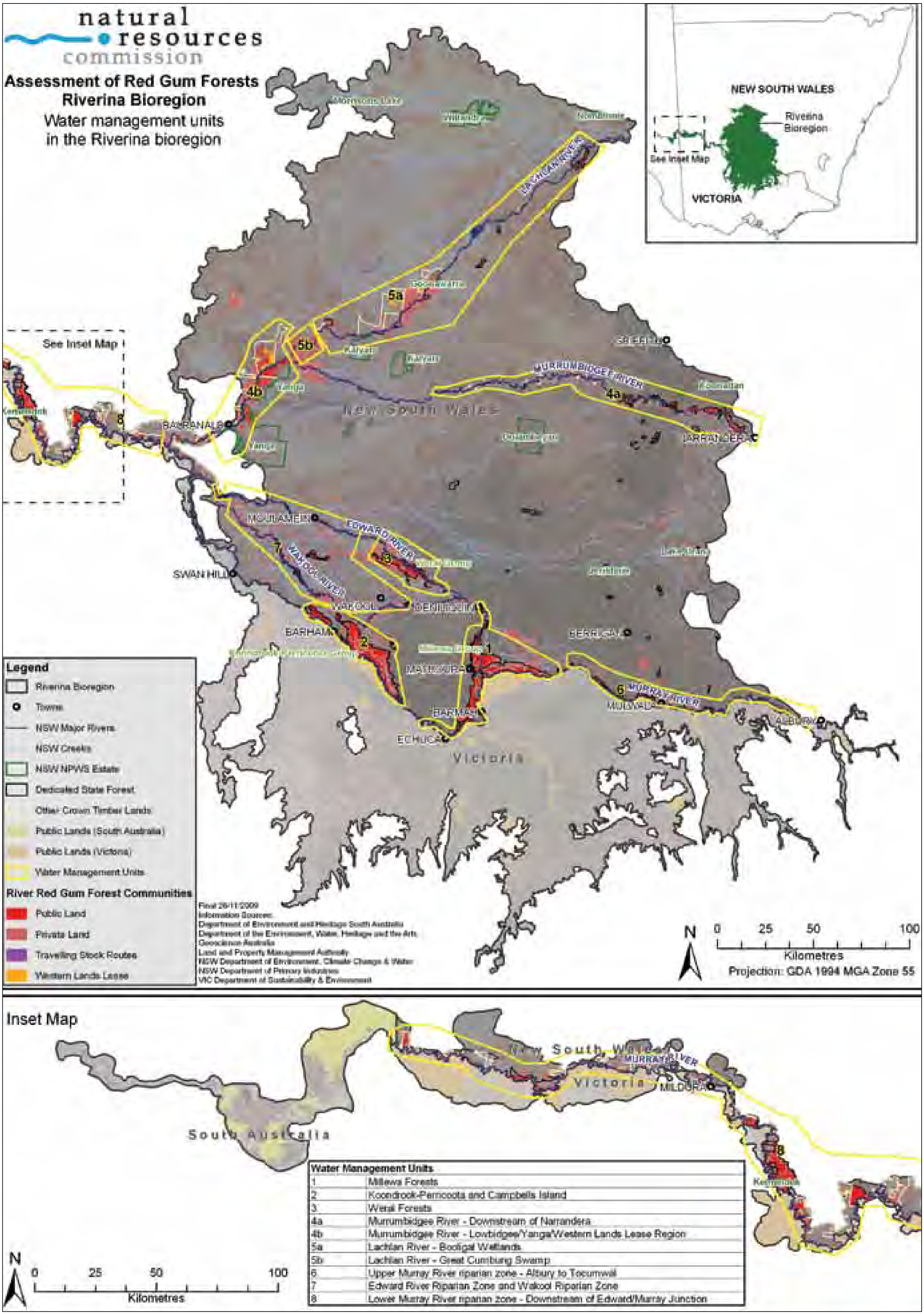
By the **1980s** most of the mature forests had been intensively harvested and timber production concentrated on thinning the maturing **1870s** to **1910** age classes. Over the past 30 years, forest use and management has responded to an increasing emphasis on forest values other than wood production, and to changing water regimes and forest dynamics. This period witnessed the cessation of ringbarking of non-commercial trees, dedication of flora reserves, the introduction of more sophisticated planning approaches and the monitoring of wetland-dependent water birds.

- The second Murray Management Plan was published in **1985**. Under this plan, harvest plans were developed which governed site-specific controls such as exclusion zones along riparian areas, habitat zones, retention of hollow bearing trees, and aspects of native fish management.

- Forest Management Zones were delineated, which differentiated areas of State Forests specifically set aside for conservation and those that were available for other activities, including timber harvesting.

- Managed flooding of site-specific wetlands commenced to protect low-lying communities such as reed beds, with site-specific plans developed by the Murray Wetlands Working Group for Reed Beds Wetland and Moira Lake Complex Wetlands.

Figure 2.6: Water management units of the NSW Riverina bioregion



- River regulation works continued, with the construction of the Mary Ada regulator and the upgrade of Millewa and Werai regulators.
- Construction of an additional 15 regulators along the Edward River was undertaken to prevent unseasonal flooding of wetlands along the river and the adjacent forests.
- Desilting of the Swan Lagoon and Burrumbarry Creek within Toorangabby freehold property was undertaken to facilitate natural flooding of the Koondrook Forests.
- In **2003**, the NSW Central Murray forests (Millewa, Koondrook and Werai Forests), and the various wetlands types within were listed as a 'Wetland of International Importance' under the Ramsar Convention. The Ramsar listing of the NSW Central Murray State Forests is based on the ecological values of the wetlands, and acknowledges the significant social, cultural and economic resources of the site and its long history of management for multiple use.
- In **2007**, the NSW Government established Yanga National Park, the first NSW national park with substantial representation of river red gum forests (around 19,000 hectares). The Yanga National Park, Nature Reserve and State Conservation area totals approximately 70,000 hectares.
- A Code of Practice for Timber Harvesting in Public Native Forests was implemented in **1998**, and its equivalent for private forests in **2007**.

2.5 Water management units

Given the centrality of flooding to the occurrence, persistence and health of river red gum forests, water management units (WMUs) provide a logical basis for the assessment and management of river red gum forests. WMUs are practical geographic and institutional units to which water can be directed. As such, they form the base unit for assessment of values, flooding requirements and implications of climate variability and climate change. WMUs in this assessment have been defined from information provided by Forests NSW (Rodda, G, Forests NSW, pers. comm., 2009).

This section defines the WMUs in the NSW portion of the Riverina bioregion and provides an overview of the major forest stands associated with each WMU.

Table 2.4 defines the WMUs and **Figure 2.6** shows their location within in the bioregion. The location of specific WMUs and associated forests are mapped in **Figures 2.7** to **2.15**.

Flooded river red gum woodland in Yanga National Park

Figure 2.7: Extent of river red gum forests on public and private land within the Millewa forests

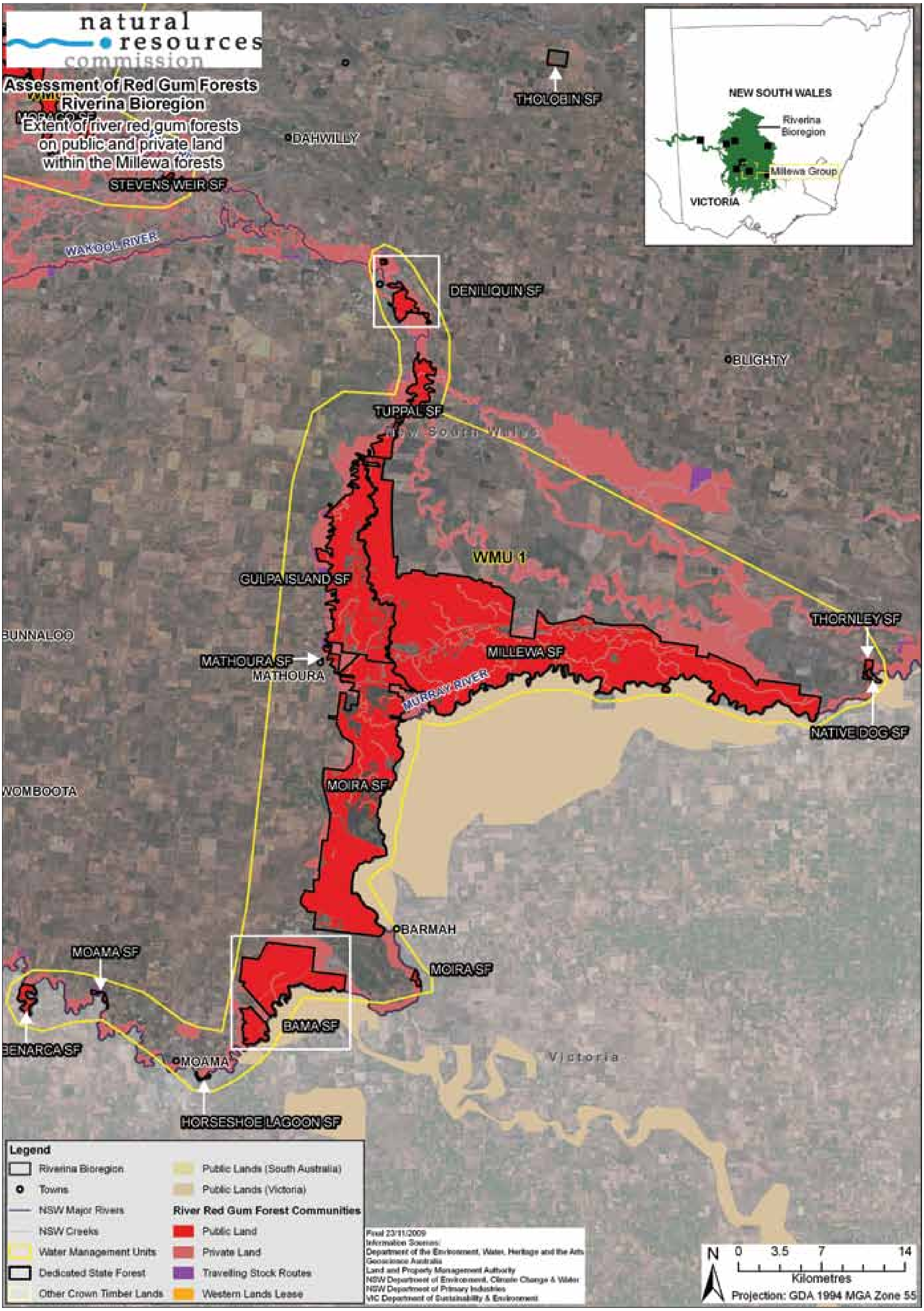


Table 2.4: Water management units

Water management units	
1	Millewa forests
2	Koondrook-Perricoota and Campbells Island forests
3	Werai forests
4	Murrumbidgee River forests a. Downstream of Narrandera b. Lowbidgee/Yanga region
5	Lachlan River forests a. Lachlan River, including Booligal Wetlands b. Great Cumbung Swamp
6	Upper Murray River riparian zone forests
7	Wakool and Edward rivers riparian zone forests
8	Lower Murray River riparian zone forests

2.5.1 Millewa forests (WMU 1)

The Millewa group of forests covers approximately 38,100 hectares and incorporates the Millewa, Moira, Gulpa Island and Tuppal State forests **(Figure 2.7)**. The main channel of the Murray River defines the southern boundary of the forest and discharges water into the forest via the Edward River, Gulpa Creek and smaller channels and overbank flow.

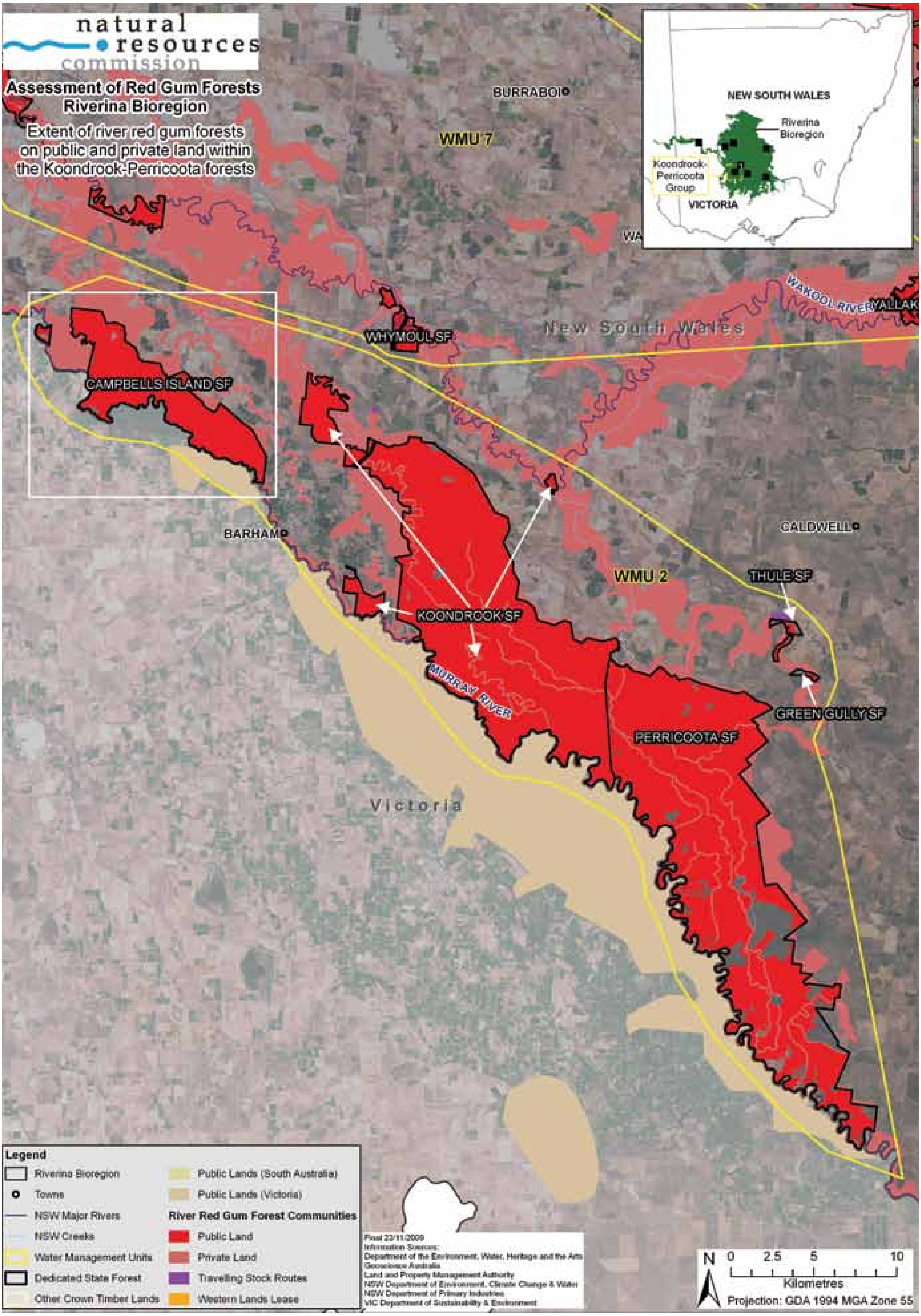
The Barmah Forest lies immediately to the south of the Murray River on the Victorian side of the state border. The combined Barmah-Millewa forests have been recognised as a highly significant wetland complex, jointly containing the largest area of river red gum forest in the world (O'Connor et al., 2006). The Barmah-Millewa forests form one of six icon sites defined under The Living Murray Program.

2.5.2 Koondrook-Perricoota and Campbells Island forests (WMU 2)

The combined Koondrook-Perricoota State forests cover an area of approximately 34,546 hectares (including Campbells Island) (**Figure 2.8**). The main channel of the Murray River comprises the southern border of the forest and discharges water into the forest via Swan Lagoon and Burrumbury Creek. The Gunbower Forest is located immediately south of Koondrook State Forest, on the Victorian side of the border. The Gunbower-Koondrook-Perricoota red gum forests form another of the six icon sites defined under The Living Murray Program.

Millewa State Forest

Figure 2.8: Extent of river red gum forests on public and private land within the Koondrook-Perricoota forests



The two major forest groups associated with this WMU are the Perricoota forest group, which incorporates the second largest area of river red gum forest after Millewa, and the Campbells Island forest group.

2.5.3 Werai forests (WMU 3)

The Werai forests occupy an area of 11,403 hectares, including the Werai State Forest and Barratta Creek State Forest **(Figure 2.9)**. The Werai group of forests is situated on the floodplain of the Edward and Niemur rivers between Yadabal Lagoon and Morago. While this site is not one of The Living Murray icon sites, it is part of the Central Murray State Forests Ramsar-listed wetlands of international importance.

The Werai forests are hydrologically linked to the Millewa forests and during large flow events in the Murray River, substantial volumes of water are diverted to the Edward River and ultimately the Werai forests.

2.5.4 Murrumbidgee River forests (WMU 4)

The Murrumbidgee region is located within southern NSW and covers 87,348 square kilometres or 8.2 per cent of the Murray-Darling Basin **(Figures 2.10 and 2.11)**. The Murrumbidgee region contains a total of 33 sites listed as wetlands of national significance, and two of these sites are Ramsar-listed as Wetlands of International Importance (Fivebough and Tuckerbill Swamps). The two large lowland areas in the Murrumbidgee catchment are the Mid-Murrumbidgee Wetlands and Lowbidgee Floodplain Wetlands.

The Mid-Murrumbidgee Wetlands (WMU 4a) are an assemblage of lagoons and billabongs along the Murrumbidgee River from Narrandera to Carrathool, with an estimated total area of 2,500 hectares. River red gum forest and woodlands dominate the vegetation of the area with black box woodland being more marginal on the floodplain (CSIRO, 2008b; Environment Victoria, 2001).

The Lowbidgee Floodplain (WMU 4b) is around the lower Murrumbidgee River downstream of Maude and covers some 200,000 hectares. The broader Lowbidgee is subdivided into the Nimmie-Pollen-Caira system near Maude Weir, and the Redbank-Yanga system further downstream. The Redbank-Yanga system is covered by river red gum forest and woodlands, with black box on the floodplain margins (CSIRO, 2008b; Environment Victoria, 2001).

2.5.5 Lachlan River forests (WMU 5)

The Lachlan River WMU is located within central western NSW and covers 85,532 square kilometres or 8 per cent of the Murray-Darling Basin **(Figure 2.12)**. The Lachlan group of forests contains several important and large Wetlands of National Significance, supporting diverse vegetation types including river red gum. Of most significance are the Booligal Wetlands and the Great Cumbung Swamp.

The Booligal Wetlands (WMU 5a) cover approximately 5,000 hectares on the lower Lachlan River, including the Booligal Swamp and Little Gum Swamp, the latter of which has a dominant over-storey of river red gum (CSIRO, 2008c; Magrath, 1992).

The Great Cumbung Swamp (WMU 5b) is around 16,000 hectares at the terminus of the Lachlan River and is adjacent to the Murrumbidgee River and the Lowbidgee Wetlands. River red gum and black box cover large areas of the swamp (CSIRO, 2008c).

2.5.6 Upper Murray River riparian zone forests (WMU 6)

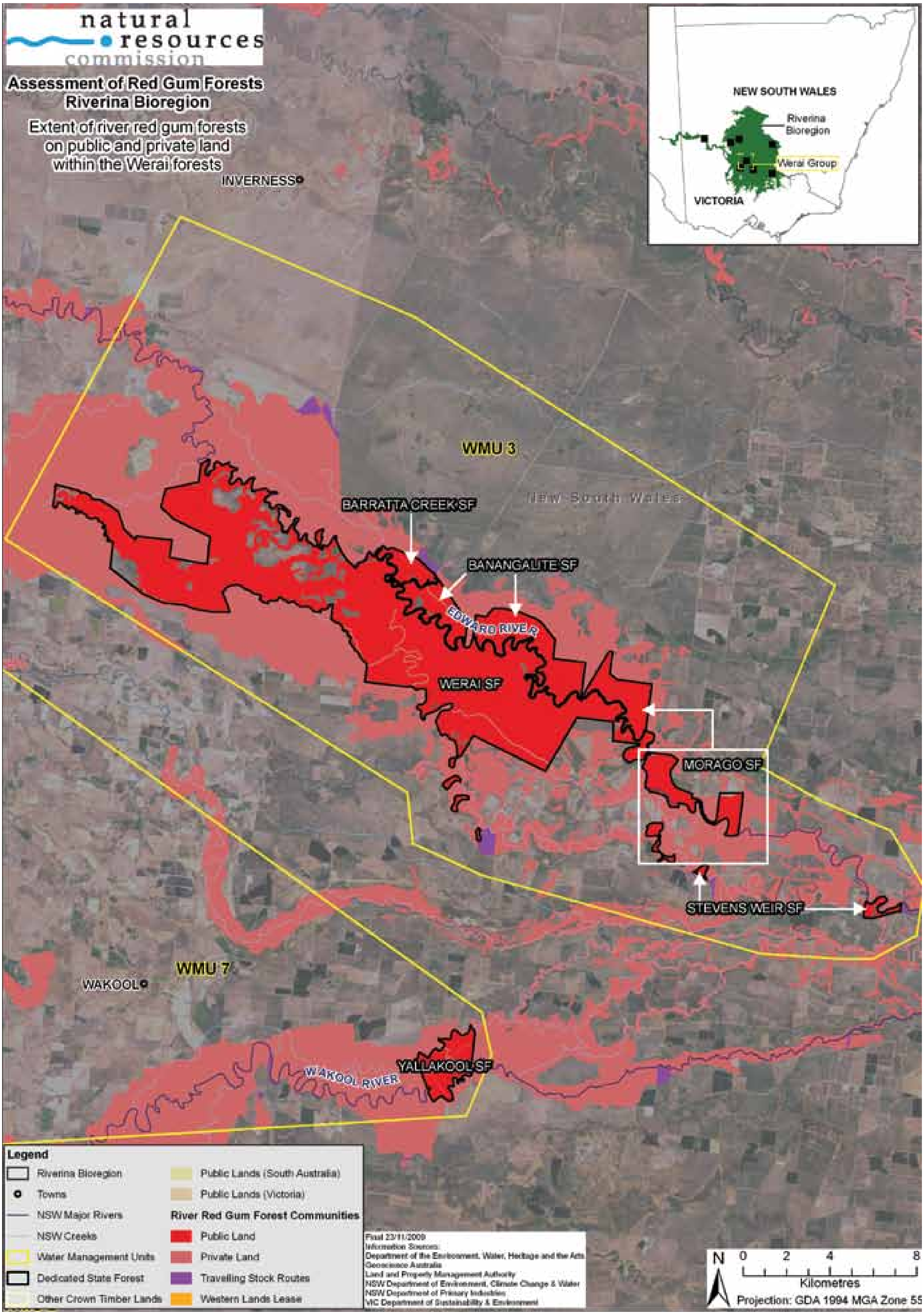
The Upper Murray River riparian zone is located between Albury and Tocumwal (**Figure 2.13**). The flow regime of this zone is heavily modified by the storages of Hume Dam, Yarrawonga Weir and the Snowy Mountains Scheme. The group of forests along the upper Murray is known to be in good condition and is likely to be more resilient to climate change. Increased rainfall and decreased evaporation in the east of the bioregion means that river red gum is less dependent on surface flooding for its survival. Augmentation of local shallow groundwater systems between Hume Dam and Lake Mulwala by high river levels during irrigation releases may also contribute to sustaining river red gum forests along this reach. These forests are the most eastern in the bioregion and comprise a mix of river red gum and yellow box.

2.5.7 Wakool and Edward Rivers forests (WMU 7)

At the Barmah Choke near Mathoura, the Edward River leaves the Murray River and flows in a north-westerly direction, joining the Wakool River before flowing back into the Murray 500 kilometres downstream from the divergence point (MDBC, 2006c) **(Figure 2.14)**. In major flood events, the Edward River takes over half of the Murray flows which pass Tocumwal (MCMA, 2006).

River red gum forests along the Murrumbidgee River

Figure 2.9: Extent of river red gum forests on public and private land within the Werai forests



The Wakool River is enclosed between the Edward and Murray rivers, and is part of an extensive network of high-level anabranches. During major flood conditions, approximately 50 per cent of the total flow passing Deniliquin leaves the Edward River via the Wakool and Yallakool rivers (MCMA, 2006). Parts of the Wakool River system adjoin the Koondrook-Perricoota Forest, and comprise hundreds of kilometres of rivers and creeks. The river system and adjoining forest are recognised as having high ecological value and feature the river red gum (MDBC, 2007). The Wakool group of forests along the Wakool River are little surveyed. They comprise river red gum woodland, box-river red gum woodland and box woodland.

2.5.8 Lower Murray River riparian zone (WMU 8)

The Lower Murray River riparian zone extends downstream from the confluence of the Edward and Murray rivers (to the border of the bioregion) **(Figure 2.15)**. The hydrological regime of this section has been significantly changed. Less than half the natural median annual discharge now reaches the border with South Australia (Gippel and Blackham, 2002). Periods of prolonged low flow are more frequent. The frequency, duration and magnitude of all but the largest floods have been reduced (Gippel and Blackham, 2002).

The western group of forests are located on the lower reaches of the Murray, with some located downstream of the Darling confluence. These forests support a diversity of communities, with river red gum forests, river red gum-box woodlands, mallee woodlands and semi-arid acacia woodlands represented.

2.5.9 State Forests

The State Forests in the NSW portion of the Riverina bioregion are listed in **Table 2.5** and located in **Figures 2.7 to 2.15**.

Table 2.6 lists some smaller State Forests located outside of the defined WMUs. All but two of these do not contain river red gum forests and will be addressed in the NRC's Cypress Forest Assessment.

Murray River at Euston State forest

Figure 2.10: Extent of river red gum forests on public and private land within the Murrumbidgee region forests

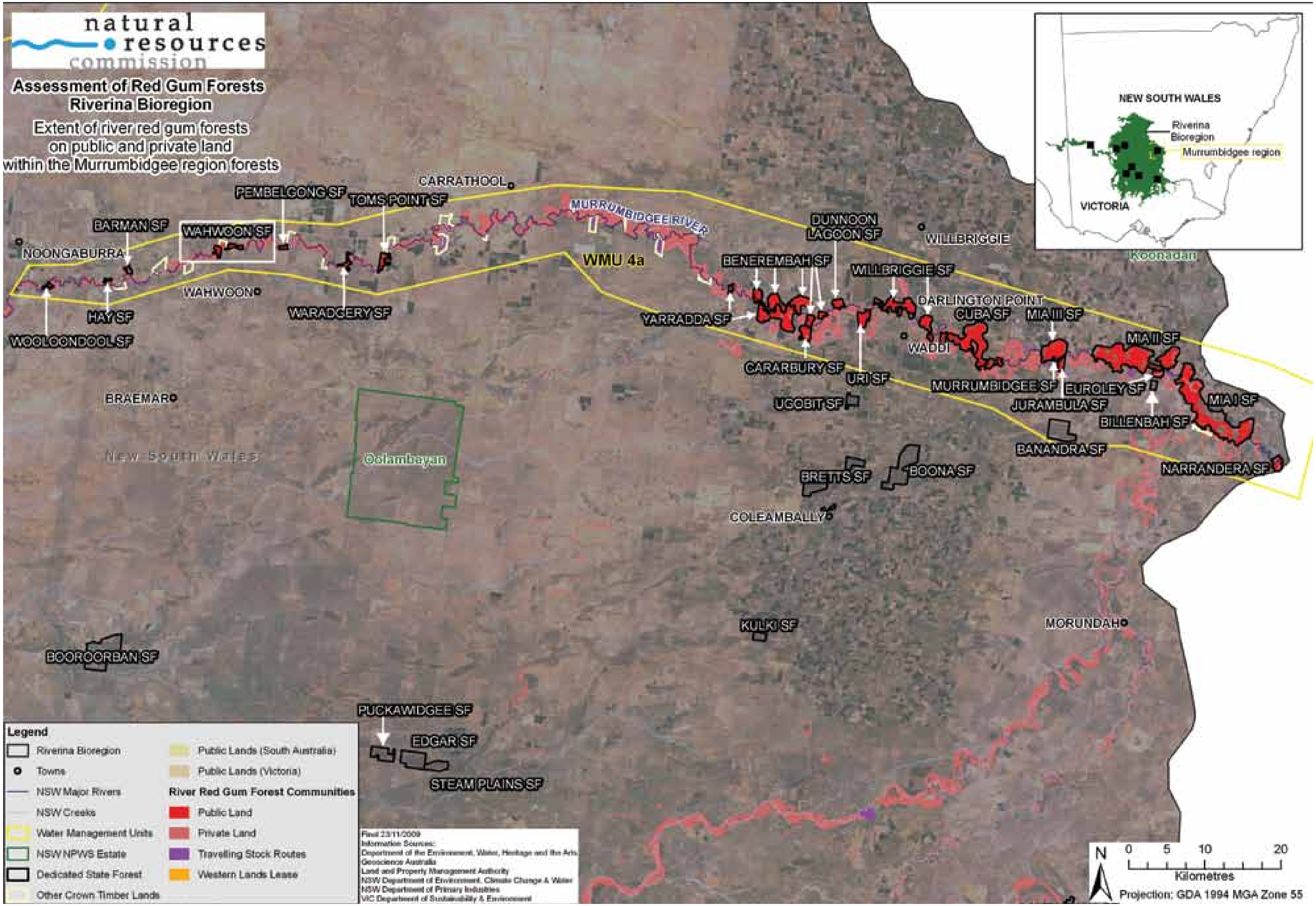


Table 2.5: State Forests in the NSW portion of the Riverina bioregion

WMU 1: Millewa forests		WMU 2: Koondrook-Perricoota and Campbells Island		WMU 3: Werai forests		WMU 4: Murrumbidgee River		WMU 5: Lachlan River		WMU 6: Upper Murray River riparian zone		WMU 7: Wakool and Edward rivers riparian zone		WMU 8: Lower Murray River riparian zone	
State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)	State Forest	Area (ha)
Bama	3,198	Campbells Island	3,819	Banangalite	1,295	Banandra	762	Hillston	2,204	Barooga	1,190	Benjee	147	Euston	3,269
Benarca	212	Green Gully	48	Barratta Creek	239	Barman	67	McFarlands	698	Boomanoo-mana	1,026	Berambong	244	Gol Gol	1,396
Deniliquin	428	Koondrook	15,153	Morago	1,040	Benerembah	1,130	Moon Moon	514	Collendina	562	Kyalite	572	Ki*	722
Gulpa Island	5,478	Perricoota	16,891	Stevens Weir	98	Billenbah	98	Oxley	1,236	Corowa	123	Liewa	427	Lake Victoria	4,431
Horseshoe Lagoon	18	Thule	131	Werai	9,464	Cararbury	237	Quandong	497	Cottadidda	672	Niemur	1,642	Mallee Cliffs	9,458
Mathoura	1					Cuba	1,642	Booligal	865	Mulwala	501	Noorong	1,875	Manie*	5,074
Millewa	21,001					Dunnoon Lagoon	155			Quat Quatta	38	Wetuppa	1,033	Moorna	3,290
Moama	38					Euroley	134			Quat Quatta East	141	Woorooma	32	Wangumma	1,635
Moira	10,600					Hay	30			Woperana	258	Woorooma East	33		
Native Dog	49					Jurambula	138					Yallakool	506		
Thornley	69					MIA 1	3,187					Whymoul	387		
Tuppal	984					MIA 11	2,544								
						MIA 111	739								
						Murrumbidgee	9								
						Narrandera	196								
						Pembelgong	51								
						Toms Point	190								
						Uri	267								
						Wahwoon	198								
						Waradgery	116								
						Willbriggie	944								
						Wooloondool	47								
						Yarradda	1,021								
						Maude	167								
						Kieeta*	628								

* Note 1: State Forest dedicated over leasehold land.

Figure 2.11: Extent of river red gum forests on public and private land within the Murrumbidgee River – Lowbidgee/Yanga/Western Lands Lease Region

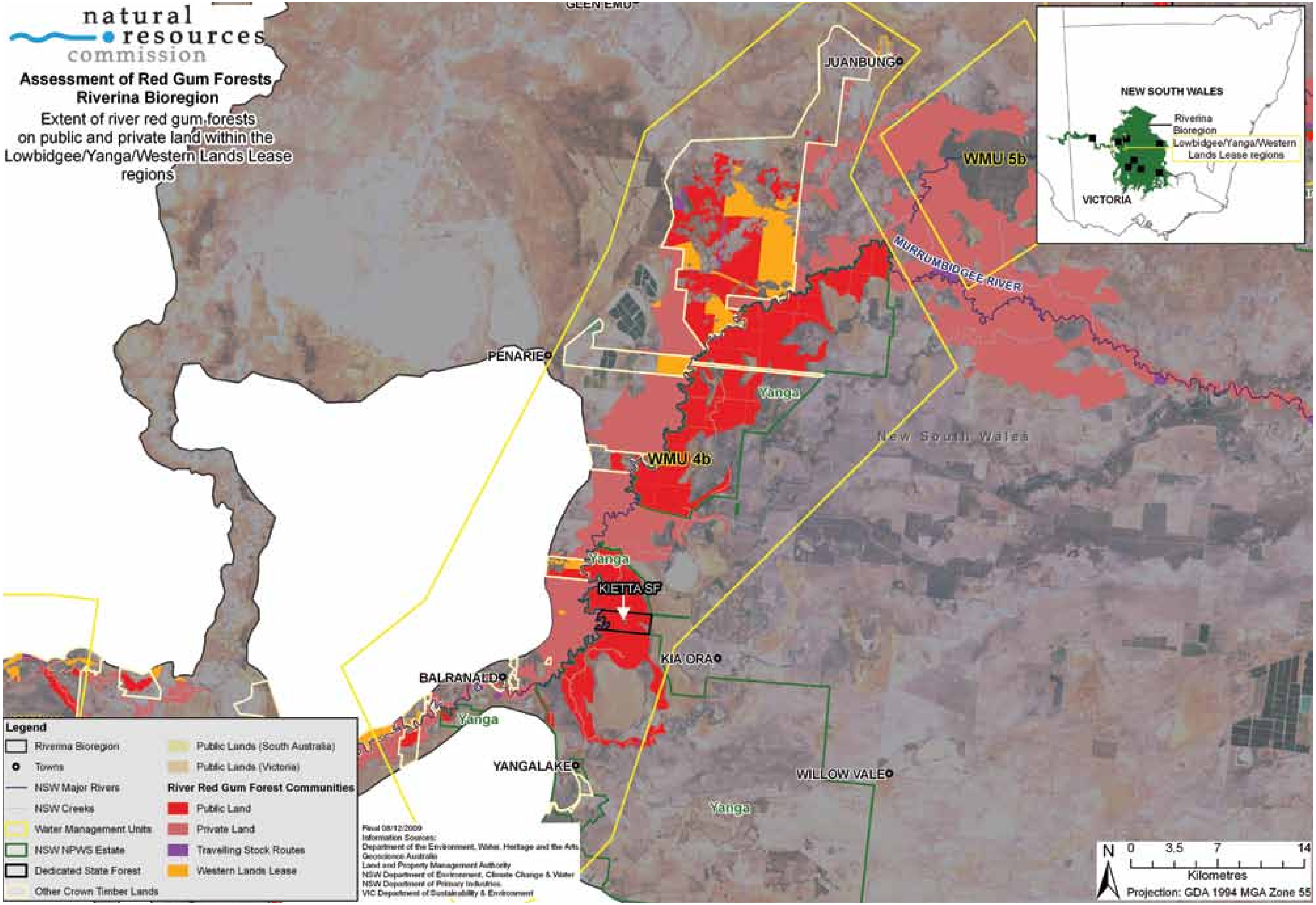
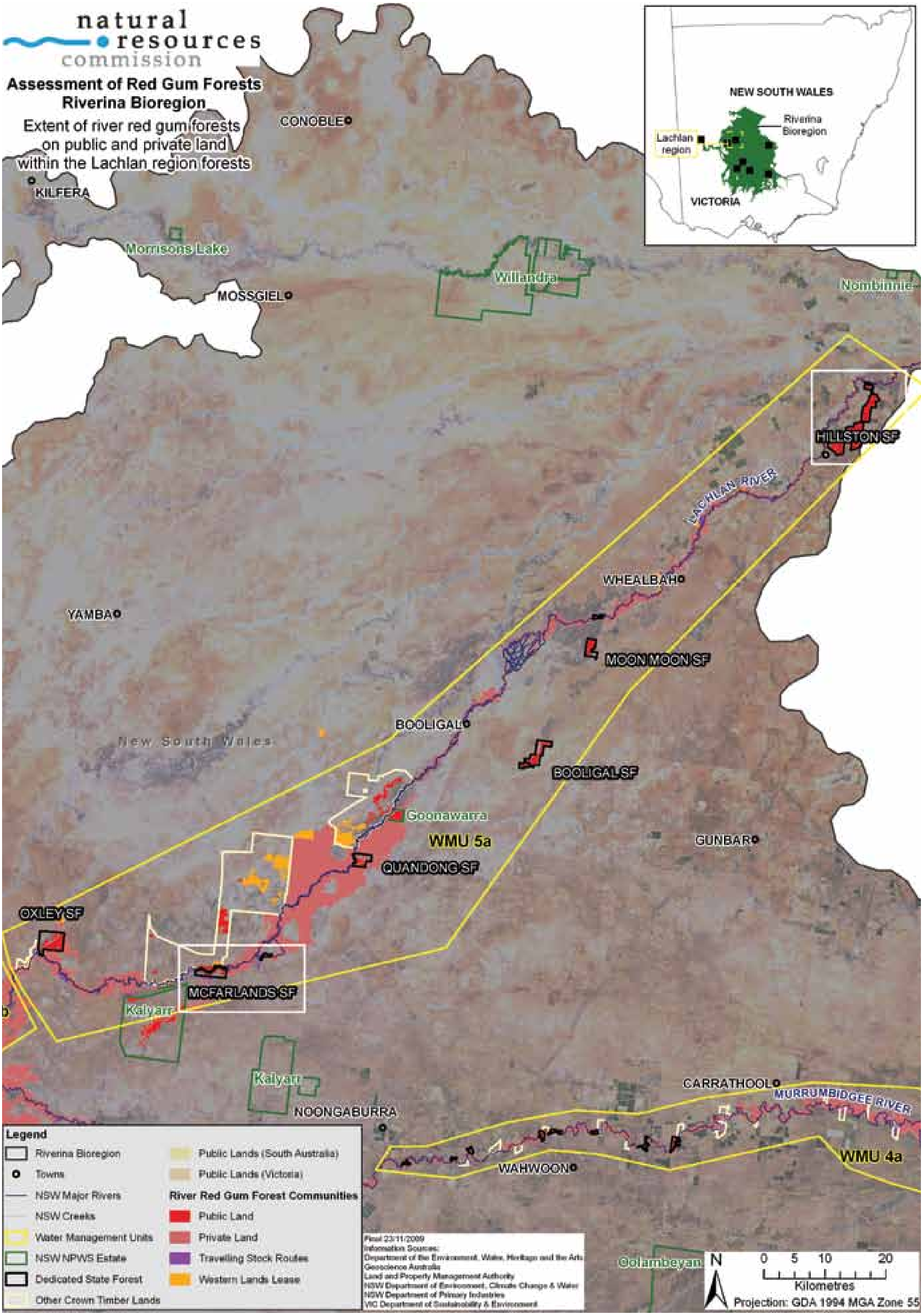


Table 2.6: State Forests located outside of defined WMUs

State Forest	Area (ha)	Nearest WMU	Presence of river red gum*
Steam Plains	327	4a: Murrumbidgee River – Downstream of Narrandera	No
Booligal	865	5: Lachlan	No
Boona	1,185	4a: Murrumbidgee River – Downstream of Narrandera	No
Booroorban	1,442	4a: Murrumbidgee River – Downstream of Narrandera	No
Bretts	735	4a: Murrumbidgee River – Downstream of Narrandera	No
Edgar	637	4a: Murrumbidgee River– Downstream of Narrandera	No
Kulki	170	4a: Murrumbidgee River – Downstream of Narrandera	No
Puckawidgee	427	4a: Murrumbidgee River – Downstream of Narrandera	Contains River Red Gum Tall Open Forest**
Ugobit	221	4a: Murrumbidgee River – Downstream of Narrandera	No
Mairjimmy	454	6: Upper Murray River riparian zone	No
Berrigan	286	6: Upper Murray River riparian zone	No
Ringwood Tank	231	6: Upper Murray River riparian zone	No
Wahgunyah	326	6: Upper Murray River riparian zone	No
Coreen	123	6: Upper Murray River riparian zone	No
Jerilderie	23	6: Upper Murray River riparian zone	No
Lake Urana	213	6: Upper Murray River riparian zone	No
Palmer	724	6: Upper Murray River riparian zone	No
Tholobin	197	1: Millewa forests	Contains River Red Gum–Box Woodland**
Total	8,586		

* Based on Binns mapping of NSWVCA vegetation types.
** These are addressed in the NRC's Recommendation Report.

Figure 2.12: Extent of river red gum forests on public and private land within the Lachlan region forests



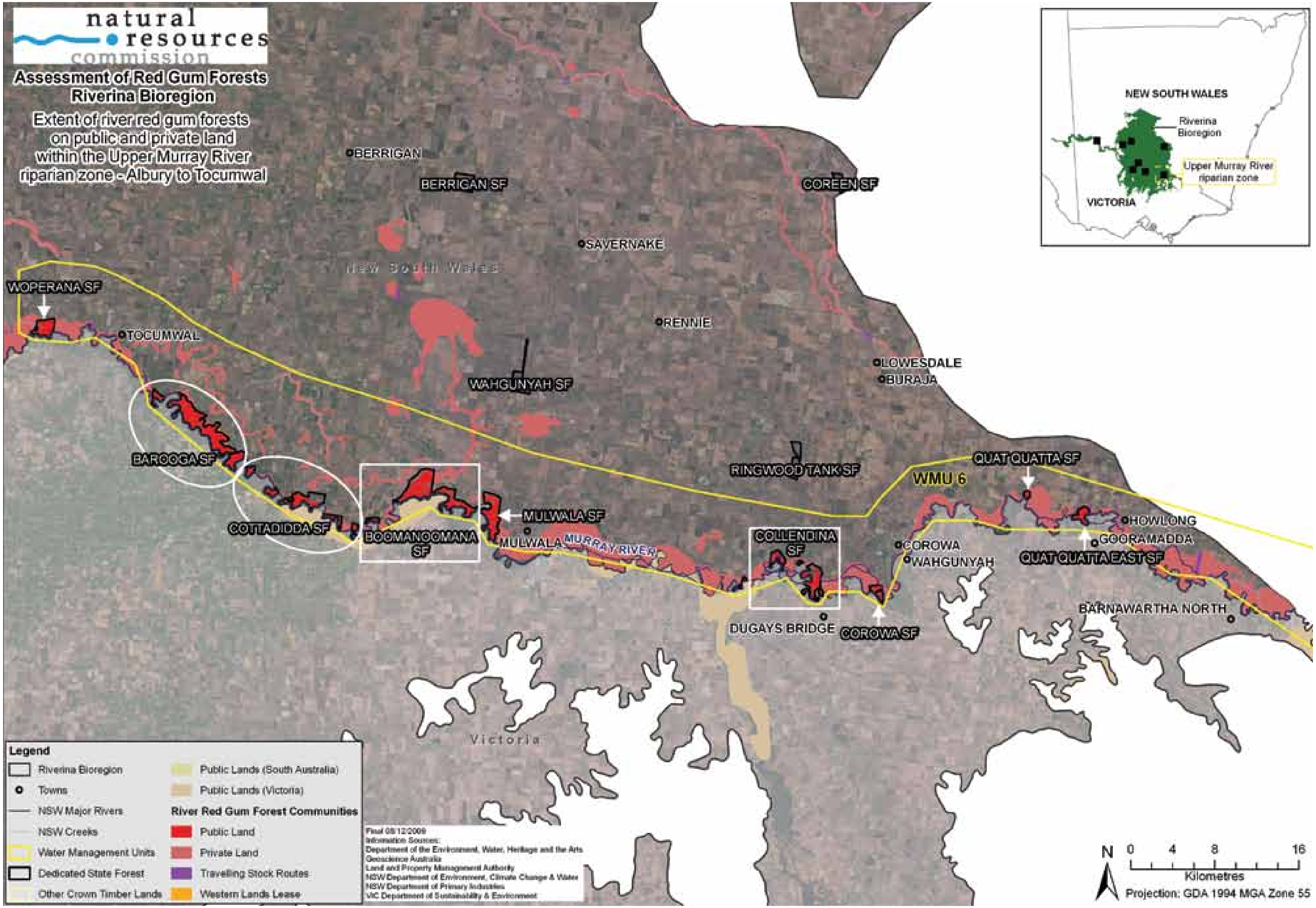
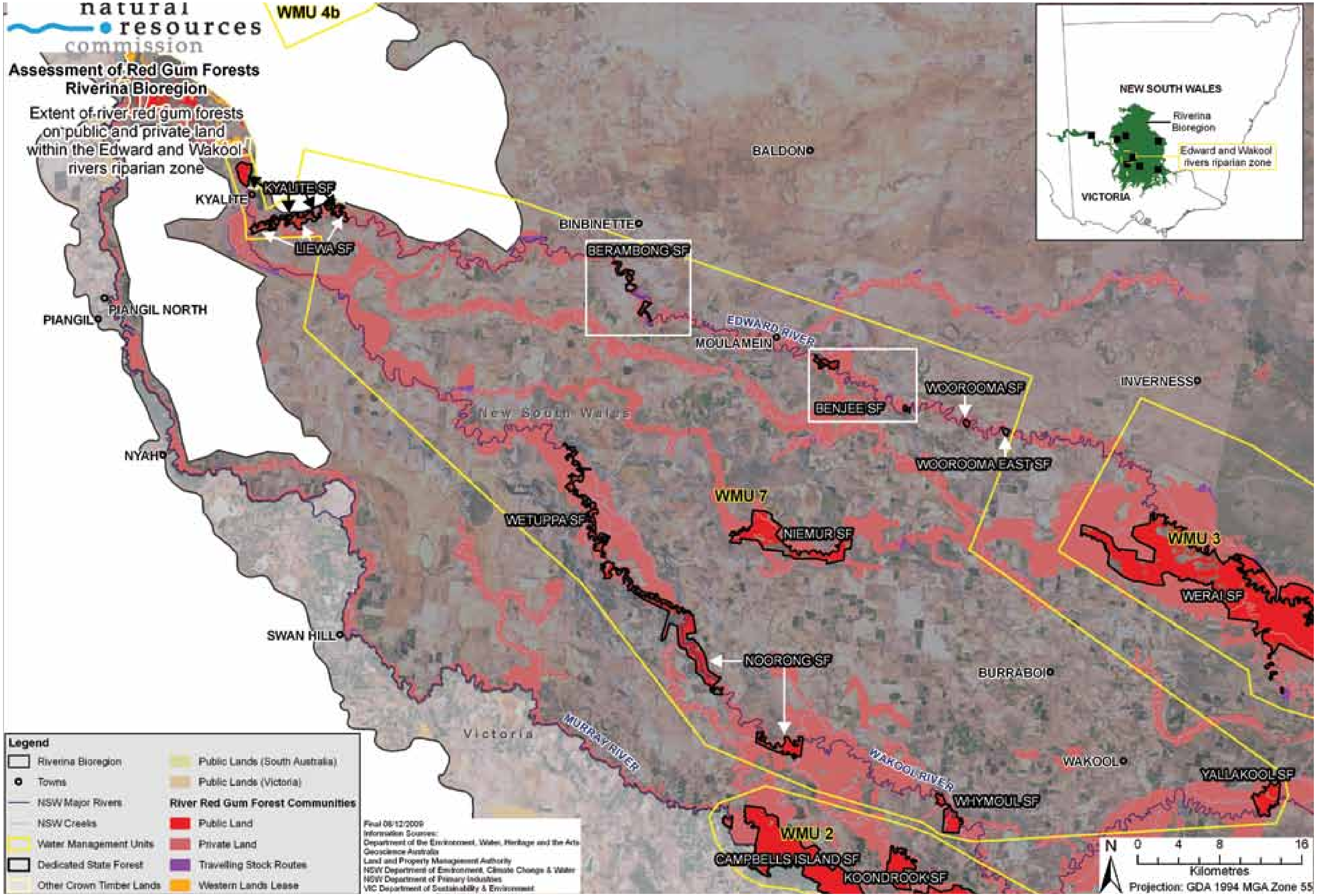


Figure 2.13: Extent of river red gum forests on public and private land within the Upper Murray River riparian zone – Albury to Tocumwal

Figure 2.14: Extent of river red gum forests on public and private land within the Edward and Wakool Rivers riparian zone



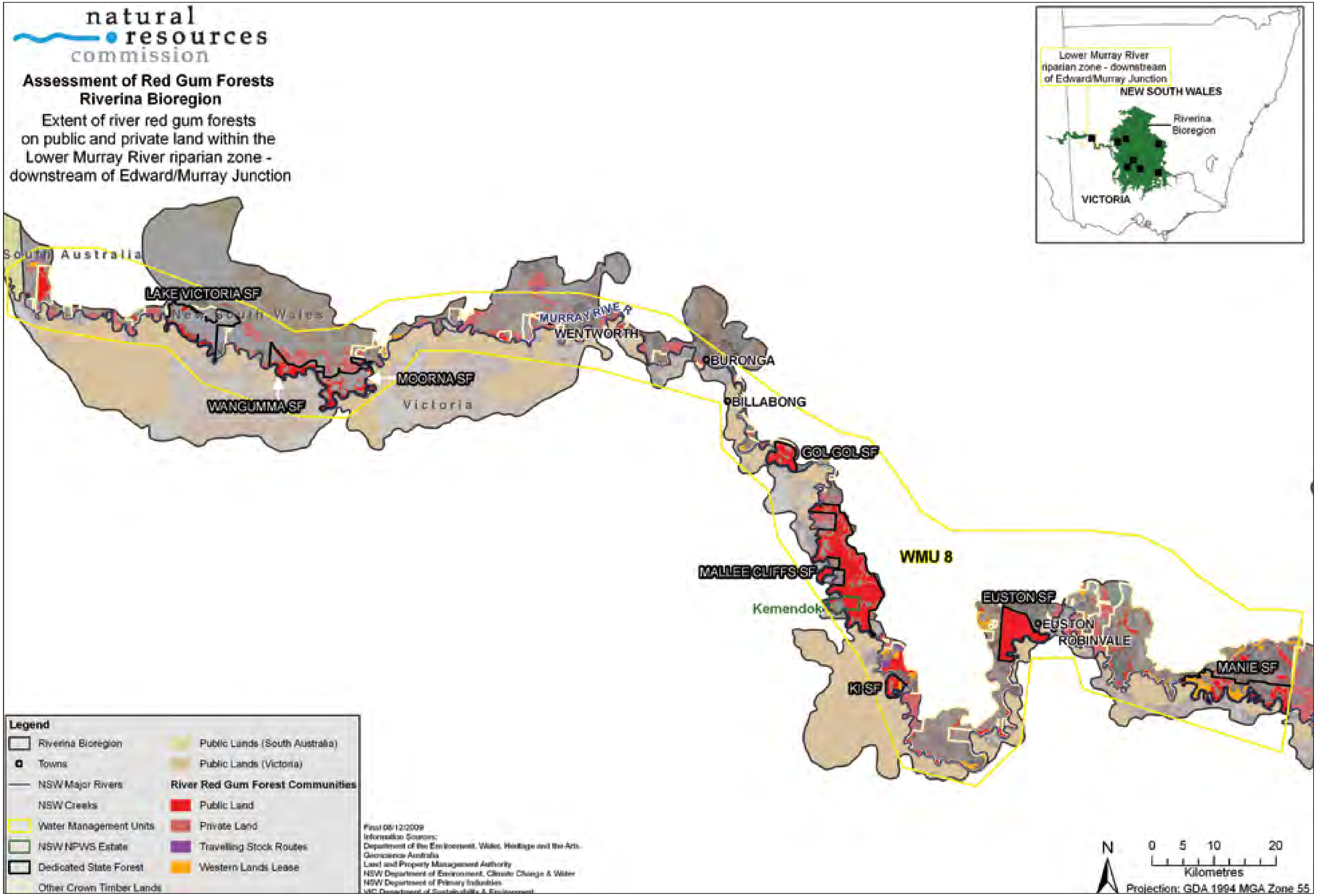


Figure 2.15: Extent of river red gum forests on public and private land within the Lower Murray River riparian zone – downstream of Edward/Murray Junction

Chapter 3

Institutional context

3.1 Overview

The river red gum forests of the Riverina bioregion are governed by a variety of policies, programs, instruments and organisations at the national, state, regional and local level. An understanding of the institutional context and the scales at which it operates is critical for considering future land use and management options for the forests under a forest agreement.

Forests NSW is a key manager of river red gum forests for multiple uses – production, conservation and recreation - on public lands in the Riverina bioregion. The NSW Department of Environment, Climate Change and Water also manage a range of different ecosystems for conservation purposes across the Riverina bioregion, including river red gum forests.

The Australian Government has obligations under international agreements and national legislation to ensure matters of National Environmental significance are protected and conserved. Water governance arrangements under the Murray-Darling Basin Authority are central to determining future water availability for the river red gum forests.

Landholders have a significant role in managing large areas of river red gum forests on private land. Catchment management authorities work with landholders and other institutions to improve ecosystem function across the landscape, for example vegetation connectivity between public and private tenures.

This chapter provides an overview of the arrangements under which the natural resources of the bioregion, particularly forests and water resources, are governed and managed.

This chapter supports Step 1 of the analytical framework by:

- assessing and describing the river red gum forests in the institutional landscape context.

Key findings of this chapter are:

- The institutional context is complex with a multitude of institutions and policies governing the management of the forests.
- National and state legislation and policy commits forestry operations to deliver on multiple objectives including commercial, conservation, recreation and cultural.
- Cross-jurisdictional management models have the potential to contribute to future management options.
- Management of these floodplain ecosystems needs to be attuned to meeting the diverse values of conservation, commercial production, cultural and social use in an increasingly dynamic water scarce future. Accordingly, current tenure models and management strategies need to be able to actively and adaptively manage the emerging challenges.
- There is a range of institutions, tenures and management models available to manage the red gum forests.

3.2 Legislative and policy framework

3.2.1 Framework at the national level

Forests in the Riverina bioregion are guided by several national policies, legislative instruments and government programs.

The National Forestry Policy Statement (Commonwealth of Australia, 1992) guides the management of Australia's forests. The National Forestry Policy Statement outlines agreed objectives and policies for Australia's public and private forests and commits all Governments to ecologically sustainable management of Australia's forests.

The National Forestry Policy Statement specifies a split in responsibilities. State governments have responsibility for forest management, local governments are responsible for land use planning and the Australian Government has responsibility for coordinating national approaches to environmental and industry development issues.

This policy was followed by the development of Regional Forest Agreements under the *Regional Forest Agreements Act 2002* (C'th). Regional Forest Agreements are 20-year plans that guide the conservation and management of native forests at a regional scale. They are negotiated between governments and in consultation with stakeholders. Regional Forest Agreements are seen to provide certainty for forest-based industries, forest-dependent communities and conservation. However, none of the Riverina bioregion is covered by a Regional Forest Agreement (and should not be confused with a NSW Forest Agreement made under the NSW *Forestry and National Park Estate Act 1998*).

The national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) also plays a role in the regulation of forestry activity. The EPBC Act is the Australian Government's key piece of environmental legislation covering environment and heritage protection and biodiversity conservation. It is administered by the Department of Environment, Water, Heritage and the Arts.

The EBPC Act focuses on protecting matters of national environmental significance. The relevant matters of NES for this assessment are wetlands of international importance (Ramsar sites), listed threatened species and ecological communities, and listed migratory species.[1]

Under the EPBC Act an action which has, will have or is likely to significantly impact upon any matter of NES requires referral to the Minister for the Environment for consideration of the need for approval under the Act, before it can proceed. The EPBC Act provides an exemption from the need for approval, if the action is undertaken in accordance with a Regional Forest Agreement, except for actions undertaken in a property included in a Ramsar wetland or incidental to another action whose primary purpose does not relate to forestry.

As there is no Regional Forestry Agreement in the Riverina bioregion, the EPBC Act potentially applies to forestry operations, if they entail significant impacts on any matter of national environmental significance.

[1] The Australian Government has entered into three bilateral migratory bird agreements – JAMBA (Japan), CAMBA (China) and ROKAMBA (Korea).

No referrals have previously been made to the Department of Environment, Water, Heritage and the Arts for forestry operations in the Riverina bioregion, and no approvals have been given. However, the NRC was required to address the EPBC Act under the terms of reference for this assessment (see **Box 3.1**).

The Ramsar Convention on Wetlands of International Importance is an intergovernmental treaty that provides the framework for national action and international cooperation on the conservation and use of wetlands and their resources. The Ramsar Convention is based on the principle of 'wise use' – maintaining the ecological character of wetlands through ecosystem-based management approaches whilst acknowledging sustainable development contexts.

There are several Ramsar listings in the Riverina bioregion (described in **Chapter 4** in more detail). Forests NSW has developed a draft Ecological Character Description for the NSW Central Murray State Forests to guide the management of the Ramsar-listed sites (GHD, 2009a). However, until endorsed by the Australian Administrative Authority for the (Ramsar) Convention, there is no formal Ramsar management plan for these sites.

Australia's Strategy for the National Reserve System 2009–2030 (Commonwealth of Australia, 2009) identifies priority actions for the ongoing development of a national system of protected areas and reserves for the next 20 years. This strategy describes the National Reserve System as the "cornerstone of (Australia's) efforts to protect terrestrial biodiversity".

The National Reserve System is made up of national parks, public reserves, Indigenous lands, reserves run by non-profit conservation organisations and ecosystems protected on private land. These protected areas are all managed for conservation according to international guidelines. The system's focus is to secure long-term protection for samples of all ecosystems and the plants and animals they support. It is intended to complement other measures to achieve conservation and sustainable use of biodiversity across the landscape.

Box 3.1: Requirements of the *Environment Protection and Biodiversity Conservation Act*

Under the terms of reference for this assessment, the NRC was required to ensure that this assessment meets the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The NRC consulted closely with the Commonwealth Department of Environment, Water, Heritage and the Arts to understand and implement this requirement during its assessment.

The NRC's assessment meets the requirements of the EPBC Act by identifying:

- matters of NES
- environmental values such as biodiversity
- activities occurring in the Riverina bioregion
- ways in which impacts can be avoided, controlled and/or reduced below the level of significance
- residual significant impacts which can then be addressed through specific measures under the EPBC Act.

There are a number of measures in the EPBC Act to protect matters of NES. These include:

- standard assessment and approval processes (Parts 7 , 8 and 9)
- Strategic Assessment (Part 10)
- Conservation Agreement (section 305).

While the NRC assessment could be used to inform any of these, a Conservation Agreement, in particular, could be closely aligned to the development of a NSW Forest Agreement.

In practice, a Conservation Agreement would be an agreement between the NSW and Australian Governments and could be made in conjunction with a Forest Agreement made under NSW's *Forestry and National Park Estate Act 1998*. A NSW Forest Agreement would not 'switch-off' the operation of the EPBC Act. However, a Conservation Agreement may include a declaration to the effect that actions in a specified class do not need approval under Part 9 of the EPBC Act, provided they are not likely to have significant impacts on the relevant matters of NES. The declaration may specify conditions relating to the taking of actions in that class.

For a conservation agreement to be suitable, the Federal Environment Minister would need to be satisfied that the agreement would protect and conserve biodiversity and the ecological character of a declared Ramsar wetland.

In the context of ongoing activities, such as forestry, in the river red gum floodplain ecosystems of the Riverina bioregion, this would mean the both the Forest Agreement and Conservation Agreement would:

- protect and conserve the ecological character of the Central Murray State Forests
- protect, conserve and manage the EPBC-listed threatened species, ecological communities, and their habitats in the Central Murray State Forests and Riverina bioregion
- manage river red gum forests in a way necessary for the protection and conservation the ecological character of the Central Murray State Forests
- abate processes and mitigate or avoid actions, that might adversely affect the ecological character of the Central Murray State Forests
- provide a net benefit to the conservation of biodiversity of the Central Murray Ramsar-listed State Forests and Riverina bioregion.

The management of protected areas within the National Reserve System are guided by and evaluated against the principles for assessing management effectiveness as outlined below:

1. **Values and Threats –** Assessments should address the effectiveness of management in protecting and enhancing values and reducing threats to those values.

2. **Landscape Context –** Assessments must take account of the relationship between protected areas and their biophysical and social landscape.

3. **Internationally Recognised Framework –** Assessments should be customised to local circumstances, but apply an internationally recognised system such as the IUCN World Commission on Protected Areas management effectiveness evaluation framework.

4. **Clear Objectives and Assessment Criteria –** Objectives and criteria for assessing management effectiveness must be clearly defined and understood by assessors, managers and stakeholders.

5. **Clear and Cost Effective Indicators –** Indicators used in assessments must be cost effective and meaningful and capable of integration with broader natural resource management indicators.

6. **Comprehensive Engagement and Capacity Building –** Managers, key stakeholders and those with expert knowledge about the environment should be engaged in the assessment process, where possible. Develop the capacity of Traditional Owners for the long-term effective management of protected areas.

7. **Qualitative and Quantitative Information –** Assessments should make use of all relevant available information rather than deferring assessment pending finalisation of precise quantitative data sets.

8. **Adaptive Management –** Assessments should be part of adaptive management processes responsive to climate change and other threats.

9. **Peer Review –** Internal assessments should be subjected to meaningful external peer review.

10. **Transparency –** Assessments should be publicly reported and routinely repeated to track trends.

(Commonwealth of Australia 2009a)

The National Strategy for the Conservation of Australia's Biological Diversity (Department of the Environment, Sport and Territories, 1996), fulfils Australia's obligations under the International Convention on Biological Diversity. A review of the National Biodiversity Strategy has been conducted by the Natural Resource Management Ministerial Council and a new strategy is expected to be endorsed late in 2009.

The Murray-Darling Basin Authority is currently in the process of developing a Murray-Darling Basin Plan. The Basin Plan is intended to be a strategic plan for the integrated management of the water resources (surface water and groundwater) in the Murray-Darling Basin in a way that promotes the objectives of the *Water Act 2007*.

The Murray-Darling Basin Authority released a conceptual framework for the Basin Plan in June 2009 which proposed the following key elements:

- sustainable diversion limits
- an environmental watering plan
- water quality and salinity management plan
- water trading rules
- social and economic analysis and implications of reforms
- a monitoring and evaluation plan (MDBA, 2009).

Sustainable diversion limits will limit the quantity of surface water and groundwater that may be taken from the Basin water resources as a whole, from individual water resource plan areas and particular parts of water resource plan areas within the Basin. These areas will be defined in the Basin Plan and will draw upon current state water resource plan areas.

Sustainable diversion limits will be set by the Murray-Darling Basin Authority and will define the level at which water in the Basin can be taken from a water resource without compromising key environmental assets, ecosystem functions, and environmental outcomes, or the productive base of the water resource. This will vary in different years and will take into account the effects of climate change and variability.

The environmental watering plan will "safeguard existing environmental water, plan the recovery of additional water, and coordinate the use of environmental water across the Basin" (MDBA, 2009). It is expected that the environmental watering plan will contain:

- environmental objectives for water-dependent ecosystems
- targets to measure progress against these objectives
- a management framework for environmental water
- the methods used to identify key environmental assets requiring water
- the principles and methods which will set the priorities for applying environmental water
- the principles to be applied in environmental watering.

The proposed draft Basin Plan will be produced by mid-2010, and following statutory consultation and refinement, the first Basin Plan will be released in 2011. Water Resource Plans will be developed for individual water resource plan areas within the Basin once the Basin Plan is in place and as the current state water resource plans expire. This will occur from 2014 to 2024 for NSW, and between 2019 and 2029 in Victoria.

The Murray-Darling Basin Authority also administers The Living Murray Program on behalf of the NSW, Victorian, South Australian and ACT Governments. The program focuses on recovering water for the Murray River specifically for the benefit of plants, animals and the millions of Australians it supports, along with improving the environment at six icon sites. The icon sites, chosen for their high ecological, cultural, recreational, heritage and economic value, are:

- Barmah-Millewa Forest[2]
- Gunbower-Koondrook-Perricoota Forest[3]
- Hattah Lakes
- Chowilla Floodplain
- Lindsay-Wallpolla Islands Lower Lakes, Coorong and Murray Mouth
- Murray River Channel.[4]

In addition to water recovered under The Living Murray Program, the Murray-Darling Basin Authority uses Living Murray water-planning frameworks to manage other environmental water allocations, such as River Murray Increased Flows (made available in the Murray River under the Snowy Agreement) and the Barmah-Millewa Environmental Water Allocation. The Australian Government is also purchasing water under its Water for the Future Program which must be managed in accordance with the Basin Plan (see **Chapter 8** for further discussion on this program).

Cuba State Forest on the Murrumbidgee river

3.2.2 Framework at the state level

Forests in the Riverina bioregion are also guided by several NSW state policies and legislative instruments. This section provides an overview on key legislation for forestry activities in NSW. A complete list of relevant legislation is provided in **Appendix 2**.

Legislation

State Forests in NSW are managed under the *Forestry Act 1916* (Forestry Act), developed to consolidate and amend the law in NSW relating to forestry and to provide for the dedication, reservation, control and use of State Forests, timber reserves and other Crown timber lands.

In addition, there is the *Forestry and National Park Estate Act 1998* (FNPE Act). This Act applies to all forestry areas within the state (excluding plantations), including Regional Forest Agreement areas. It provides a legal basis for the making of NSW Forest Agreements and for environmental assessment of forest areas prior to undertaking forestry operations. The FNPE Act's main objectives are to:

- make provision with respect to forestry operations and the national park estate following regional resource and conservation assessments
- transfer certain State Forest and other Crown lands to the national park estate or Aboriginal ownership
- provide for Ministerial agreements and a system of integrated approvals for future forestry operations.

NSW Forest Agreements are NSW Government documents setting out agreements between various NSW Ministers under the FNPE Act, and differ from the Regional Forest Agreements outlined earlier. NSW Forest Agreements outline various NSW agency obligations, tasks and undertakings or milestones. Regional Forestry Agreements milestones may also be mirrored in NSW Forest Agreements.

Where land is covered by a Forest Agreement, the FNPE Act applies in addition to the Forestry Act. Where no agreement exists, only the Forestry Act applies.

Some forestry operations are subject to approvals under the NSW Environmental Planning and Assessment Act 1979 (EPA Act). However, the Act does not apply to forestry operations approved under the FNPE Act. Forestry activities in an area zoned for that use in a Local Environment Plan do not require consent under Part 4 of the EPA Act (as guided by the Standard Instrument – Principal Local Environment Plan). Such activities do however require environmental assessment under Part 5 or Part 3A of the EPA Act. Under Part 5, a public authority may be both the proponent and determining authority. Under Part 5, if it is determined that if the activity is likely to have a significant effect on the environment, an environmental impact statement must be prepared in accordance with Schedule 2 of the *Environmental Planning and Assessment Regulations 2000* and publicly exhibited. The Minister for Planning determines whether proposals are of state or regional planning significance and to which Part 3A applies. Under Part 3A, environmental impact assessment is not prescribed but rather customised for each proposal by the Director-General's requirements.

Forests in NSW National Parks are managed under the *National Parks and Wildlife Act 1974*.

[2] Millewa Forest is included in NRC's assessment.

[3] Koondrook-Perricoota is included in NRC's assessment.

[4] Included in NRC's assessment.

State Plan

The NSW Government's State Plan *Investing in a Better Future* (2009), includes commitments to meeting state-wide targets for natural resources management. Natural resources management priorities include:

- increasing the extent and improving the condition of native vegetation and habitats
- continuing to build a 'Comprehensive, Adequate and Representative' reserve system, based on National Parks and Reserves as the core biodiversity conservation mechanism, as well as other public and private land conservation
- developing incentives to help farmers be both sustainable stewards of their land and successful producers
- securing water entitlements to protect iconic wetlands in the Lachlan, Murrumbidgee and Murray valleys and sustain river ecosystems
- managing fires, weeds, and pest species, through sustainable fire management, improved fire ecology science and tackling priority threats such as introduced weeds and pests
- introducing a new biodiversity strategy to protect threatened native species and ecosystems and address the impacts of climate change
- providing greater opportunities for Indigenous people to take part in management of Country, including joint management of national parks
- increasing the number of visits to State Government parks by 20 per cent by 2016.

Forestry policies

The regulatory regime for forestry policies encompasses approvals and licences issued pursuant to Commonwealth and NSW environmental legislation (outlined in **Appendix 2**).

Forests NSW prepare Ecologically Sustainable Forest Management Plans (ESFM Plans) that guide forest management for each of the 12 Forests NSW regions. ESFM Plans provide the strategic framework for managing planted and native forests over a five year period. They include broad strategies, performance indicators and measurable outcomes for forest management. The Riverina ESFM Plan incorporates the Ramsar management principles and replaced the Forest Management Plan for the Mid-Murray Forest Management Area (2002) as the management plan for the Ramsar sites.

In areas where a NSW Forest Agreement has been created, an Integrated Forestry Operations Approval under the FNPE Act is issued. The approval sets out the terms and conditions under which logging may occur. There are currently four Integrated Forestry Operations Approvals in NSW. The Upper North East, Lower North East, and Eden Integrated Forestry Operations Approvals commenced on 1 January 2000 and another for the Southern Region commenced on 13 May 2002. An Integrated Forestry Operations Approval for the Brigalow and Nandewar Community Conservation Area is currently being developed.

Conservation policies

Management of forest ecosystems will also be influenced by the NSW Biodiversity Strategy when this is finalised. Development of this strategy is a requirement of the *Threatened Species Conservation Act 1995*. The new strategy will encompass terrestrial, aquatic and marine biodiversity and will aim to meet the NSW's Government's obligations under the National Biodiversity Strategy. A 2008 discussion paper identifies a number of goals, principles and objectives for inclusion in the strategy (NSW Government, 2008). It adopts the NSW natural resource management targets for 2015 and proposes a 20-year strategic goal for widespread biodiversity recovery and increasing landscape connectivity, with the involvement of the whole community. It also proposes a 100-year vision of minimising the effects of climate change on biodiversity so that ecological change does not equate to loss of diversity.

The National Parks and Wildlife Service within the Department of Environment, Climate Change and Water released a New South Wales National Parks Establishment Plan 2008 (DECC, 2008). The plan states:

To conserve the full diversity of this state's landscapes, fauna and flora and to protect places of important Aboriginal and non-indigenous cultural heritage, more parks and reserves are needed. Furthermore, many existing reserves require augmentation to improve their size and configuration in order to better buffer and manage the values they were established to protect. To this end, the NSW Government is committed to the long-term objective of building a fully comprehensive, adequate and representative reserve system and providing increased opportunities for public nature-based recreation in a more diverse range of environments across NSW (DECC, 2008).

The plan "acknowledges that the establishment and management of DECC public reserves alone cannot ensure the achievement of healthy and sustainable landscapes, and that this can only occur through a broad range of conservation activities across the whole landscape on both public and private land".

Land use planning policies

Regional Strategies are the key instruments for managing and integrating development and guiding land use planning in NSW. These strategies consider issues such as service and infrastructure delivery, environmental sustainability, housing demand and economic development. They provide the broader context within which local strategies are formulated.

Although not statutory plans, Regional Strategies are given statutory force through the Local Planning Directions No. 30 – Implementation of Regional Strategies under Section 117(2) of the EPA Act. This direction gives legal effect to the vision, land use strategy, policies, outcomes and actions contained in Regional Strategies. Draft Local Environment Plans prepared by local councils must be consistent with Regional Strategies.

The Draft Murray Regional Strategy represents the NSW Government position on the future of the Murray Region. The strategy aims to protect the riverine environment of the Murray Region and includes model planning provisions for Local Environment Plans that control riverfront and river development, which requires local government consent. The model provisions establish setbacks for development on riverfront land being 40 metres from the top of the bank in urban areas and 100 metres in non-urban areas. The provision requires that development within these areas be "not likely to cause environmental harm". The management of riverfront land is important to landscape and ecosystem function. 'Off reserve' conservation policies are important to provide connectivity across the landscape.

The draft strategy identifies a significant number of 'high conservation areas' on both private and public lands. It directs local councils to protect these areas in the preparation of their Local Environment Plans through the use of environmental protection zones, local provisions and development controls. The draft strategy also requires that local government work with catchment management authorities to ensure that catchment action plan objectives are considered in planning.

3.3 Organisational framework

3.3.1 Roles and responsibilities of Australian Government agencies

There are a number of Australian Government agencies with responsibilities across the Riverina bioregion. **Table 3.1** lists these agencies and describes their responsibilities in relation to forest management and water management.

Many cross-jurisdictional matters are managed through the Natural Resource Management Ministerial Council. The council is the peak government forum for consultation, coordination

Table 3.1: Responsibilities of Australian Government agencies in forest and water management

Department of Environment, Water, Heritage and the Arts
• Develops and implements national policy, programs and legislation to protect and conserve Australia's environment and heritage. • Administers the EPBC Act. • Administers Australia's role for the Ramsar Convention on Wetlands of International Importance.
Department of Agriculture, Fisheries and Forestry
• Develops and implements policy, programs and legislation for sustainable forestry (among other things). • Oversees the implementation of the 1992 National Forest Policy Statement. • Supports research and innovation in the forestry industry and has provided innovation funding to support the production of higher-value products.
Murray-Darling Basin Authority
• Sets the framework for Basin-wide planning and management of water resources across the Basin. • Administers 'The Living Murray Program' on behalf of the NSW, Victorian, South Australian and ACT Governments. • Collaborates with Commonwealth Environmental Water Holder, state government agencies, catchment management authorities and regional environmental groups on environmental watering events.
National Water Commission
• Leads national water reform under the National Water Initiative. • Manages the Raising National Water Standards Program and the National Groundwater Action Plan.

and, where appropriate, integration of action by governments on natural resource management issues.

3.3.2 Roles and responsibilities of NSW Government agencies

There are a number of NSW Government agencies with responsibilities across the Riverina bioregion. **Table 3.2** lists these agencies and describes their responsibilities in relation to forest management and water management.

3.3.3 Roles and responsibilities of local government

Local governments are responsible for managing public land under the *Local Government Act 1993* and often manage Crown land in trust. Local government works with statutory agencies to protect landscape function. Depending on the local government policies, they manage issues of timber removal, weed control for land under local government control (an obligation under the *Noxious Weeds Act 1993*, and in the case of the Victorian authorities, native vegetation retention controls.

Table 3.2: Responsibilities of NSW Government agencies in forest and water management

Forests NSW

- Manages (and proponent) of forestry activities on Crown-timber land in NSW, as regulated by the *Forestry Act 1916* and the *Forestry and National Park Estate Act 1998.*
- Manages licensing mills and harvest contractors, and providing allocations of timber volumes to mills.
- Manages river red gum (and other) State Forests for commercial, ecological and social objectives.
- Prepares and implements ecological sustainable forest management plans to meet multiple objectives including prescriptions to minimise the environmental impact of harvesting and biodiversity management e.g. RAMSAR-listed areas under its control.

Department of Environment, Climate Change and Water

- Regulates activities that may impact upon the natural environment under a range of legislation.
- Undertakes biodiversity management planning to provide information and coordinated action for the conservation of the natural environment of NSW.
- Manages lands vested in the Minister of Environment, including National Parks, nature reserves, regional parks and state conservation areas.
- Approves Property Vegetation Plans to harvest timber from private lands.
- Manages environmental water allocations and licenses held by the NSW Government.
- Leads water management planning, water allocation and regulation under the NSW *Water Management Act* 2000, and granting water access licences and water use approvals.

NSW State Water

- Delivers bulk water to water infrastructure operators servicing irrigation areas in the region, including Murray Irrigation Limited, Western Murray Irrigation Limited, Coleambally Irrigation Cooperative Limited, Murrumbidgee Irrigation Limited and Jemalong Irrigation Limited.

Catchment management authorities

- Delivers NSW and Australian Government's NRM investment through catchment action plans.
- Invests in native vegetation (amongst other things) for rehabilitation, biodiversity conservation, water quality and bank stability – study area encompasses Lachlan, Murrumbidgee, Murray, and Lower Murray Darling CMAs (**Figure 3.1**).
- Approves Property Vegetation Plans under the NSW *Native Vegetation Act 2003*.
- Manages adaptive environmental water under *Water Management Act 2000.*

Land and Property Management Authority

- Manages state-owned lands in NSW, over a total area of approximately 12.7 million hectares including Western Lands Leases Travelling Stock Routes and State Parks.

NSW Department of Planning

- Establishes land use planning policy that guides development either directly or through local government land use planning schemes.
- Develops regional strategies that represent the NSW Government's priorities for managing a region's growth over the next 25 years.
- Consent authority for development of state significance under Part 3A of the *Environmental Planning and Assessment 1979*.

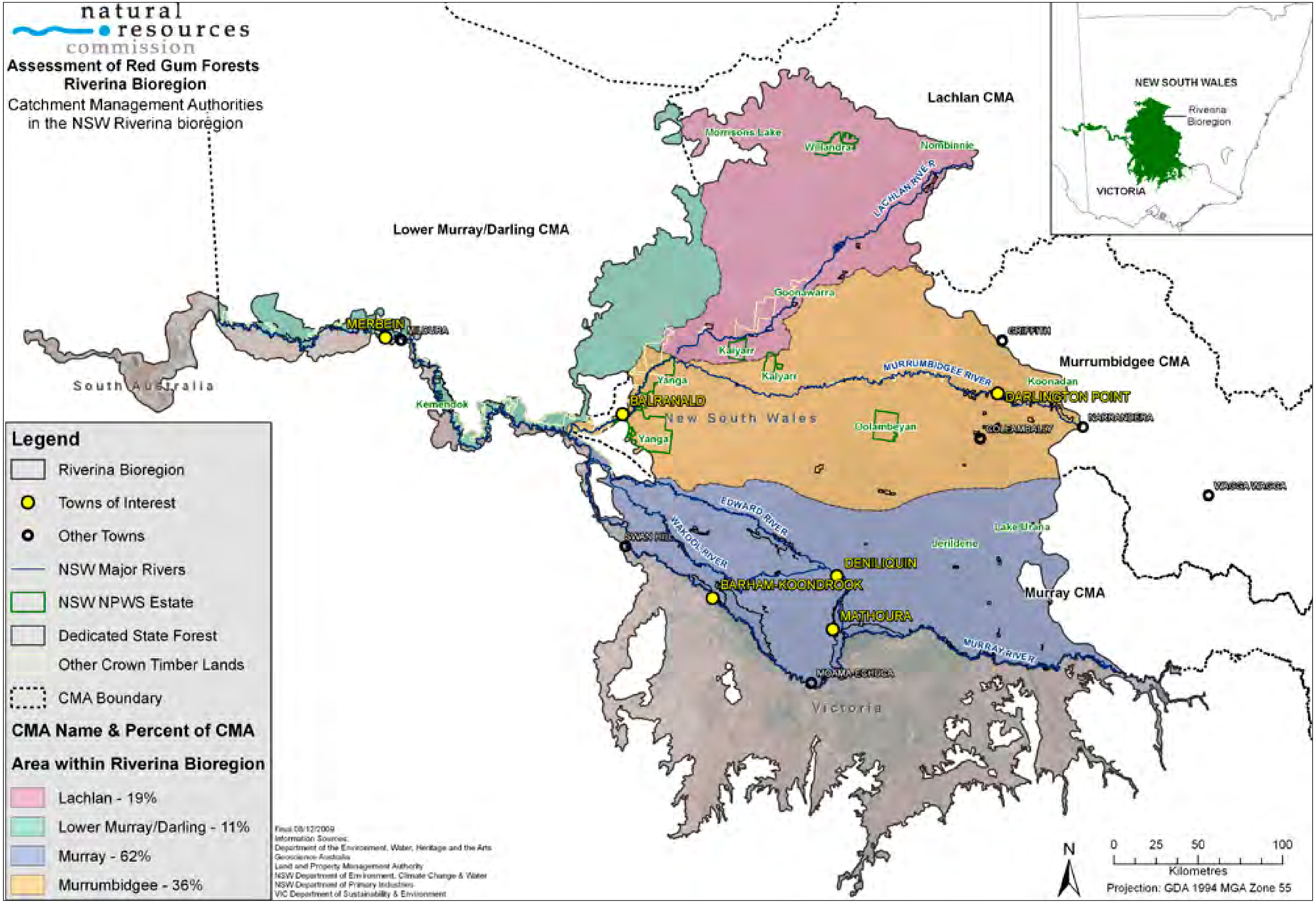
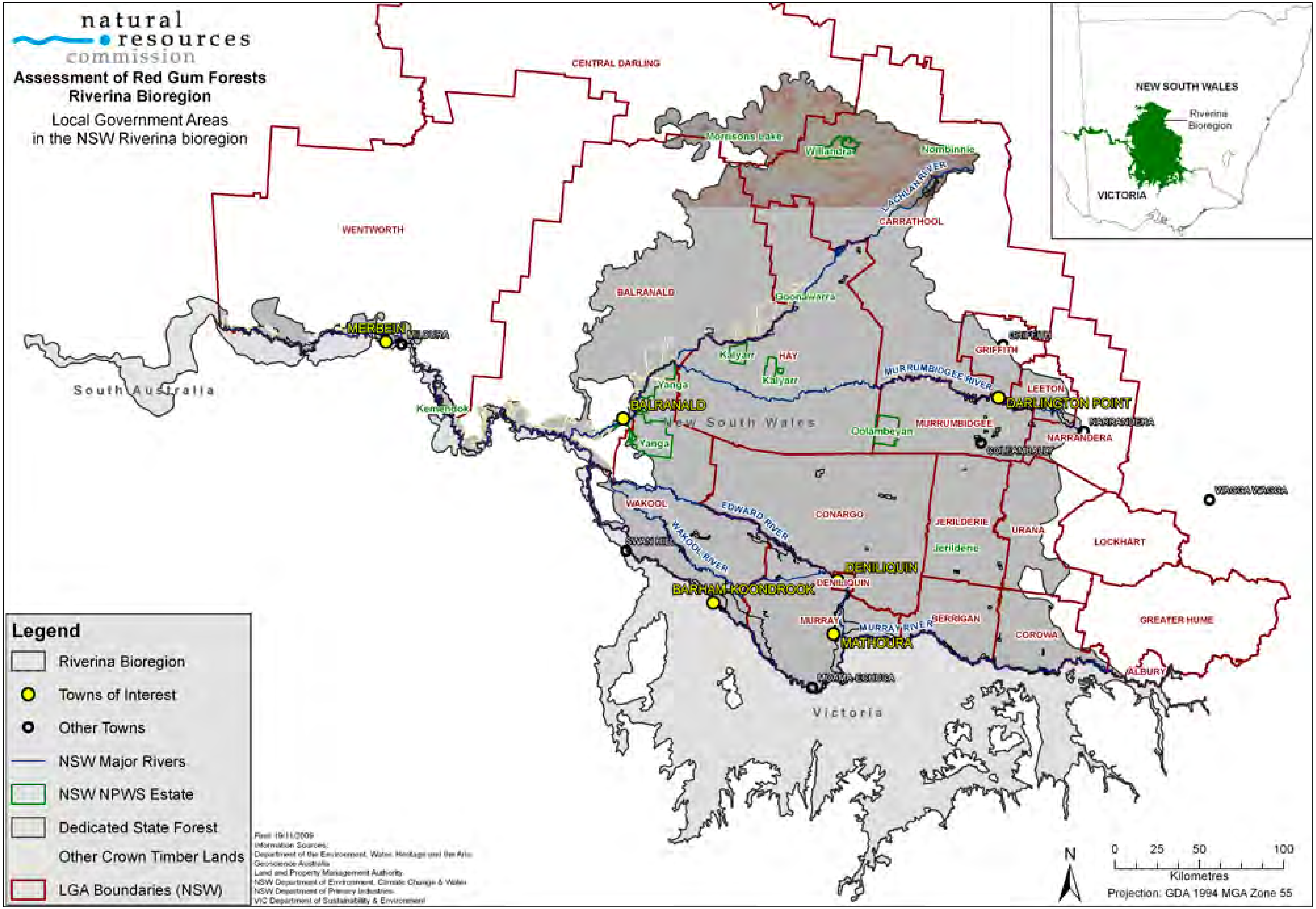


Figure 3.1: Catchment Management Authorities in the NSW Riverina bioregion

Figure 3.2: Local Government Areas in the NSW Riverina bioregion



Local governments have the primary responsibility for determining land use configurations and controls through Local Environment Plans. They employ a variety of planning tools such as zonings and development control plans, to achieve stated environmental outcomes. Local governments are also responsible for assessing development proposals on private land against established controls. Local government areas for the NSW part of the Riverina bioregion are shown in **Figure 3.2**.

3.4 Management arrangements for public land

This section describes the different public land use categories in the Riverina bioregion, and the management arrangements associated with each.

3.4.1 Crown land

Crown land is land that is owned and managed by the State Government. It accounts for over half of all land in NSW and includes:

- Crown lands held under lease, licence or permit
- community-managed reserves
- lands retained in public ownership for environmental purposes
- lands within the Crown public roads network
- other unallocated lands.

Crown lands managed by the Land and Property Management Authority (LPMA) should not be confused with other forms of Crown or state-owned lands such as National Parks, State Forests and state rail property. 'Crown timber land' includes State Forests, leased Crown land and purchase tenure land over which the government retains the right to take timber. Forestry on Crown land is required to be in accordance with relevant environmental regulation.

3.4.2 State Forests

Forestry on Crown-timber land is regulated primarily by the Forestry Act and the FNPE Act 1998. Where there is a NSW Forest Agreement the FNPE Act applies. Where no agreement exists, the Forestry Act applies.

Forests are managed to maintain ecological function and provide benefits to the community. For instance, Forests NSW encourages safe and responsible use of forests for commercial and private recreation, sport, tourism and training in a way that complements multiple-use, sustainable forest management (Forests NSW, 2005).

Management for multiple objectives is achieved through Forest Management Zoning. Forest Management Zoning is a land classification system which sets out in map format the way Forests NSW intends to manage forest areas (**Table 3.3**). Through Forest Management Zoning, a protected area network that comprises dedicated reserves and informal reserves can be created.

3.4.3 National Parks Estate

Under the *National Parks and Wildlife Act 1974*, the Director-General of the Department of Environment, Climate Change and Water is responsible for the care, control and management of all National Parks, historic sites, nature reserves, reserves, Aboriginal areas and state game reserves. State conservation areas, karst conservation reserves and regional parks are also administered under the Act, which establishes the management principles for each type of reserve (summarised in **Table 3.4**).

The categorisation of reserves under the *National Parks and Wildlife Act 1974* provides flexibility to accommodate a variety of uses. The application of this has been limited to a small number of regional parks predominately in and surrounding Sydney. Plans of management prepared for reserves in consultation with park users and the community provide the capacity to both control multiple uses and adhere to reserve management principles.

Table 3.3: State Forest Zone Types (NSW Forests, 1999a)

Zone type	Management principles
Special Protection (Zone 1)	Management to maximise protection of very high natural and cultural conservation values
Special Management (Zone 2)	Specific management and protection of natural and cultural conservation values, where it is not possible or practicable to include them in Zone 1
Harvesting Exclusion and Special Prescription (Zone 3)	Management for conservation of identified values and/or forest ecosystems and their natural processes, whilst also facilitating other management and production activities
General Management (Zone 4)	Management of native forests for timber production, utilising the full range of silvicultural options as appropriate and for conservation of broad area habitat and environmental values that are not dependant on the structure of the forest
Hardwood Plantation (Zone 5)	Management of hardwood plantations to maximise sustainable timber production on a continuing and cyclical basis
Softwood Plantation (Zone 6)	Management of softwood plantations to maximise sustainable timber production on a continuing and cyclical basis
Non-Forestry Use (Zone 7)	Management of cleared (non-forested) areas, such as those used for special developments
Areas for Further Assessment (Zone 8)	An interim zoning of areas where field investigation is required to determine final Forest Management Zoning

Table 3.4: National Parks Estate reserve types

Land type	Purpose
National Parks	Identify, protect and conserve areas containing outstanding or representative ecosystems, natural or cultural features or landscapes or phenomena that provide opportunities for public appreciation and inspiration and sustainable visitor use and enjoyment.
Nature reserves	Identify, protect and conserve areas containing outstanding, unique or representative ecosystems, species, communities or natural phenomena.
State Conservation Areas	Identify, protect and conserve areas that: • contain significant or representative ecosystems, landforms or natural phenomena or places of cultural significance • are capable of providing opportunities for sustainable visitor use and enjoyment, the sustainable use of buildings and structures or research • are capable of providing opportunities for uses permitted under other provisions of this Act in such areas, including uses permitted under section 47J of the Act (provisions relating to mining). These parks often contain important natural environments, which have been set aside for conservation, public enjoyment and potential mineral exploration.
Regional parks	Identify, protect and conserve areas in a natural or modified landscape that are suitable for public recreation and enjoyment.
Aboriginal areas	Identify, protect and conserve areas associated with a person, event or historical theme, or containing a building, place, object, feature or landscape: • of natural or cultural significance to Aboriginal people, or • of importance in improving public understanding of Aboriginal culture and its development and transitions.
Historic sites	Identify, protect and conserve areas associated with a person, event or historical theme, or containing a building, place, feature or landscape of cultural significance.

Table 3.5 lists the areas in the National Parks Estate in the Riverina bioregion.

3.4.4 Western Lands Leases

Nearly all the land in the Western Division is held under Western Lands Leases granted under the *Western Lands Act 1901*. The primary purpose of the Act is to ensure the appropriate management of this fragile environment.

Conditions are attached to each Western Lands Lease to ensure the land is managed sustainably, this requires that land must not be overgrazed and that approvals must be obtained to cultivate land and to subdivide or transfer the lease. The Western Lands Commissioner has the power to impose notices on lessees to destock areas, refrain from certain activities, or rehabilitate damaged or degraded areas.

Western Lands Leases are bought and sold in the same way as freehold property. However, when people 'buy' leases they are in fact only buying the improvements on the lease and the right to lease the land. Leaseholders do not have the right to exploit the fisheries, mineral or forestry resources on the land. These rights are retained by the Crown though the leaseholder may be paid a royalty if these resources are utilised.

3.4.5 Travelling Stock Routes

Travelling Stock Routes are Crown reserves historically formed to provide for the movement of stock into areas across the landscape. Travelling Stock Routes function as habitat corridors as they often contain good quality native vegetation and provide habitat for flora and fauna.

Travelling Stock Routes transect the bioregion and contain river red gum forest. They are also used for emergency refuge for stock during floods and drought, as well as some local agistment. In addition they often provide opportunities for recreation, particularly where these reserves include watercourses.

Travelling Stock Routes are managed by Livestock Health and Pest Authorities. Forests NSW requires the consent of the responsible Livestock Health and Pest Authority before it issues any licence to cut or remove timber on a controlled travelling stock route.

3.4.6 Crown reserve trusts

A reserve trust is a corporation established under the *Crown Lands Act 1989* to manage a Crown reserve. It is not a department of government. The trust is responsible – under the oversight of the Minister – for the care, control and management of a specific Crown reserve. Reserve trusts are not conducted for private profit.

The Crown reserve system promotes the cooperative care, control and management of Crown reserves by the community, with assistance from government agencies. Multiple uses of reserves are encouraged, where those uses are consistent with the purpose of the reserve.

Table 3.5: National Parks Estate in the Riverina bioregion
(NSW NPWS Estate layer, Version 2/2009, DECCW)

National Parks Estate	Hectares
Yanga State Conservation Area	33,717
Yanga National Park	29,043
Oolambeyan National Park	21,876
Willandra National Park	18,888
Kalyarr State Conservation Area	10,856
Kalyarr National Park	8,202
Yanga Nature Reserve	1,940
Kemendok Nature Reserve	1,069
Nombinnie Nature Reserve	700
Goonawarra Nature Reserve	411
Morrisons Lake Nature Reserve	320
Lake Urana Nature Reserve	302
Nombinnie State Conservation Area	199
Jerilderie Nature Reserve	37
Koonadan Historic Site	22
Total	127,582

Trusts can be managed by a community or local organisation, a local government council, Ministerial Corporation, community Trust Board or an administrator. A reserve trust enjoys a level of autonomy in its care, control and management of the Crown reserve. This includes entering into maintenance contracts, determining the development of the land (subject to Crown consent), setting entry fees and employing people to work for it. The Land and Property Management Authority provide each trust with operational support, financial assistance and guidance.

A government order or notification of reservation or dedication of a reserve sets out the purposes for which that reserve may be used. A reserve's use can only be consistent with or supporting the purposes stated in the reservation or dedication. The *Crown Lands Regulation 2006*, however, lists various additional purposes for which reserves can be used under temporary licenses.

3.4.7 Local Government Reserve

All local government public land must be classified by council as either 'community' or 'operational' land according to the *Local Government Act 1993*. 'Operational' land has no special restrictions other than those that may apply to any piece of land. Classification as 'community land' reflects the importance of the land to the community because of its use or special features. Community land is generally intended for public access and use. Community land must be categorised (e.g. Sportsground, Natural Area). All current and intended uses of the land must comply with the core objectives of the category assigned to that area of land.

3.5 Management arrangements for private land

Vegetation management on private land in non-urban areas is primarily governed by the *Native Vegetation Act 2003*. Under the *Native Vegetation Act* it is an offence to clear native vegetation unless it is approved, permitted or excluded. Clearing of remnant native vegetation or protected regrowth will only be approved if management actions improve or maintain environmental outcomes overall.

NSW/Victoria state border

Firewood for collection

The State Government holds the rights to the control, use and flow of all water in rivers, lakes and aquifers and water that occurs naturally on or below the surface of land. Landholders have the right to extract and use water for some purposes without permission from the State Government, but in other circumstances landholders may need to obtain permission. The NSW Office of Water is responsible for granting water access licences and water use approvals.

3.5.1 Private native forestry

Private native forestry is the sustainable logging of native vegetation on private property. Following changes to the *Native Vegetation Act*, harvesting of timber for the purposes of private native forestry requires approval through a private native forestry property vegetation plan. **Chapter 5** discusses private native forestry in more detail. **Appendix 10** lists specific management arrangements for private native forestry.

3.5.2 Conservation on private land

There are a number of programs through which landholders can voluntarily conserve areas of ecological value on their property. Programs range from non-binding, temporary agreements to binding agreements that are attached in-perpetuity to the title of the land. Such agreements may require landholders to carry out particular actions to improve the ecological value of the land, or may impose restrictions on use of the land.

In-perpetuity programs include Voluntary Conservation Agreements under the *National Parks and Wildlife Act*, and Conservation Agreements under the NSW *Nature Conservation Trust Act 2001*. The NSW Nature Conservation Trust uses a revolving fund to purchase high conservation value land, protect these values through an in-perpetuity agreement and resell the property so that the money can be 'revolved' to purchase other properties of high conservation value.

Private land may also be included in the National Reserve System. An example is the Toogimbie, a 4,600-hectare Indigenous Protected Area on the Murrumbidgee River. The reserve is owned and managed by the Nari Nari Tribal Council.

3.6 Cross-jurisdictional issues

Landscapes function with no regard for administrative or tenure boundaries. The Riverina bioregion transcends the borders of NSW, Victoria and South Australia. This section summarises the findings and recommendations of the recent assessment of river red gum forests in Victoria and discusses the potential for cross-jurisdictional management models to contribute to future management options.

3.6.1 River red gum investigation in Victoria

In April 2005, the Victorian Environmental Assessment Council (VEAC) commenced an investigation of river red gum forest of the River Murray and Victorian tributaries (VEAC, 2008). The purpose of the investigation was to:

- identify and evaluate the extent, condition, values, management, resources and uses of riverine red gum forests and associated fauna, wetlands, floodplain ecosystems and vegetation communities
- develop recommendations relating to the conservation, protection and ecologically sustainable use of public land.

The investigation area encompassed a 1,600-kilometre corridor of public land along the River Murray in northern Victoria (between Wodonga and the South Australian border), and along tributary rivers such as the Avoca, Goulburn and Ovens Rivers. The investigation was undertaken over a three-year period between April 2005 and July 2008.

The key findings of the investigation were that:

- There are many ecosystems that are under represented in the conservation reserve system
- There are numerous threatened species reliant on these habitats for survival
- There is a need to maintain and enhance connectivity of ecosystems across the landscape
- Protection of these ecosystems in conservation land categories will not be sufficient
- Appropriate water management, and particularly adequate environmental flows, are critical to the long-term survival of riverine forests and wetlands.

The investigation made the following principal recommendations:

- Establishment of five new (Barmah, Gunbower, lower Goulburn, Warby Range-Ovens River, and Leaghur-Koorangie) and two significantly expanded National Parks (Murray-Sunset and Terrick Terrick), primarily to protect threatened riverine forests and wetlands, and provide a long-term future for recreation and tourism based on the natural environment.
- Establishment of seven new and expanded parks along the River Murray and nearby major towns, to provide for recreation and tourism in natural bush settings.

- 21 expanded or retained and 29 substantially new nature conservation reserves to improve the protection of depleted and fragmented ecosystems.
- Environmental watering of the floodplain should take into account newly compiled information on water requirements to sustain the flood-dependent ecosystems of the region.
- Co-management with Aboriginal owners of the Barmah National Park and Nyah-Vinifera Park through boards of management, and Aboriginal Advisory Committees for a number of other park and reserve areas.
- The region's traditional camping, fishing, horse riding and vehicle access uses continue across all public land categories.
- Continuation of enjoyment of campfires and associated collection of firewood in all riverine parks and forests, except in high fire danger periods.
- Recreational hunting continues in 23 wildlife areas, as well as State Forest, water frontage areas and certain water storages.
- Grazing of stock cease on public land to give long-term protection to waterways and associated ecosystems.
- Timber harvesting to continue only in Gunbower, Benwell and Guttram State Forests.
- Zones in eight areas where domestic firewood collection under permit can continue.

The Victorian Government response to the recommendations included:

- creating four new national parks and expanding existing national parks in the region including funding for an additional rangers, and positions to undertake fencing and ecological thinning
- an assistance package for timber workers and the provision of opportunities for timber workers to participate in a range of active forest management activities, including ecological thinning
- adaptive management research and monitoring programs particularly in relation to climate change trends
- protecting and restoring river red gum forests and other vegetation communities on private land through incentive and market-based mechanisms
- a conservation land purchase program that focuses on acquiring areas of high conservation value when they come on the market
- commitment to an effective and efficient delivery and management of environmental water to protect environmental assets (DSE, 2009).

3.6.2 Cross-jurisdictional management models

The Natural Resource Management Ministerial Council's *Framework for future NRM programmes* proposes a framework for the future development of these programs across Australia (NRMMC, 2006). It encourages the participation and coordination of multiple jurisdictions for natural resource investments that

An Indigenous scar tree at Moon Moon State Forest involve Australia's international obligations and involve key issues such as adaptation to climate change and industry.

There have been a number of Australian examples of the application of cross-jurisdictional management models to natural resource management. These models may be relevant to the future management of the river red gums in the Riverina bioregion:

- The intergovernmental agreement on Murray-Darling Basin Reform
- The Australian Alps Co-operative Management Program between the NSW, Victorian, ACT and Australian Governments
- Forests NSW's management of forest health issues through liaison with and coordination of relevant state agencies in NSW and Victoria as well as local government, lessees and neighbouring landholders
- Great Artesian Basin Coordinating Committee. Queensland, NSW, South Australian and Northern Territory Governments.

The benefits of co-operative natural resource management models are derived from the system being managed as a 'whole' rather than its constituent parts. Benefits also arise from the consistent and co-ordinated treatment of issues.

3.7 Adaptive and collaborative governance

More decentralised and collaborative forms of natural resource governance have emerged in many countries, as the limits of centralised, 'command and control' modes become apparent (Gunningham, 2007). These forms have become common in the management of natural resources, particularly forests (Petheram et al., 2004).

Research in natural resource management stresses the need for 'adaptive' regional governance that is better able to operate at multiple scales within complex, dynamic social-ecological systems (Marshall, 2008). Adaptive governance systems must operate at a scale that provides the agility required to both learn from and respond to feedbacks from the ecological system. The scales of such governance structures may transcend traditional administrative boundaries.

Good governance systems that are 'adaptive' may be more adept at managing the complex interactions and uncertainty that typify periods of change. Key characteristics of adaptive governance include collaborative, flexible and learning-based approaches across different scales (Folke et al., 2009). Lockwood et al., (2008) outline a complementary suite of governance principles for regional natural resource management:

- legitimacy
- transparency
- accountability
- fairness
- interconnectedness
- capability
- adaptability.

Interconnected governance structures may comprise representatives from different interest groups. Such governance structures have the capacity to mobilise diverse social networks which further enhances adaptive capacity, the ability to deal with change and unexpected events (Brooks and Adger, 2005). The reciprocity-driven cooperation that typifies small groups may with supportive conditions advance to the scale of the large group (Marshall, 2008).

There have been a number of initiatives within countries and internationally to build networks of forests managed collaboratively such as the International Model Forests Network (IMFN). The IMFN seeks to foster participatory governance that:

- promotes voluntary and equitable participation
- ensures a wide diversity interests and values are represented
- promotes collaboration among stakeholders using consensus-based processes
- promotes the development of a shared vision for the management of the landscape
- fosters transparency and accountability within Model Forest governance structures (IMFN, 2009).

With much of the river red gum forests predicted to undergo further ecological transition and transformation, it is critical that institutional arrangements display sufficient characteristics and capacity to enable collaborative and adaptive governance.

Chapter 4

Current forest extent, condition and environmental values

4.1 Overview

Our landscapes need to function effectively and have the capacity to absorb change to support the environmental, social and economic values of the community (NRC, 2005). These values include healthy soils, rivers and vegetation which ensure key ecosystem processes – nutrient cycling, oxygen production, carbon storage and water purification – can continue to meet our needs. Our communities are placing increased emphasis on environmental values, in particular on biodiversity and threatened species. Governments at all levels have codified specific policies in legislation to protect and maintain biodiversity across the landscape.

The river red gum forests of the Riverina bioregion possess a wide range of environmental values. They are an important component of floodplain ecosystems in the bioregion and supply critical ecosystem services. They are listed as Wetlands of International Importance under the Ramsar Convention, and provide significant breeding habitats for many colonial wetland bird species and long-distance migratory wetland bird species. They also provide critical breeding and refuge habitats for inland forest fauna species and contain a mosaic of vegetation types, which support at least 60 terrestrial animal species and 40 plant species listed as threatened under NSW and Commonwealth legislation.

This chapter supports Step 2 of the analytical framework by:

- identifying current vegetation types and their extent across the bioregion
- describing the condition of river red gum forests and associated wetlands
- describing the ecosystem services provided by the forests and their specific ecological attributes
- outlining the status of threatened and endangered ecological communities and species
- detailing the implications of application of reserve principles to the forests.

The key findings of this chapter are:

- River red gum forests provide significant remnants of forest vegetation in a heavily cleared and modified bioregion, and provide refugia to support a diversity of ecological processes and species assemblages in a changing climate.
- Many river red gum vegetation communities are expected to change as a consequence of river regulation and climate change. Likely changes are the incursion of river red gum onto the periphery of some wetlands; the transition of some river red gum tall forests into river red gum open woodlands; and the transition of some river red gum and river red gum-box woodlands to derived shrublands and grasslands.
- The condition of river red gum within State Forests and elsewhere in the bioregion is generally in decline, largely as a result of poor health from substantially reduced river flows and altered flooding regimes. This decline is predicted to worsen under climate change. The threat status of the river red gum forests is assessed as vulnerable.
- The forest ecosystems function as an important component of a broader floodplain ecosystem and provide a variety of valued ecosystem services. Major floods will be required to maintain the resilience of the forest ecosystems, and the floodplains they are a part of, so that they can continue to provide these services.
- A total of 68 fauna species listed as threatened under Commonwealth or NSW legislation are known to utilise river red gum forests, including a number that are matters of national environmental significance. Many other declining species also use these forests as preferential or supplementary habitat.

Blackbox woodland with cane grass understorey – photo courtesy of DECCW (Michael Pennay)

4.2 Current vegetation type and extent

4.2.1 Major ecosystem types of the Riverina bioregion

A diversity of ecosystem types extends across the Riverina bioregion, from water-dependent forested wetlands dominated by river red gum (*Eucalyptus camaldulensis*) along the main channels and inner floodplains, to semi-arid woodlands, mallee, shrublands and grasslands on the dry rangelands. The following information is drawn from Rowe (2002) unless stated otherwise.

River red gum forest occurs along the major rivers, creeks, lakes and floodplains in the bioregion, where intermittent floodwaters supplement the sparse annual rainfall enough to saturate the root zone. This forest is typically found on grey soil, and comprises a river red gum overstorey, scant shrub layer and dense groundcover.

Black box woodland occurs along ephemeral watercourses and depressions, but is less frequently flooded than river red gum forest. In this ecosystem type there is often a more-established shrub layer and less dense groundcover.

Ephemeral wetlands appear within both types. They comprise moira grasslands, lignum, nitre goosefoot, canegrass cumbungi and other reedbeds or marshlands.

A range of other eucalypt woodland types, including inland grey box woodland, bimble box woodland and white cypress pine inland grey box woodlands, occur above periodically inundated areas. The dominant species is influenced by moisture availability, soil type, soil fertility and topography. Several other canopy species can co-occur, such as yellow box, bull oak, belah, dwyers mallee gum, kurrajong and black cypress pine. These communities vary from grassy woodlands to dry forests with a scant groundcover and healthy understorey.

Myall woodland is common on the gently undulating plains, and occurs on a range of soil types, from red-brown earths to grey and brown clays. It is likely to have been a dominant ecosystem type prior to clearing for grazing and irrigation.

Boree woodland occurs where there is periodic inundation from high-rainfall events. Boree is a favoured source of drought fodder for stock.

Mallee woodlands are found on the sandy dunes and plains in the northern parts of the bioregion. They are typically diverse in flora and fauna, and comprise distinct shrub and ground layers.

In the western parts of the bioregion, extensive rangelands of saltbush and bluebush are common. These chenopod shrubland are one of the most dominant ecosystem types within the Riverina. However, much of the chenopod shrubland converted to derived grasslands as a result of ongoing grazing.

Grasslands, both natural and derived, also cover extensive areas (McDougall, 2008). The extent of natural grasslands is poorly known, but they are thought to have once been widespread in the Deniliquin, Conargo, Jerilderie and Urana regions (McDougall, 2008).

4.2.2 Extent and threat status

The river red gum forests are major remnants of native forest and woodland vegetation in a largely cleared and modified bioregion. **Figure 4.1** shows the current extent of chenopod shrublands and grasslands, much of which has been derived from former woodlands and cropland in the NSW Riverina.

The river red gum ecosystems that occur west of the Great Dividing Range are referred to as inland riverine forests (Keith, 2004). They are structurally and floristically diverse across their climatic range, which varies from temperate in the east (mean annual rainfall of around 600 millimetres) to arid in the west (mean annual rainfall of around 250 millimetres).

The NSW Vegetation Classification and Assessment (NSWVCA) (Benson, 2008; Benson, et al., 2006) provides the most recent fine-resolution classification of river red gum forests and other vegetation in the Riverina. The NSWVCA describes each type in terms of its structure, diagnostic species and landscape context. It provides estimates of 'pre-European', 'current' and 'reserved' areas, and includes information on threats and appropriate management actions.

The NSWVCA uses all available mapping and reconnaissance data to estimate the area of vegetation types in the absence of complete and consistent mapping. It also provides the most recent published and peer reviewed area estimates for all vegetation types in the NSW Riverina (Benson, 2008; Benson et al., 2006) and has been adopted as the basis for area analyses in this report. However due to the composite nature of the data sets used to compile these figures, they are estimated to be accurate to plus or minus 30 per cent for extant vegetation (Benson, J., pers. comm., 2009).

It should be noted that the accurate estimation of pre-European areas of vegetation communities is difficult. In addition, the use of historical data to inform natural resource management strategies is nowadays being questioned. Some suggest that the impacts on ecosystems have been of such a large scale that it is no longer desirable or cost-effective to return systems to a past state (Chapin, et al., 2009).

Table 4.1 lists the pre-European and current area estimates (Benson et al., 2006; Benson, 2008) and reserved areas estimates (DECCW, unpubl. data) for each NSWVCA type mapped in State Forests.

The statistics for the reserved area of each type incorporate:

- all lands managed by DECCW
- all lands dedicated as Flora Reserves[1] in State Forests
- all lands managed as Indigenous Protected Areas
- all private lands over which a Voluntary Conservation Agreement or Property Agreement has been established for conservation purposes.

The threat status for each type is drawn from Version 3 of the NSWVCA database (Benson, unpubl. data). Threat status takes into account the current and former area of the vegetation type, as well as the magnitude and likely impact of key threatening

[1] Flora Reserves are categorised as Forest Management Zones 1 and 2.

Figure 4.1: Broad distribution of woody and non-woody vegetation in the NSW Riverina

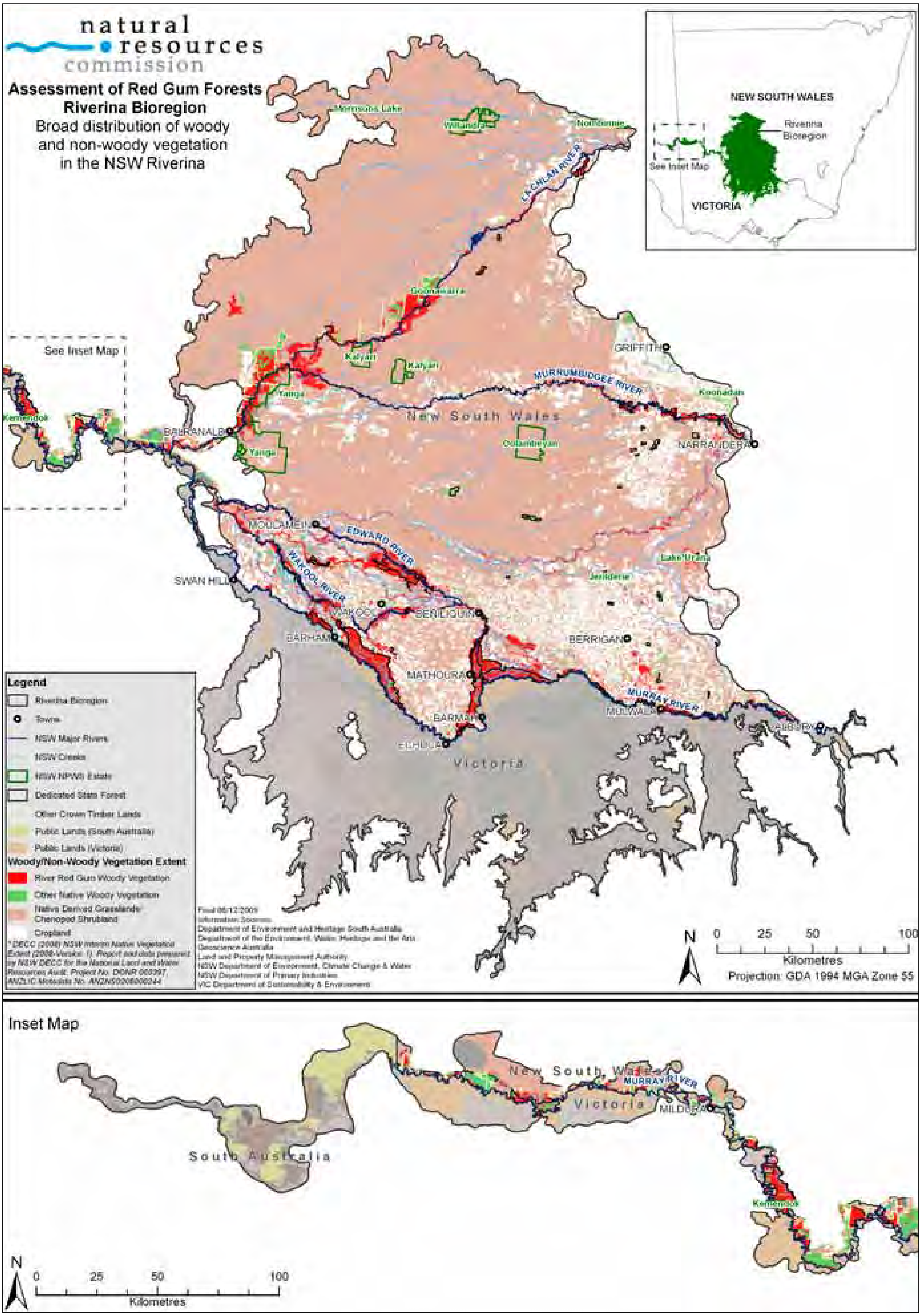


Table 4.1: Area and threat status of vegetation types occurring in the bioergion's State Forests

		Area (ha)			
NSWVCA No.	NSWVCA name	Pre-European	Current	Reserved	Threat status
2	**River Red Gum–Sedge** dominated very tall open forest in frequently flooded sites along major rivers and floodplains in south-western NSW	35,000	30,000	5,700	Vulnerable
5	**River Red Gum** herbaceous grassy very tall open forest on inner floodplains in the lower slopes sub-region of the NSW South West Slopes Bioregion and the eastern Riverina Bioregion	15,000	9,000	1,000	Vulnerable
7	**River Red Gum–Warrego Grass** herbaceous riparian tall open forest mainly in the Riverina Bioregion	100,000	85,000	2,800	Vulnerable
8*	**River Red Gum–Warrego Grass–Couch Grass** riparian tall woodland of the semi-arid (warm) climate zone (Riverina and Murray Darling Depression Bioregions)	30,000	25,000	100	Vulnerable
9	**River Red Gum–Wallaby-grass** tall woodland on the outer River Red Gum zone mainly in the Riverina Bioregion	35,000	12,000	0	Endangered
10	**River Red Gum–Black Box** woodland of the semi-arid (warm) climatic zone (mainly Riverina and Murray Darling Depression Bioregions)	70,000	40,000	100	Vulnerable
11	**River Red Gum–Lignum** very tall open forest or woodland on floodplains of semi-arid (warm) climate zone (mainly Riverina and Murray Darling Depression Bioregions)	60,000	35,000	12,600	Vulnerable
13	**Black Box–Lignum** woodland of the inner floodplains in the semi-arid (warm) climate zone (mainly Riverina and Murray Darling Depression Bioregions)	350,000	150,000	8,100	Vulnerable
15	**Black Box** open woodland with chenopod understorey mainly on the outer floodplains in south-western NSW (mainly Riverina and Murray Darling Depression Bioregions)	500,000	25,000	9,100	Near Threatened
16	**Black Box** grassy open woodland of rarely flooded depressions in south-western NSW (mainly Riverina and Murray Darling Depression Bioregions)	200,000	100,000	0	Near Threatened
17	**Lignum** shrubland of the semi-arid (warm) plains (mainly Riverina and Murray Darling Depression Bioregions)	400,000	150,000	3,600	Vulnerable
19	**Cypress Pine** woodland of source-bordering dunes mainly on the Murray and Murrumbidgee River floodplains	1,000	300	0	Endangered
21	**Slender Cypress Pine–Sugarwood–Western Rosewood** open woodland on sandy rises mainly in the Riverina and Murray Darling Depression Bioregions	4,000	800	0	Critically Endangered
26	**Weeping Myall** open woodland of the Riverina and NSW South-western Slopes Bioregions	1,600,000	160,000	800	Critically Endangered
28	**White Cypress Pine** open woodland of sand plains, prior streams and dunes mainly of the semi-arid (warm) climate zone	300,000	8,000	1,600	Vulnerable
57	**Belah/Black Oak–Western Rosewood–Wilga** woodland of central NSW including the Cobar Peneplain Bioregion	350,000	200,000	0	Near Threatened
70	**White Cypress Pine** woodland of central NSW	200,000	70,000	0	Vulnerable
74	**Yellow Box–River Red** Gum tall grassy riverine woodland of NSW South West Slopes and Riverina Bioregions	30,000	8,000	0	Endangered

* River red gum type occurring in Riverina, but not mapped in State Forests.

Table 4.1 NSW threat status of vegetation types occurring in State Forests in the Riverina continued

		Area (ha)			
NSWVCA No.	NSWVCA name	Pre-European	Current	Reserved	Threat status
75	**Yellow Box–White Cypress Pine** grassy woodland on deep sandy-loam alluvial soils of the eastern Riverina and western NSW South-western Slopes Bioregions	100,000	8,000	300	Endangered
80	**Inland Grey Box–White Cypress Pine** tall woodland on loam soil on alluvial plains of NSW South-western Slopes and Riverina Bioregions	800,000	140,000	400	Endangered
153	**Black Bluebush** low open shrubland of the alluvial plains and sandplains of the arid and semi-arid zones	1,500,000	900,000	8,100	Near Threatened
157	**Bladder Saltbush** shrubland on alluvial plains in the semi-arid (warm) zone including Riverina Bioregion	1,500,000	600,000	2,500	Vulnerable
160	**Nitre Goosefoot** shrubland on clays of the inland floodplains	50,000	100,000	8,200	Least Concern
164	**Cotton Bush** open shrubland of the semi-arid (warm) zone	50,000	460,000	7,200	Least Concern
237	**Riverine Inland Grey Box** grassy woodland of the semi-arid (warm) climate zone	15,000	4,000	0	Endangered
249*	**River Red Gum** grass swamp woodland to open woodland on cowals (lakes) and associated flood channels in central NSW	6,500	3,000	100	Vulnerable
336	**Rush–Sedge Common Reed** mainly lentic channel wetland of the Upper Murray and Mid-Murrumbidgee River floodplains in the NSW South Western Slopes Bioregion	3,000	1,500	0	Near Threatened

* River red gum type occurring in Riverina, but not mapped in State Forests.

processes. The threat status of several river red gum types was upgraded in September 2009 to 'vulnerable' in response to the observed decline of these types over the past few years. Note, river red gum communities are not currently listed as vulnerable under either NSW or Commonwealth legislation.

The 'reserved areas' above do not include areas of State Forest categorised as Forestry Management Zone 3: Harvesting Exclusions and Special Prescription. The inclusion of Forest Management Zone 3 would increase the 'reserved area' of river red gum by 19,000 hectares (or 62.5 per cent).

The *Nationally Agreed Criteria for the Establishment of a Comprehensive Adequate and Comprehensive Reserve System for Forests in Australia* (the JANIS criteria) recognise different types of public land reserves:

- Dedicated reserves – equivalent to IUCN categories I, II, III or IV. These include reserves under the *National Parks and Wildlife Act 1974* and Flora Reserves under *Forestry Act 1916*. These reserves have security of tenure as parliamentary action is required to revoke them.
- Informal reserves – to be used where it is not possible (or practicable) to include conservation values in dedicated reserves.
- Values protected by prescription – for values that are needed to contribute to the 'Comprehensive, Adequate and Representative' reserve system but where they are not able to be included in dedicated or informal reserves. These values can be protected by codes of practice or management plans, including through forestry prescriptions.

Measures taken by Forests NSW through forest management planning, such as Forest Management Zone 3 and timber harvesting prescriptions, are considered 'values protected by prescription' and outside of the reserve system. However, these measures do give some protection to natural values and therefore complement the reserve system.

The exclusion of areas of State Forest categorised as Forest Management Zone 3 from 'reserved areas' follows the precedent established in the VEAC river red gum forest investigation and the Brigalow-Nandewar bioregional assessment.

Table 4.2: Vegetation groups identified in the Riverina bioregion

Vegetation group	Equivalent NSWVCA No.(s)
Box–White Cypress Woodland	75, **76**, 80, **86**
Chenopod Shrubland	**18**, **63**, **152**, **153**, **154**, 157, **159**, 160, **163**, 164, 166, 216, 236
Freshwater Wetlands	**12**, **53**, **182**, **238**, 336
Ironbark Shrubby Woodland	**217**, **243**
Mallee Woodland	**190**
River Red Gum Very Tall Forest	2
River Red Gum Tall Open Forest	5, 7
River Red Gum Woodland	8, **9**, 11, **249**
River Red Gum–Box Woodland	10, 13, 74, 237
Riverine Box Woodland	15, 16
Riverine Shrubland	17, **240**
Semi-arid Acacia Woodland	**23**, 26, **134**, **139**
Semi-arid Oak Woodland	**20**, 57, **58**
Slender Cypress Woodland	21
Swamp Grassland	**24**, **47**, **181**, **242**
Tussock Grassland	**44**, **45**, **46**, **50**, **165**, **250**
White Cypress Woodland	19, 28, **48**, 70

Note: Bold text represents those NSWVCAs known to occur in the Riverina bioregion, but not mapped in State Forests.

4.2.3 Distribution of vegetation groups

NSWVCA vegetation types occurring in the Riverina bioregion were collated into broader 'vegetation groups' for the purpose of reporting and mapping within State Forests and Western Lands Leases.

Table 4.2 lists vegetation groups in the bioregion and their associated NSWVCA types. There are three main vegetation groups for forest and woodland dominated by river red gums:

- NSWVCA 2 River Red Gum Very Tall Forest
- NSWVCA 5, 7 River Red Gum Tall Open Forest
- NSWVCA 8, 9, 11 and 249 River Red Gum Woodland.

Two other vegetation groups are known to support river red gum. The river red gum–box woodland vegetation group includes NSWVCA types 10, 13, 74 and 237. The riverine box woodland group is dominated by black box and includes NSWVCA types 15 and 16.

The distribution of vegetation groups has been mapped across all State Forests in the Riverina bioregion (based on Binns mapping, **Figure 4.2**), and also specifically for the following individual water management units:

- Millewa forests (**Figure 4.3**)
- Koondrook-Perricoota and Campbells Island forests (**Figure 4.4**)
- Werai forests (**Figure 4.5**)
- Murrumbidgee forests (**Figures 4.6 and 4.7**)
- Lachlan forests (**Figure 4.8**)
- Upper Murray River riparian zone forests (**Figure 4.9**)
- Wakool and Edward rivers forests (**Figure 4.10**)
- Lower Murray River riparian zone forests (Figure **4.11**).

Figure 4.2: Distribution of vegetation groups within all State Forests in the Riverina bioregion

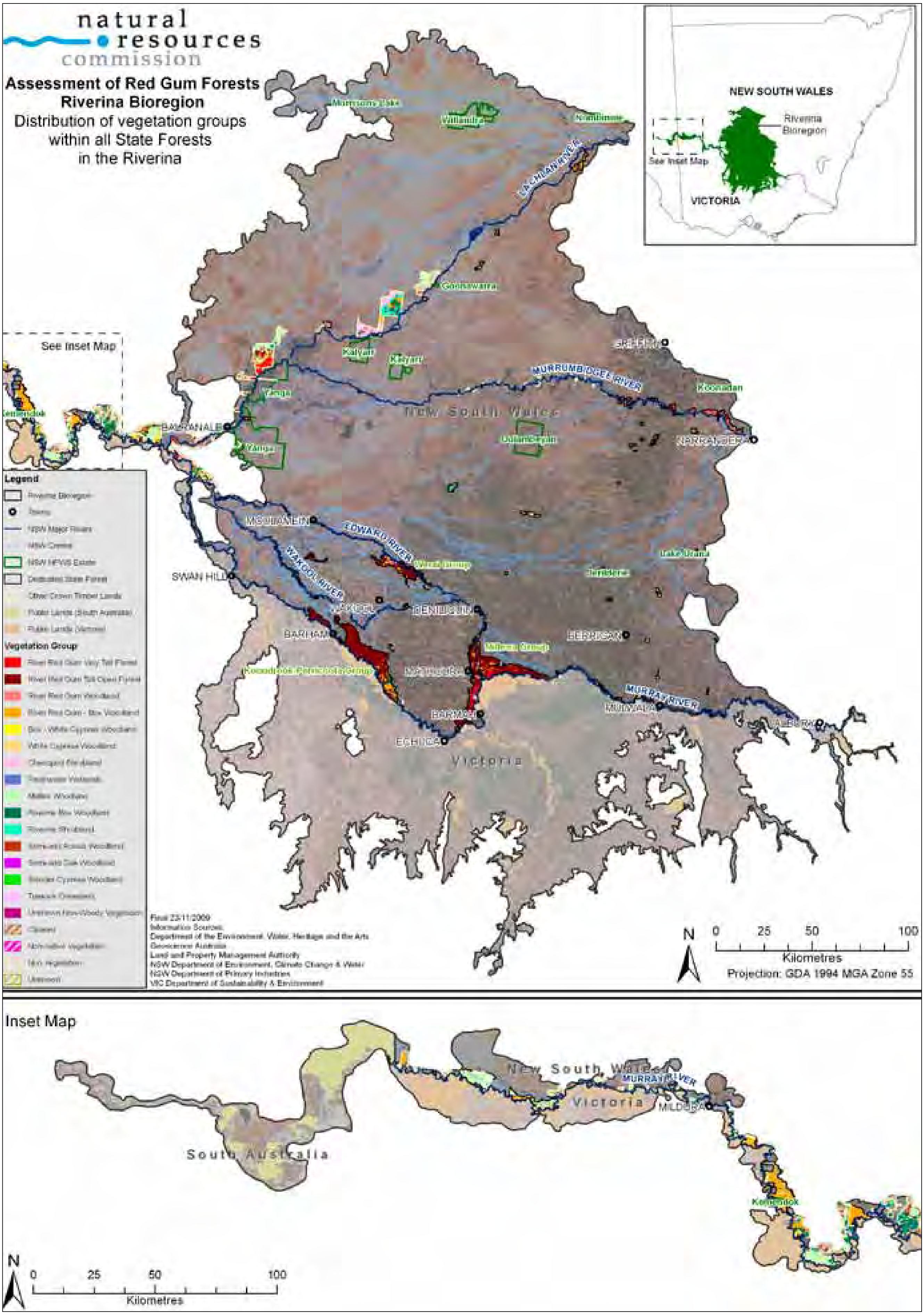


Figure 4.3: Distribution of vegetation groups within the Millewa forests

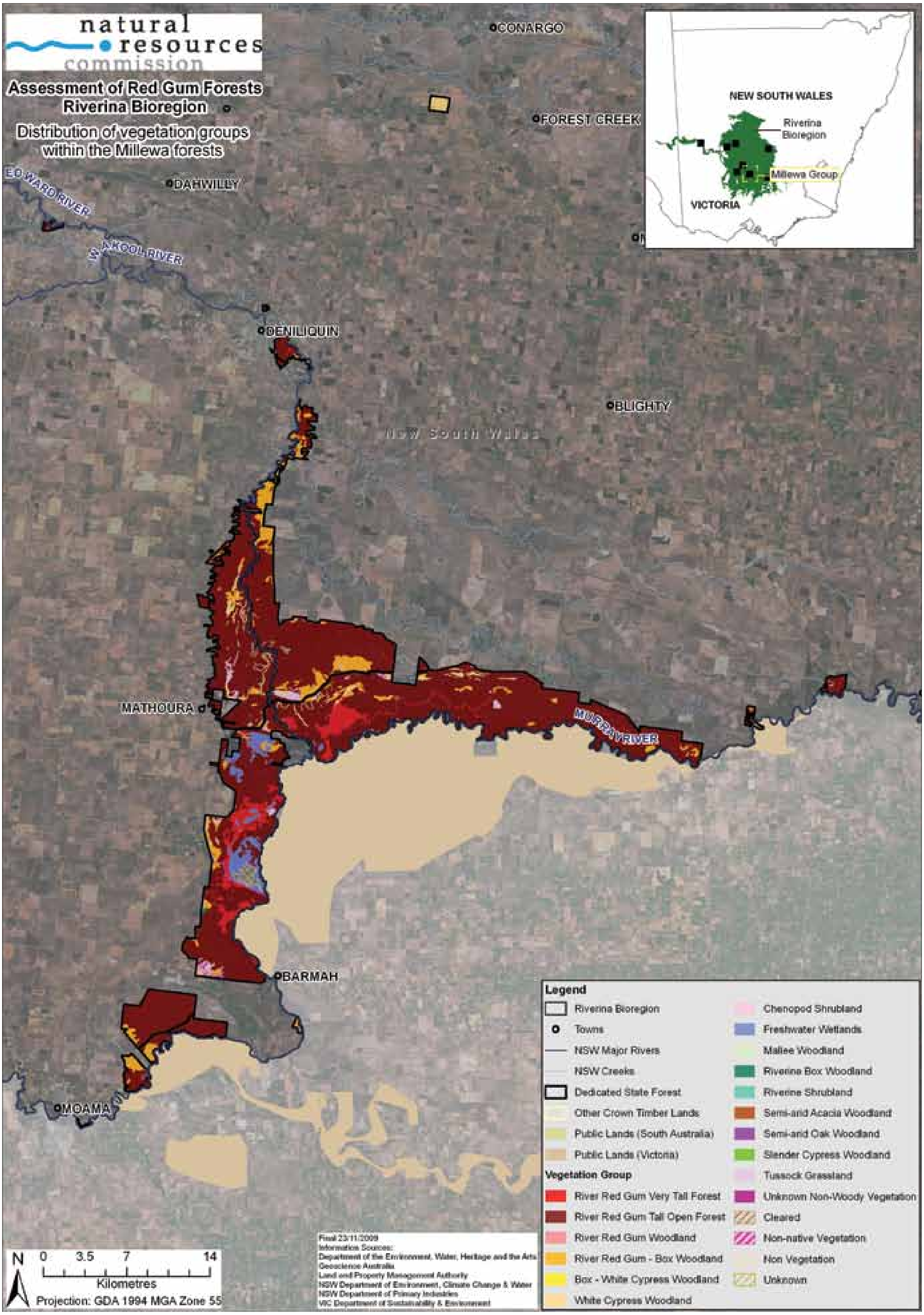


Figure 4.4: Distribution of vegetation groups within Koondrook-Perricoota and Campbells Island forests

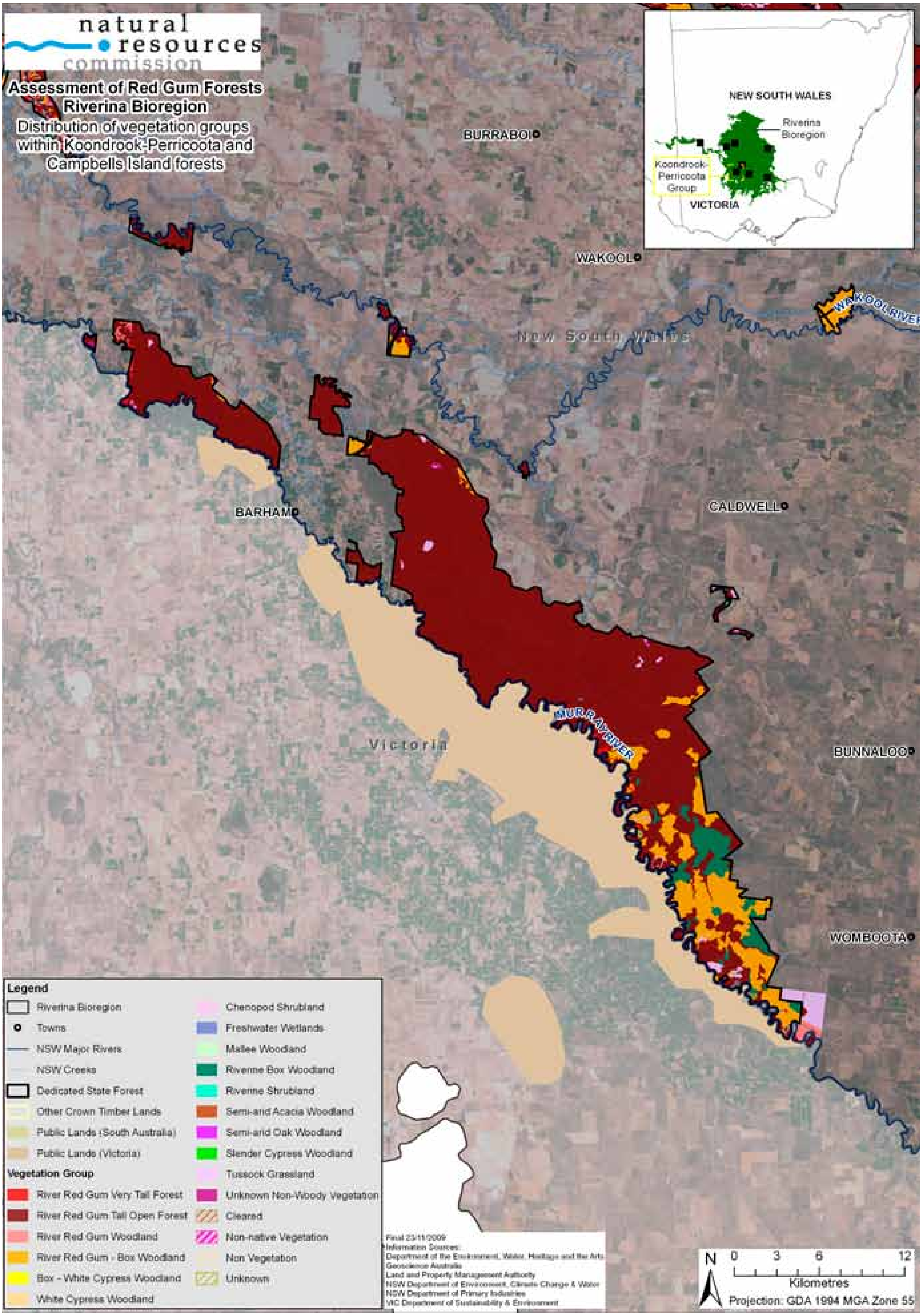


Figure 4.5: Distribution of vegetation groups within the Werai forests

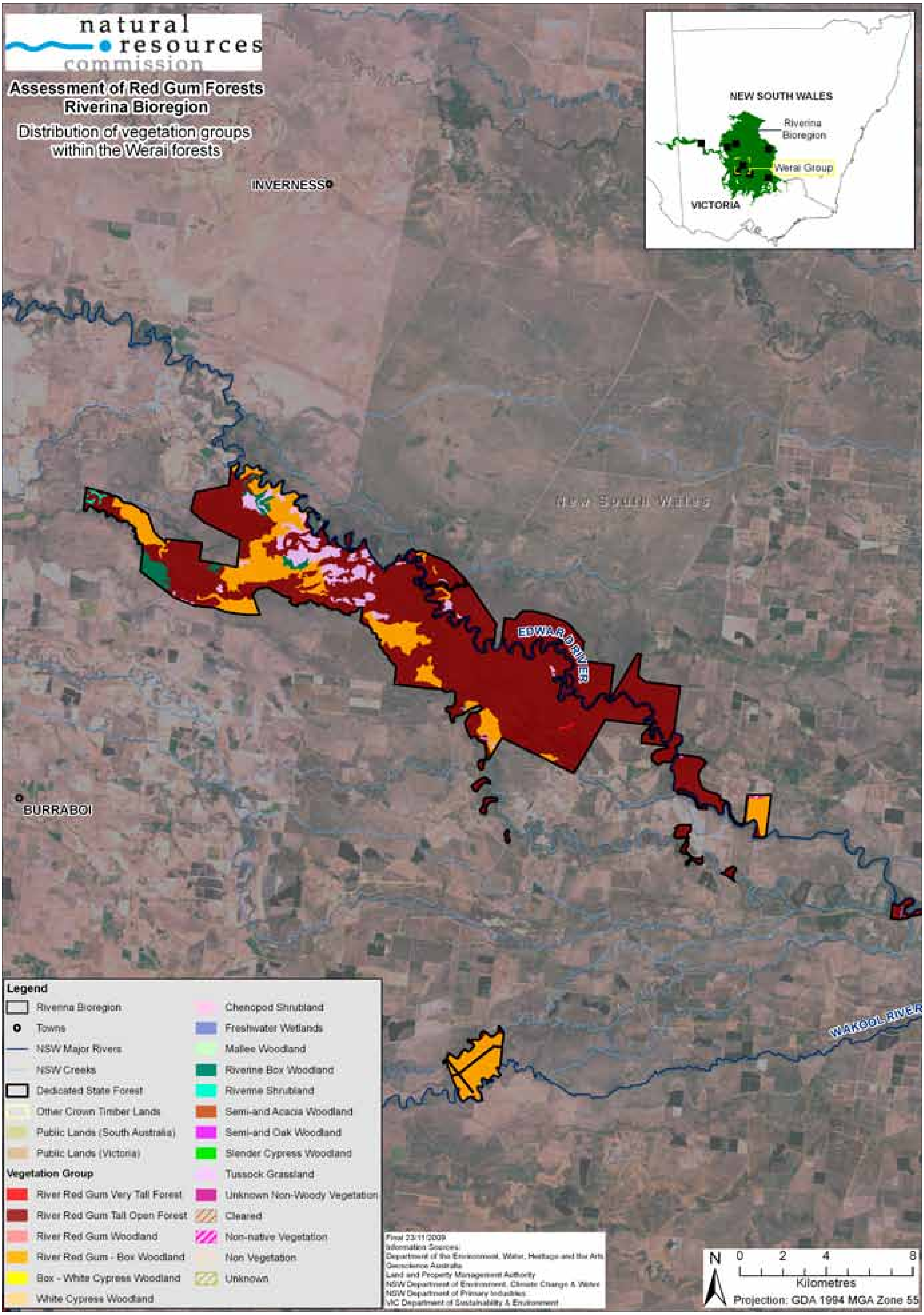
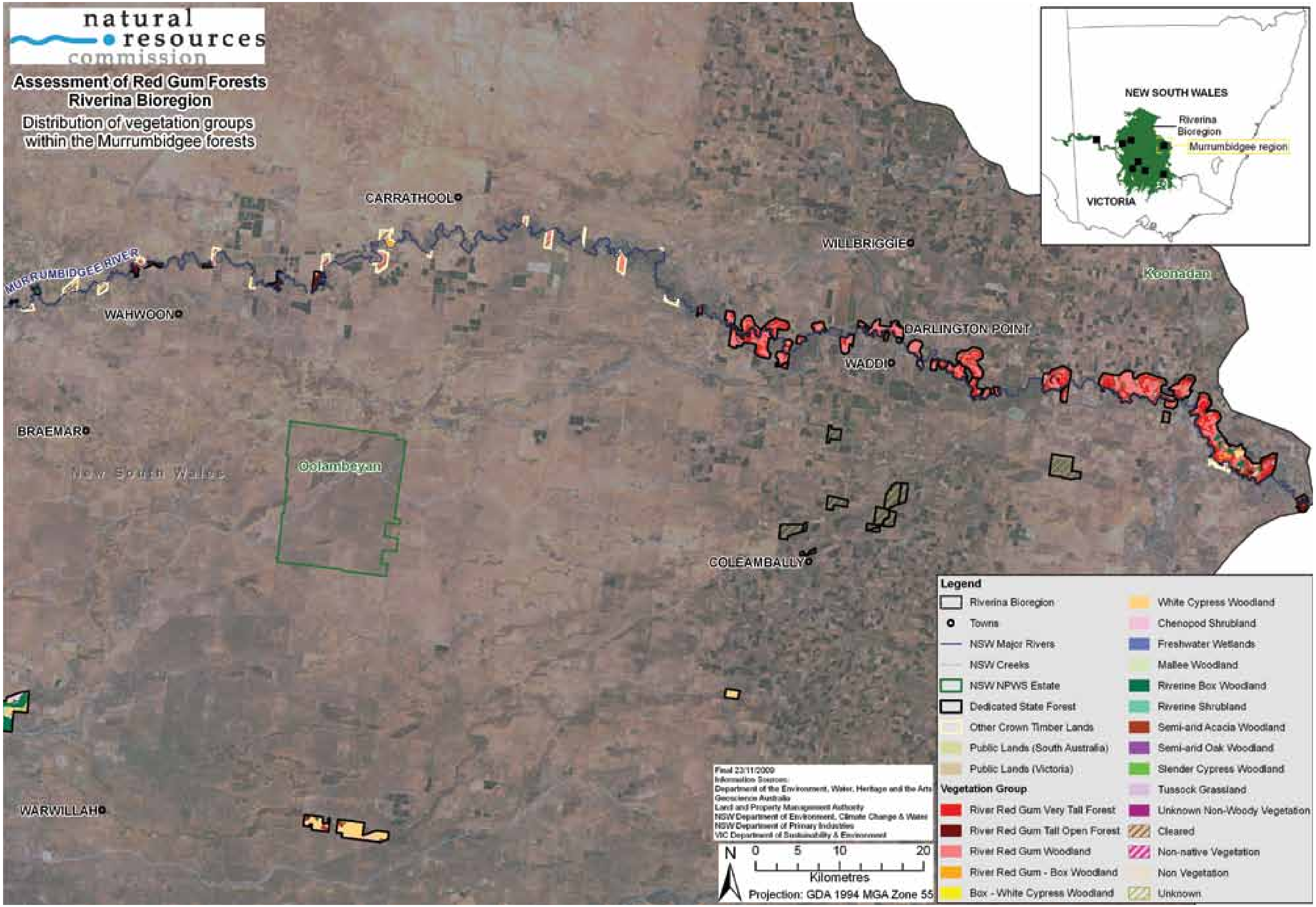


Figure 4.6: Distribution of vegetation groups within the Murrumbidgee forests



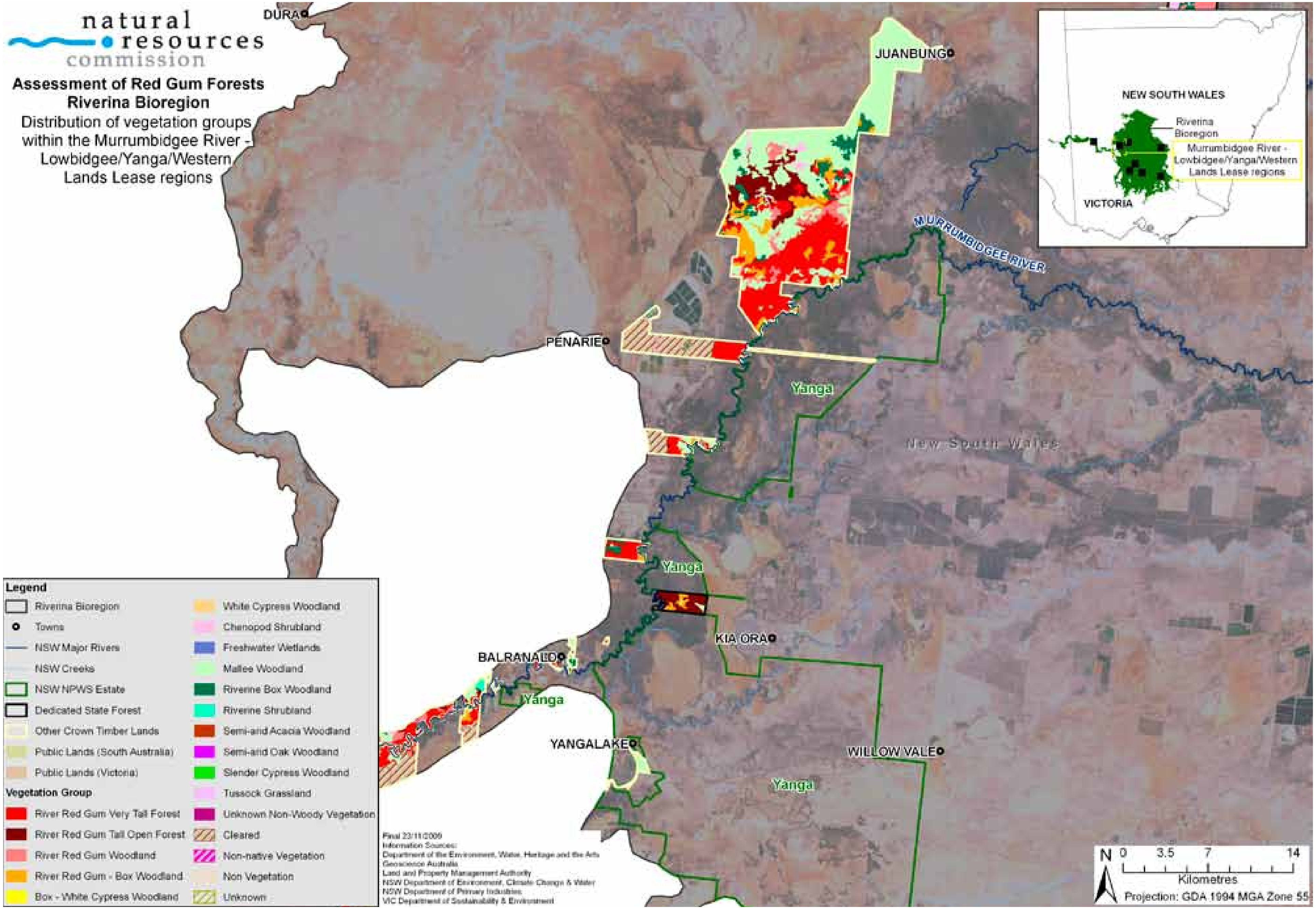
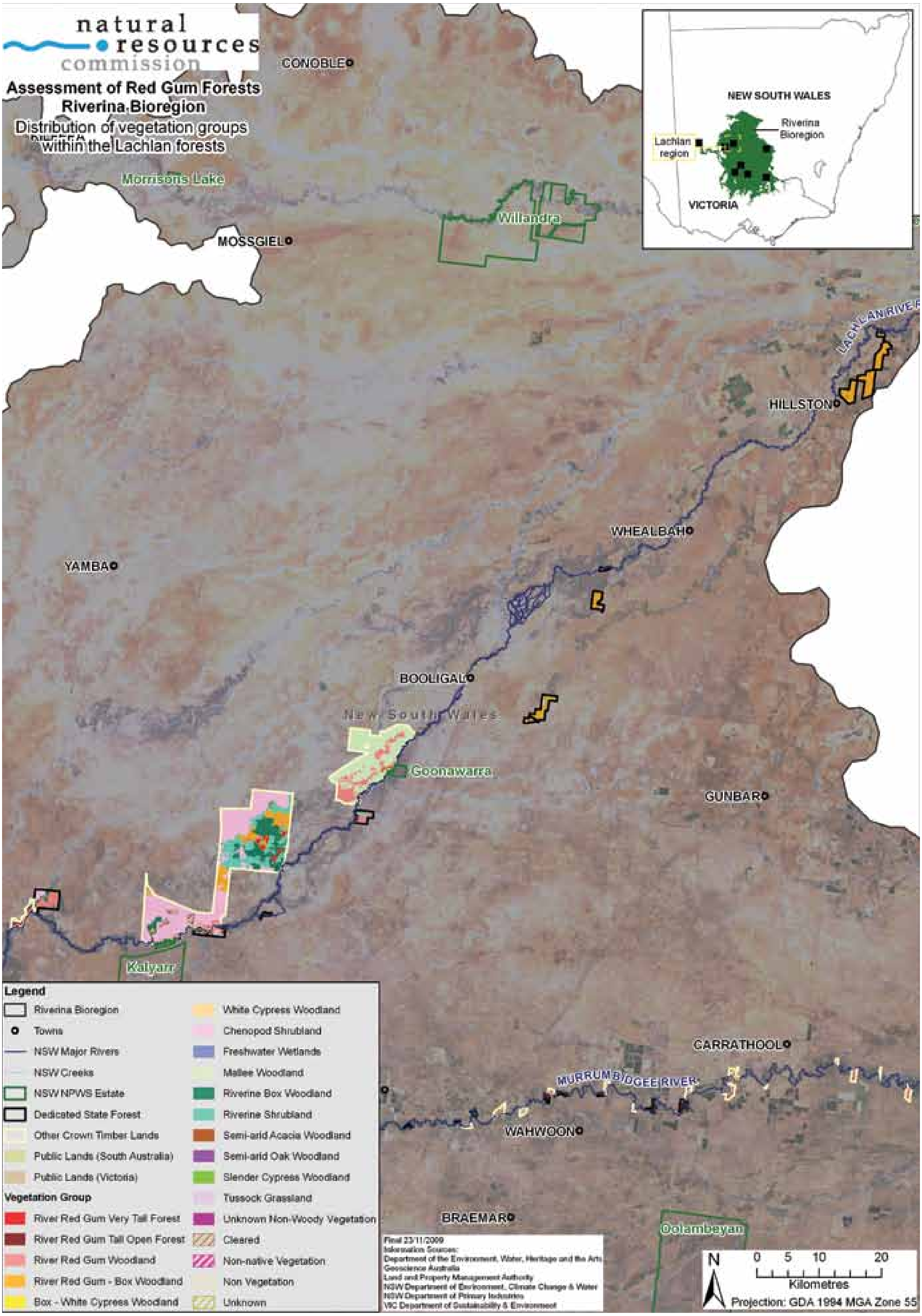


Figure 4.7: Distribution of vegetation groups within the Murrumbidgee River – Lowbidgee/Yanga/Western Lands Lease regions

Figure 4.8: Distribution of vegetation groups within the Lachlan forests



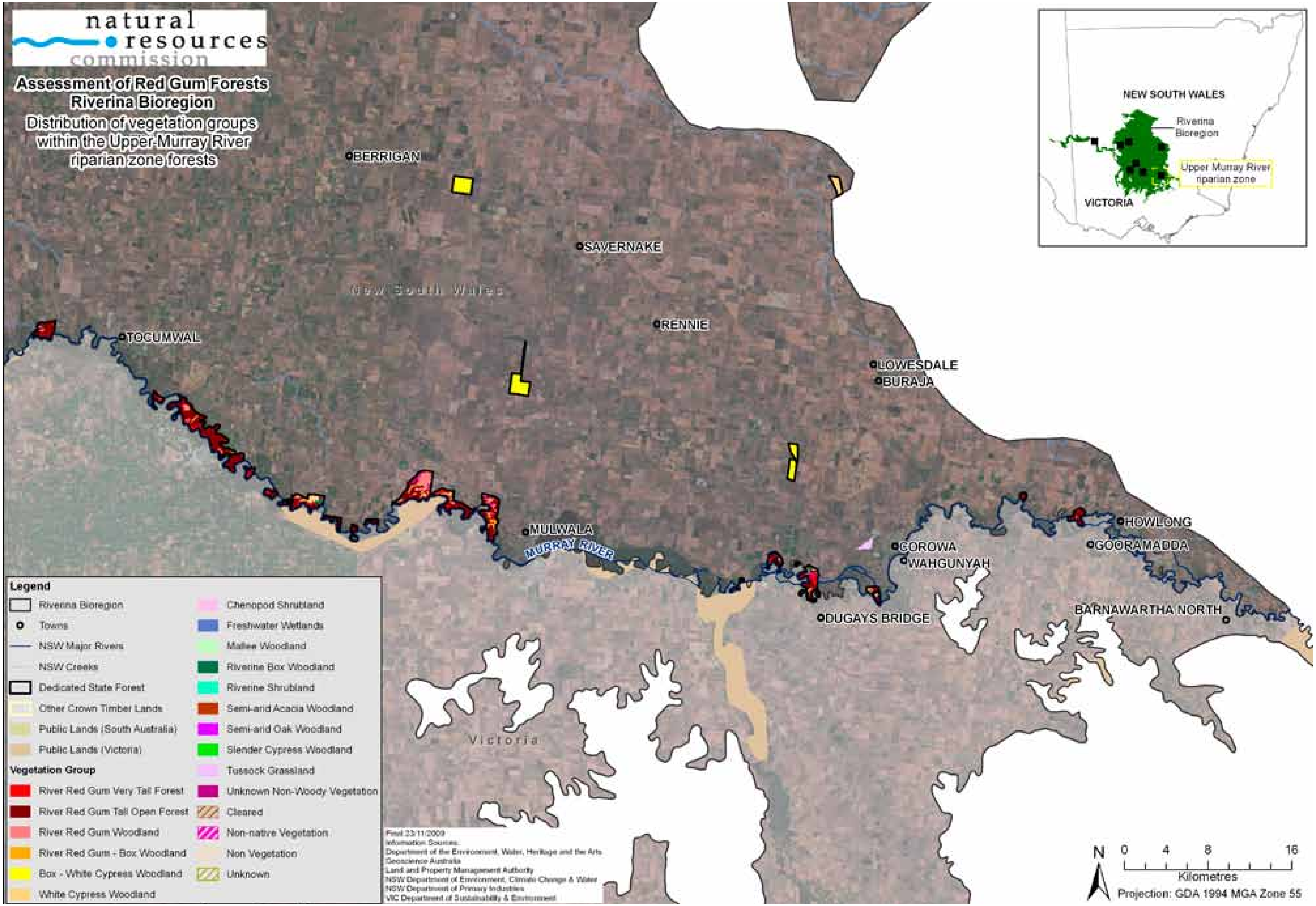
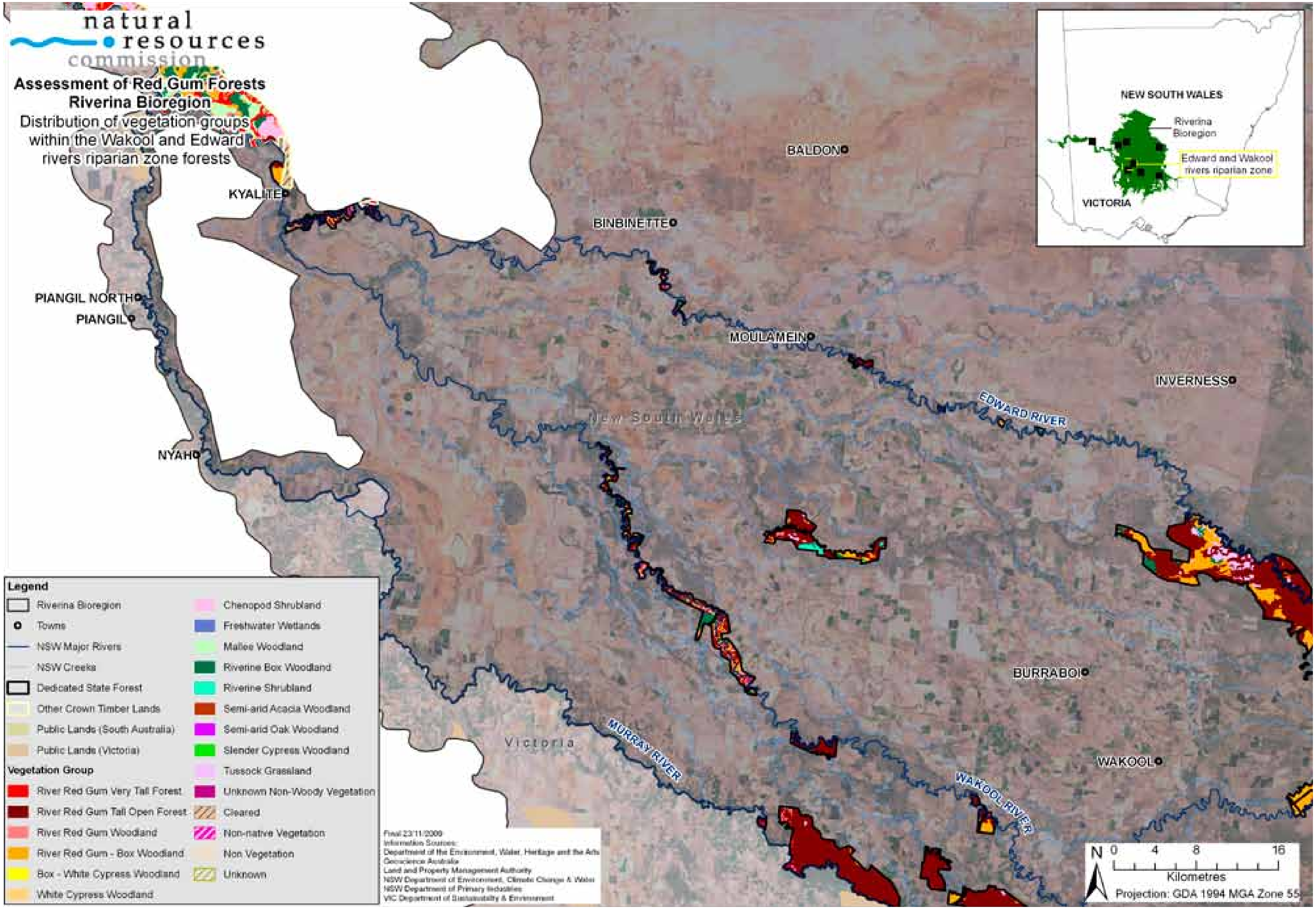


Figure 4.9: Distribution of vegetation groups within the Upper Murray River riparian zone forests

Figure 4.10: Distribution of vegetation groups within the Wakool and Edward rivers riparian zone forests



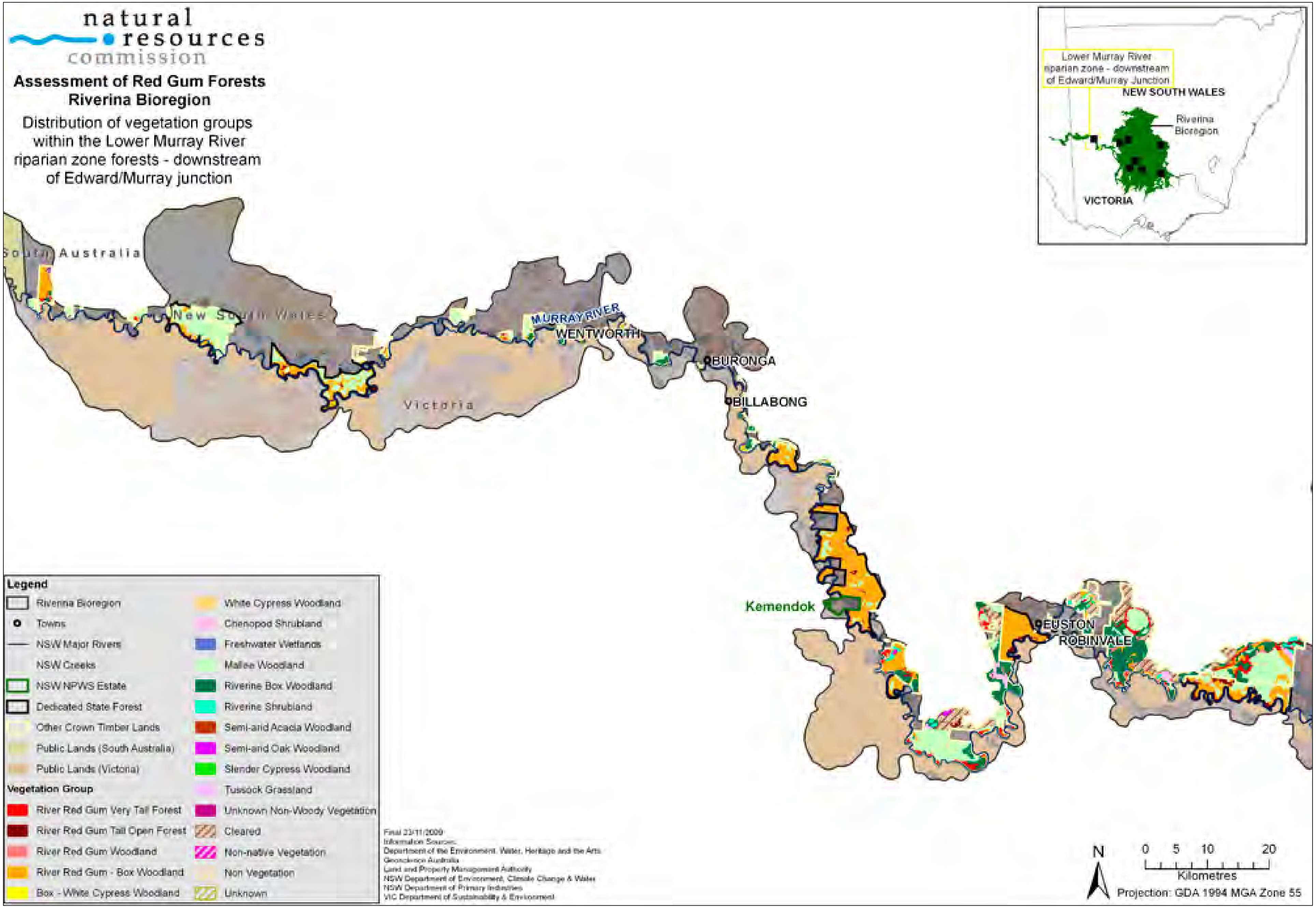


Figure 4.11: Distribution of vegetation groups within the Lower Murray River riparian zone forests – downstream of Edward/Murray junction

4.3 Condition of river red gum forest ecosystems

The condition of river red gum in the Riverina bioregion is generally poor and in decline. This is the result of poor health from substantially reduced river flows due to river regulation and compounded by climate variability and climate change. Other threats, such as clearing and fragmentation, firewood collection, livestock grazing, timber harvesting and exotic plants and animals, have also contributed to the decline in condition.

4.3.1 Definitions

This section uses the following terms to describe the overall condition of river red gum forests:

- **Health** relates to the vigour of the tree canopy, where poor health is denoted by canopy dieback relating to stress factors such as drought, insects, disease or soil chemical imbalance.
- **Condition** is the capacity of a forest stand to support the key elements of ecosystem function that operate in and underpin a reference stand (see below). Condition takes into account forest health, but also includes structural and floristic changes to the forest arising from human activities such as continuous grazing, inappropriate use of fire and logging. Thus a forest may be in reasonable health, but in poor condition if its structure and flora have been significantly modified (for example, through the loss of hollow-bearing trees, coarse woody debris, age class diversity, canopy cover, species richness or proliferation of weeds).

4.3.2 Reference condition

The condition of any vegetation type is measured in terms of its departure from a 'benchmark' or 'reference' vegetation condition.

The reference condition is usually determined by sampling a set of ecological parameters in a healthy and undisturbed (or minimally disturbed) stand. Sample parameters relate to state, persistence and functioning of vegetation communities and normally include species diversity, percentage cover, recruitment of canopy species and groundcover variables. Following that, any stand of vegetation of the same type can be compared against the reference condition by sampling and comparing the same set of ecological parameters.

A number of Ecological Vegetation Classes (EVCs) dominated by river red gum occur in the Victorian part of the Riverina bioregion and are close relatives of river red gum types in NSW. These include Floodplain Riparian Woodland (EVC 56) and Grassy Riverine Forest (EVC 106), which exhibit the following characteristics in reference condition:

- good health (no observed stress)
- support 15–20 large trees (>80–90 centimetre diameter at breast height) per hectare
- support regenerating red gum saplings
- a projected canopy cover of 25–30 per cent
- a total species richness of greater than 15 taxa (all natives, few weeds), and
- support a total length of 300 metres of fallen logs per hectare (DSE, 2004, 2007).

BioMetric is the biodiversity database module in the Native Vegetation Assessment Tool package that facilitates preparation of property vegetation plans under the *Native Vegetation Act 2003*. Reference condition data for Inland Riverine Forests are also presented in the Biometric database providing the following additional characteristics:

- support 20 hollow-dependent trees per hectare
- support a midstorey cover of up to 35 per cent
- support a grass groundcover of up to 30 per cent.

Any river red gum stand in the Riverina bioregion with the above characteristics would be considered to be in reference condition.

4.3.3 Condition of river red gum in the NSW Riverina bioregion

A number of recent studies have described the condition of river red gums in the Riverina bioregion as generally being poor and in decline.

Cunningham et al. (2007, 2009) presented a quantitative assessment of the stand condition of river red gum along the Murray River floodplain in Victoria. They surveyed stand condition at 140 sites across the floodplain, used this to build a model that predicted stand condition from remotely sensed environmental variables and tested the predictions of the model with follow-up surveys. The spatial model showed:

- only 30 per cent of river red gum stands across the Victorian Murray River Floodplain were in good condition, and
- there was a downstream decline in the condition of river red gum forest and woodland along the Victorian Murray River Floodplain.

Forests NSW assessed the health of the NSW Central Murray State Forests (Millewa, Werai and Koondrook areas) in 2005. The majority of trees were not severely stressed. Of the 1,843 eucalypts assessed on the NSW side of the border, 38 per cent were severely stressed, 27 per cent were stressed and 1 per cent were dead. Eleven per cent were healthy. High levels of stress were apparent in areas of lower commercial productivity, unthinned sites, old trees and subdominant trees (Jurskis et al., 2005). Black box was relatively healthy compared to the river red gum. Black box is more resilient to drought as it is able to persist on limited supplies of soil moisture tightly bound in clay soils, whereas river red gum is believed to rely on groundwater in lenses of sand and gravel in parts of the landscape (see **Chapter 8**). It should be noted that dieback from drought stress in otherwise healthy trees is a protective mechanism to reduce water loss. For example, the recovery of trees in a very low rainfall area at Wangumma State Forest after good spring rains in 2006 was proportional to their initial degree of dieback (Jurskis, 2008).

Turner and Kathuria (2008) used satellite imagery techniques to assess forest health across 48,000 hectares of native river red gum forests in the Gunbower-Koondrook-Perricoota Icon Site along the NSW–Victorian border. Their key findings supported the observation that black box and grey box stands are generally healthier than river red gum stands, and that

Healthy river red gum tree

Stressed river red gum tree

most of the river red gum plots (87 per cent) exhibited either an unhealthy status (<25 per cent of original canopy remaining) or stressed (25–50 per cent of original canopy remaining). A total of 56 per cent of river red gums in the Icon Site were unhealthy.

The distribution of forest health within the Gunbower-Koondrook-Perricoota Forests Icon Site was also modelled by Turner and Kathuria (2008) using remote sensing techniques supported by ground-truthing. The resultant mapping (GHD, 2009) illustrated that the proportion of the forest in an unhealthy condition is currently far greater north of the Murray River than the Icon Site as a whole, because the Koondrook-Perricoota did not receive flooding in 2005–06. This reinforces the critical role of floodplain geomorphology and hydrology in forest health, as the Koondrook-Perricoota forests have high commence-to-flow levels to achieve floodplain inundation and have experienced little or no flooding over the last decade.

The NSW Central Murray State Forests Ramsar Site Draft Ecological Character Description (ECD) report cites data from the MDBA which includes the summary of forest health across the three forests that constitute the Ramsar site (**Table 4.3**).

The Draft ECD report states that the above observations represent a snapshot within a period of 'extreme drought'. However, recent work has concluded that that there are firm signals that the current drought correlates with future projections of reduced rainfall in southern Australia and is therefore associated with climate change (SEACI, 2009) (see also **Chapter 7**).

A recent analysis of the condition of the forests in the Riverina bioregion was undertaken by DECCW using the Statewide Landcover and Trees Study (SLATS), derived from existing multi-temporal Landsat data. Pennay (2009) used SLATS data from 1988 to 2009 to observe changes in projected foliage cover indicative of condition and moisture stress in river red gum forests of the bioregion, including state forests of the Central Murray State Forests Ramsar site (**Figure 4.12**). Projected foliage cover was observed to be declining in Koondrook-Perricoota forests, reasonably stable in Millewa forests, and slightly improved in Werai over the 21 years. Negative changes were extensive in the Koondrook-Perricoota and Campbells Island forests, particularly the central and western portions. The Millewa forests showed mixed changes in cover over the period, the most intense decline being apparent in the south-western section of the forest around Moira Lake. The Werai forests in general had relatively low decline in foliage cover, probably because of the more open woodland areas.

In other parts of the bioregion, SLATS data indicate rapidly declining cover in the Lachlan-Booligal wetlands area, declining cover along the western Murray, unchanged cover in the Edward, Wakool and Upper Murrumbidgee sections, and a slight increase in cover in the forests of the Upper Murray.

Consistent with other areas, the condition of river red gum forest in Yanga National Park in western Riverina is also poor, with relatively small areas of river red gum forest and black box woodland currently in good condition (McCosker, 2008). However, since its dedication in 2005, environmental flows into several thousand hectares of Yanga National Park have been observed to have regenerated areas of wetland habitat, stimulated some breeding of water birds and improved tree health (Webster, R, pers. comm., 2009).

4.3.4 Resilience of river red gum

Resilience describes the amount of change a natural system can undergo, or disturbance it can absorb, without compromising its long-term identity, including function, structure and feedbacks (see for example, Walker and Salt, 2006). The resilience of a system can be regarded as good or bad, depending on whether a system is in a desirable or undesirable state. Resilience thinking seeks to understand how societies, economies and ecosystems can be managed to either confer resilience or transform into alternative states. That is, how to maintain the capacity of a system to absorb disturbance without change, or how to promote transformation into a different state. Any actions implemented to improve the resilience of ecosystems should aim to make space and opportunities for ecosystems to self-adapt and reorganise while maintaining fundamental ecosystem processes that underpin vital ecosystem services (Commonwealth of Australia, 2009).

In terms of a forest, resilience is the capacity of that forest to assume its prior state of health following stress-related departure from that state. The resilience of a forest may be adversely affected by a change in system dynamics resulting in a decline in condition.

River red gum types have shown capacity to bounce back from external shocks, as evidenced by the recent response to the environmental flow events that have occurred in Yanga National Park and the Millewa group since 2000 (Webster, R, pers. comm. 2009). This capacity has been confirmed by recent changes to vegetation cover observed from SLATS data (Pennay, 2009). For example, river red gums, sedges, reeds, aquatic macrophytes and invertebrates, and vertebrate fauna have all responded positively to flooding following longer than normal (historical) periods between flood events. However, other areas of these red gum forest ecosystems appear to be in continued decline, with some stands dying recently.

To maintain resilience in red gum forest ecosystems managers will need to:

- understand the system's dynamics and the key variables, driving the system's functioning
- maintain well-functioning ecosystems
- protect a representative array of ecosystems
- remove or minimise existing stressors
- maintain and/or build appropriate connectivity
- identify and protect refugia
- boost the adaptive capacity of the ecosystem through improved watering.

The resilience of any individual ecosystem needs to be considered as part of the wider social ecological system within which it operates. **Chapters 7** and **8** discuss the hydrological challenges facing the Murray-Darling Basin which are causing significant changes to ecosystems within it. Acquisition of environmental water by both the Australian and NSW Governments should help to ensure that environmental flow events continue to occur, thus reducing one of the major stressors on these ecosystems. Major flooding events will be required to maintain resilience of stands on the outer floodplain.

The red gum forests of the Riverina bioregion form major corridors linking habitats from the semi-arid regions of inland NSW to the more temperate regions of the slopes. These corridors will allow species that are reliant on these ecosystem types to move if climate change affects their current habitats. The larger forest blocks may have greater resilience as a result of their size and exposure to future environmental flows. An analysis of those areas displaying resilience during the current drought may provide insights on those areas likely to be resilient in the future under continued climate variability or climate change.

Table 4.3: Health of the Millewa, Koondrook and Werai river red gum forests (adapted from GHD, 2009)

Site/water management unit	Health/trend
Millewa Forests	**Poor** Despite the 2005–06 environmental watering allocation managed flood only 20 per cent of the river red gums in the Forest remain in a healthy condition. **Declining** 75 per cent of the Forest now in a state of decline and a further 5 per cent considered to be in poor health (MDBC, 2006a).
Koondrook Forests	**Very Poor** In 2005, 71 per cent of trees sampled in the Koondrook Forest were highly stressed, near dead or dead and forest understorey was also classed as 'poor' and 'unsatisfactory' (Jurskis et al., 2006). In 2007–08, 87 per cent classed as 'unhealthy' (Turner and Kathuria, 2008). **Declining** The forests have not been extensively flooded since 2001 and so health is continuing to deteriorate (MDBC, 2006b).
Werai Forests	**Poor** Majority unhealthy, including 92 per cent of site quality 2 sampled 'highly stressed, near dead and dead' (Jurskis et al., 2005). **Trend** unknown, probably declining.

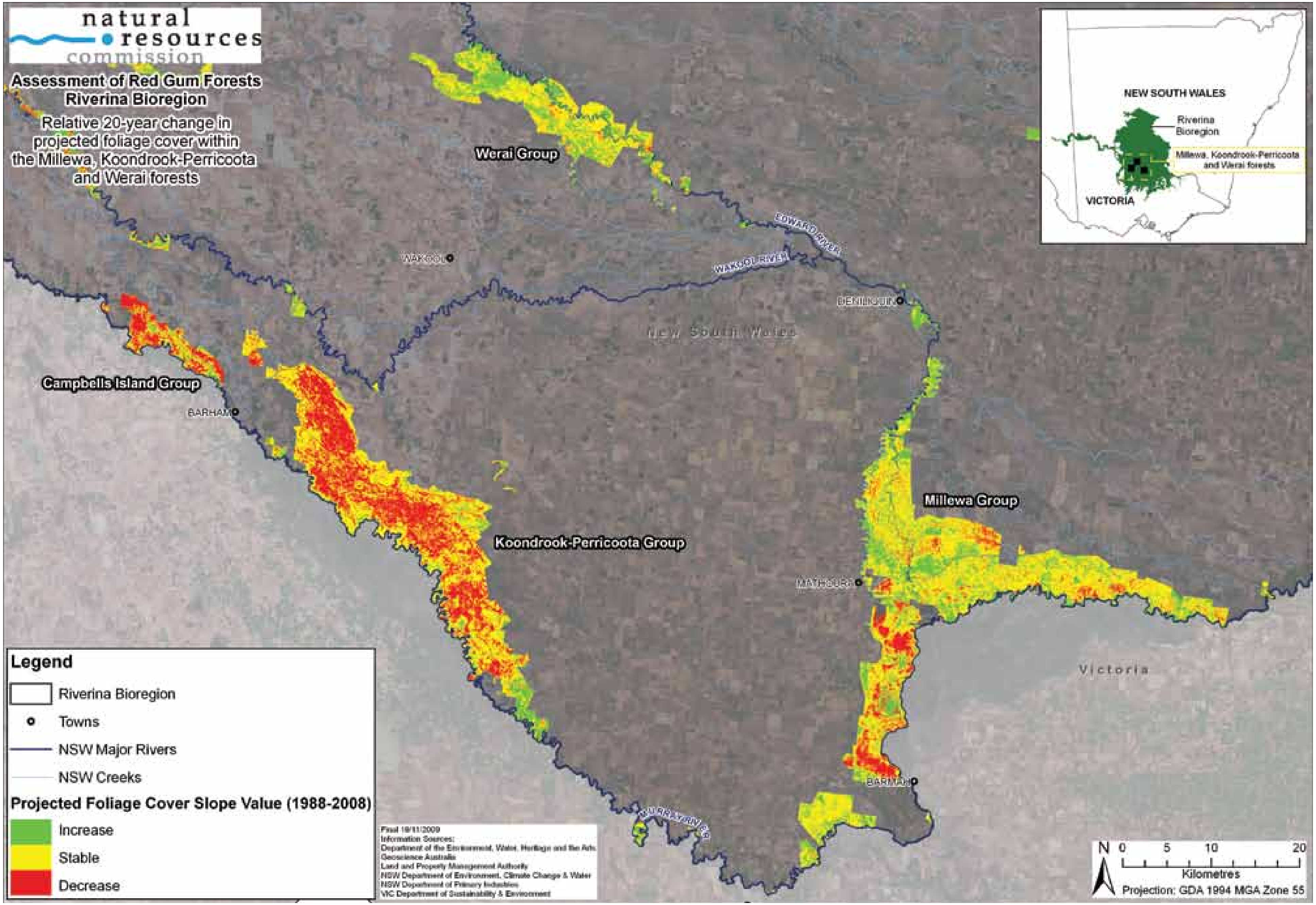


Figure 4.12: Relative 20-year change in projected foliage cover within the Millewa, Koondrook-Perricoota and Werai forests (from Pennay, 2009)

4.4 Ecosystem services provided by the forests

Cork et al. (2003) define ecosystem services as transformations of natural assets (soil, water, air, living organisms) into products that are important to humans. Daily (1997) defines them as the conditions and processes through which ecosystems, and the species that make them up, sustain and fulfil human life.

Ecosystems provide many services to humans, including:

- provision of clean air and water
- maintenance of soil fertility and structure
- maintenance of livable climates
- pollination of crops and other vegetation
- control of the vast majority of potential pests, diseases and weeds
- provision of genetic resources
- production of goods like food and fibre
- provision of cultural, spiritual and intellectual values (Daily, 1997; Binning et al., 2001).

Daily et al. (2000) describe ecosystem services, such as pollination and water purification, as being 'life support processes', while those such as beauty and serenity are 'life-fulfilling conditions'.

The river red gum forests provide all of the above services. The forests' structural features and ecological attributes interact to drive ecosystem processes. These processes supply ecosystem services and maintain biodiversity.

Taller trees provide habitat for many invertebrates and vertebrates which are supported on the leaves and branches, on and beneath the bark, in tree hollows and within the wood fibre. A wide diversity of native shrubs, sedges and grasses coexist on the forest floor. Along with coarse woody debris, leaf litter, mosses and lichens, these combine to support a unique assemblage of ground-dwelling fauna. Flowering trees, shrubs, herbs and grasses provide food for many nectivorous and insectivorous bird and mammal species.

Periodic flooding brings water and nutrients to the wetlands and stimulates pulses of biological activity. A complex subsurface ecology is supported by organic matter which accumulates on the forest floor and is mineralised below.

Wetlands are important for provision of clean water that flows downstream, as well as mitigation of floods and recharge of groundwater. Their natural beauty has been a popular subject of Indigenous and non-Indigenous Australian art.

The river red gum forests function as an important component of the broader floodplain ecosystem. For example, they produce significant amounts of organic carbon and other nutrients in the form of forest litter which is distributed across the floodplain in flooding events, driving other key ecological processes such as algae production in the river channel (Hillman, T, pers. comm., 2009).

These ecosystems (and their inherent functions) extend over large areas to provide major islands of refugia and critical habitat for a large variety of native inland fauna and flora of south-eastern Australia. The river red gum forests represent the largest remnants of floodplain forest and woodland in NSW, provide a major corridor of continuous vegetation from eastern NSW to South Australia, and support a mosaic of natural habitats.

It is difficult to quantify the magnitude of ecosystem services provided by these forests. **Table 4.4** describes the role of river red gum forests in the broader river floodplain ecosystem across four distinct phases of flooding – initial inundation of the floodplain, the 'flooded' period, receding of flood waters and post inundation. **Figure 4.13** shows schematically the interaction of different parts of the riverine landscape and their ecological processes during the phases of a flood event.

Floods have shaped the ecology of the river red gum forests and the channels and wetlands they line. Delivery of floodwater and alluvial sediments from the channel to the floodplain and exchange of biotic resources via leaf litter and woody detritus from the floodplain to the channel stimulates ecological processes that maintain the character, particularly the diversity and resilience, of lowland river ecosystems – channels, wetlands and forests. The different stages of flooding events and the landscape in which they function provide a complex and dynamic ecology which responds differently to each unique flood event.

4.4.1 Carbon sequestration

The sequestration of atmospheric carbon is an increasingly important ecosystem service provided by forests. The significance of forests for carbon sequestration, and the adverse consequences of deforestation, are now recognised internationally (IPCC, 2007) and in the Australian context (Garnaut, 2008).

However, the implications for management of standing forests remain a matter of research and debate, particularly where objectives other than simply carbon sequestration are sought (Keith et al., 2009; Garnaut, 2008; Miles and Kapos, 2008). Notwithstanding some preliminary studies (Richards et al., 2007, Ximenes et al., 2008), knowledge of the implications of alternative forest management regimes, and of the life cycle analysis of carbon in forest products, is generally lacking.

4.5 Ecological attributes of the forests

Several ecological attributes of the river red gum forests contribute most significantly to ecosystem functioning. These include:

- refugia and connectivity
- vegetation mosaics
- wetlands
- tree hollows
- coarse woody debris.

4.5.1 Refugia and connectivity

Provision in the landscape of islands of natural habitat, or 'refugia', of a quality and spatial configuration suitable for maintenance of ecological function and diversity is a basic requirement for biodiversity conservation. Accordingly, habitat loss and fragmentation are often cited as the main factors contributing to the decline in biodiversity worldwide, (for example, Noss et al., 1997; Bennett, 1998; Dobson et al., 1999; Lindenmayer and Fischer, 2006). Habitat preservation and restoration, including enhanced habitat continuity and/or functional connectivity, have been recognised as conservation planning priorities (for example, Bennett, 1998; Lindenmayer and Nix, 1993; Dobson et al., 1999; Lindenmayer and Franklin, 2002).

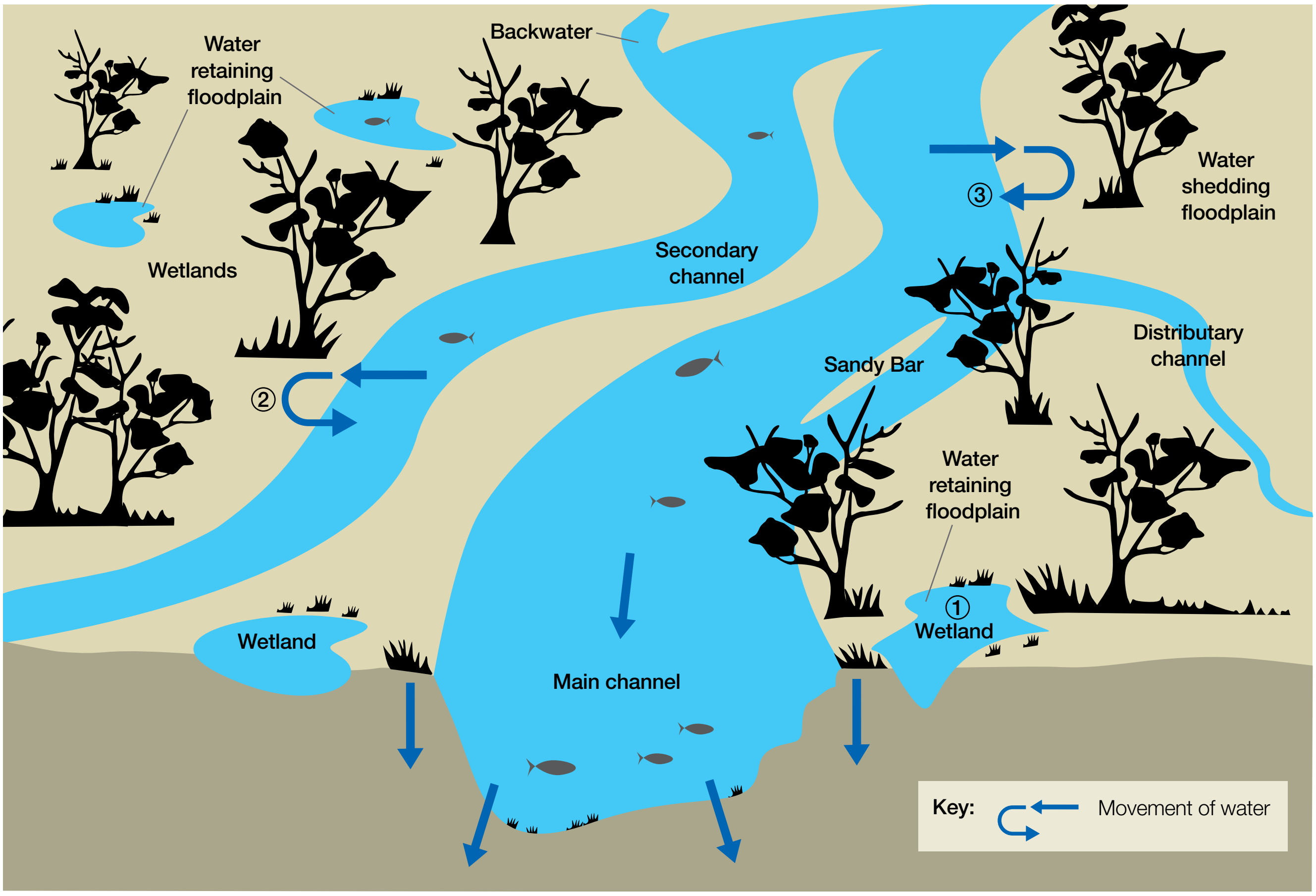
Habitat connectivity is more than habitat contiguousness – it is the provision of habitat islands or micro-refuges across which biota can move through variegated landscapes. It is a key feature of natural environments.

Healthy river red gum forests are pivotal to the long-term functioning of ecosystems in the Riverina bioregion because they provide:

- the major areas of core habitat or refugia in the bioregion (much of the adjacent woodland has been cleared)
- the only major east-west corridors, along the major channels
- points on the floodplain from which to achieve north-west connectivity across major catchments
- a source of carbon and nutrients for aquatic biodiversity
- resilience against climate change.

Management effort may be focused on retaining or creating forested corridors as an important part of building overall connectivity in the landscape in order to maintain, or enhance, regional biodiversity outcomes. The available evidence indicates that corridors can provide benefits in many instances (Beier and Noss, 1998; Lindenmayer and Franklin, 2002), assuming that they are of suitable size, shape and habitat type, and that they functionally connect areas of substantial habitat value (Perault and Lomolino, 2000; Doerr et al., in review).

Figure 4.13: Interactions between the riverine landscape and ecological processes



① Refugial habitat within wetlands is relieved by the floodwaters. The filling of the wetlands triggers plant growth and seed dispersal which leads to a more productive and biodiverse wetland.

② Invasive, non- flood tolerant, vegetation species such as grasses, forbs and shrubs are removed by the floodwaters which leaves more resources available for large trees such as red-gums. After the floodwaters have receded many of the large tree species begin their recruitment process.

③ Litter from the floodplain enters the channel and is important to the development of the riverine food web. Eucalypt leaves take a long time to decay which provides an instream source of carbon long after the flooding period.

Table 4.4: Role of river red gum forests in river floodplain ecosystems

Flooding phases	River sub-system			Outcome
	Water-shedding floodplain Eucalyptus forest, mainly red gum	Water-retaining floodplain Wetlands, backwaters and lakes	Channel Main stream and free-flowing anabranches	
Initial flooding	• Upper soil and stringers recharged • Nutrients, organic matter and salts dissolved • Microbial activity increased and distributed through soil and water	• Upper soil and stringers recharged (for previously dry wetlands) • Forest litter returned to channel and distributed (supporting food-web) • Refugial conditions for fish populations relieved • Plant regrowth and seed dispersal stimulated	• Upper banks wetted • Backwaters scoured with possible movement of organic material biota • Some fish species move to floodplain	Water moves onto the floodplain, wetting previously dry forests, including red gum, and sediments in wetlands, backwaters and lakes. Under flood conditions, alluvial sediments are deposited on the floodplain.
Flooded period	• Anaerobic conditions (nitrogen, pH, phenolics) increased due to increased microbial activity • Competitive advantage of river red gum increased • Invasive and non-flood-tolerant vegetation species removed	• Soils continue to be recharged • Dissolved organic matter released • Micro-organisms and micro-invertebrate activity rapidly increased	N/A	Water covers forests and wetlands, backwaters and lakes (although levels may fluctuate). Flood waters may provide an opposing head at sites where saline groundwater incursion presents a threat.
Flood recession	• Upper soil start and remain litter aerated (if anoxic conditions have occurred) • 'Dryland' trees and plants germinated, particularly along flood-line • Forest litter transported into channel zone – where returning flow is sufficient	• Wetlands filled to maximum volume • Fish communities isolated – depending on the degree of connectivity and duration of inundation • Backwaters are reinstated – incoluated with bacteria and micro-invertabrates	• Waters returned from floodplain – may be oxygen depleted (in warmer periods), phenolics and sometimes salt • Productivity increased from nutrients and micro-invertebrates in returning waters	Significant volume of water returns from the forest zones, including 'over-capacity' water from wetlands, backwaters and lakes (excluding terminal systems and perched streams)
Post flooding	• Aerobic microbial activity and nutrient absorption to inorganic and organic particles increased • Solutes deposited as soil water moves to the surface through evaporation • Red gum recruited and respond to water supply and increase nutrients (where flooding has been seasonally appropriate)	• High productivity in system continued • Diversity in wetland plants and invertebrates increased • Terrestrial fauna activity increased particularly birds and bats • High diversity of fish, frogs and other organisms assemblages – depending on the degree of connectivity and duration of inundation	• Riverine food web reinforced due to nutrients returning from water shedding zone – significant proportion of aquatic and invertebrate taxa and their predators are dependent on organic carbon (red gums being a significant contributor)	Forests return to 'dryland' ecosystems and wetlands; backwaters and lakes commence gradual drying cycle through seepage and evaporation.

The suggested benefits of functional corridors include:

- providing habitat, such as residential habitat for some species and supplementary habitat for wide-ranging species
- assisting species to move through the landscape, including dispersing individuals, and nomadic and migratory species
- increasing immigration rates to habitat isolates, for example, by maintaining or enhancing genetic interchange between, and allowing recolonisation of, metapopulation elements
- facilitating the continuity of ecological processes, such as flow of energy, nutrients, biota and abiotic matter via wind, water and animal vectors, and
- providing increased resilience against climate change through provision of a climate gradient across which species may respond and adapt (see Bennett, 1998; Noss et al., 1997; Beier and Noss, 1998; Lindenmayer and Franklin, 2002; Doerr et al., in review).

Functional habitat corridors can be made up of either contiguous habitat or a combination of fragments (stepping stones) interspersed with less favourable habitat (Scotts and Drielsma, 2003; Lindenmayer and Fischer, 2006). It may be possible in the long term, through stewardship and other NRM programs, to build more effective connectivity between the major river systems, integrating remnant patches of dry woodland, riparian vegetation, isolated trees, chenopod shrublands and derived native grasslands.

Figure 4.14 depicts a network of potential river red gum corridors to enhance refugia and connectivity across the NSW portion of the bioregion. The potential network of corridors, derived from outputs of the spatial links tool (Drielsma et al., 2007):

- provides landscape-scale assistance in movement of forest and woodland fauna, connecting intact remnant vegetation, and avoiding urban areas and croplands
- connects large areas of core habitat managed for biodiversity values in NSW and Victoria
- follows tenures which are more likely to exhibit relatively good vegetation condition and are least subject to clearing pressures (e.g. travelling stock reserves)
- provides for broad north-south linkages across the Riverina, taking account of altitudinal and latitudinal diversity
- includes major riparian corridors, including the Murray and Murrumbidgee Rivers.

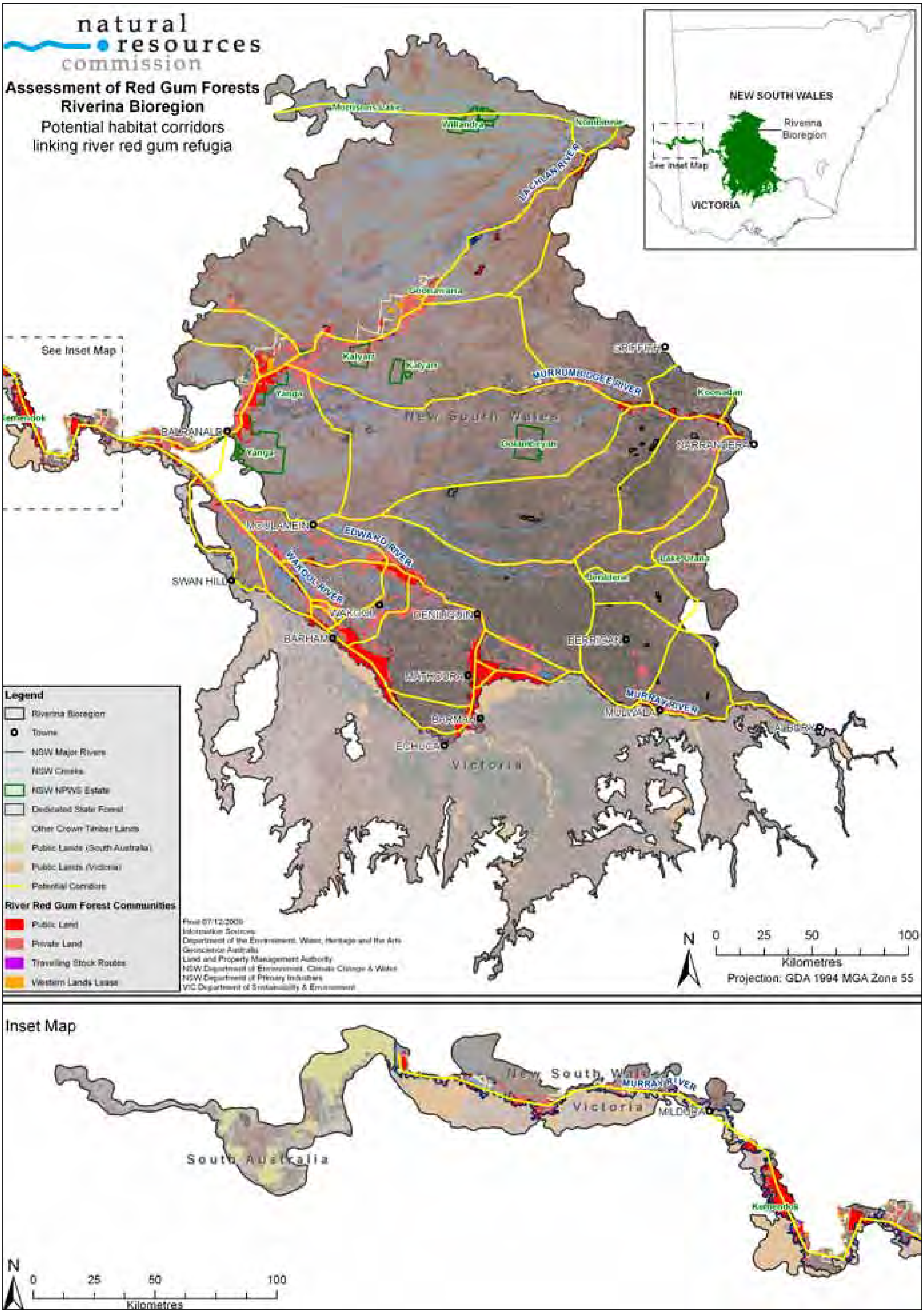
4.5.2 Vegetation mosaics

The pattern of differing vegetation types within a designated area is referred to as a vegetation mosaic. While some animal species may exist within a single vegetation type, several other species rely on habitat diversity (or vegetation mosaics) to complete their life cycle (Lambeck and Saunders, 1993). Mosaics may provide foraging and roosting habitat in different vegetation communities, provide pathways for movement and dispersal, or act as a refuge to a sudden depletion of resources (caused by, for example, fire, flood, drought or timber harvesting) (Burbidge, 1985; Webster and Ahern, 1992).

Movement between different vegetation types occurs on a variety of spatial and temporal scales (Law and Dickman, 1998). Some waders migrate seasonally between hemispheres, while other species will utilise different habitats on a daily basis. The regent parrot is known to rely on mallee and river red gum as part of its ecology, and some woodland birds use ecotones (transitional zones) between vegetation types. Some bats have been observed to roost in red gum forests and forage within remnants in agricultural lands (Lumsden and Bennett, 2000)

Jurambula State Forest

Figure 4.14: Potential habitat corridors linking river red gum refugia



Mosaics can also occur within vegetation types. For example, fire can create multiple stands of a single vegetation type which differ in age and structure depending on their fire history. A north-west facing slope may have less grass and herb cover than a south-east slope. Human-induced disturbances such as grazing and logging also create vegetation mosaics (Roberts, 2004).

Mosaics of red gum forest, box woodlands, sandplain woodlands and open wetlands provide a diversity of ecological habitats. This mosaic facilitates co-occupancy by different fauna assemblages, providing resilience around ecosystem function and buffering against attrition of biodiversity in the region. Several organisms require micro- or macro-habitat variation.

4.5.3 Wetlands

Wetlands are found across the Murray-Darling Basin and include swamps, floodplain forests, saline and freshwater lakes, billabongs, marshes and anabranches (river branches that rejoin the main stream or become absorbed in sandy ground). They are extremely variable in their size, shape, species composition, wetting and drying cycles, frequency at which they are wet or dry (Nias, 2002) and duration of inundation (Kingsford and Thomas, 2004). The source of water for a wetland varies as well, from waterways, groundwater and run-off to rainfall. Wetlands are either:

- permanent – such as those maintained by weir pools
- semi-permanent – such as those replenished by floodwaters, and commonly on the inner floodplain and close to the major channels
- ephemeral – sporadically replenished by major flooding events or local storm events but dry for most of the time, and commonly associated with the outer floodplains.

The wetting and drying cycles of wetlands in the Murray-Darling Basin are an integral part of their function and the life cycle of a multitude of organisms that use them. A healthy wetland provides the diverse array of micro-organisms and algae that form the base of the food web; a home for fish and other fauna; and a key feeding and breeding habitat for waterbirds (Scott, 1997).

The important role of wetlands in floodplain ecology can be summarised in the context of the four major stages of the flood event – initial inundation, flooded period, receding inundation and post-inundation. Initial inundation of previously dry wetland sediment results in uptake into solution of floodplain nutrients, organics and salts, each made available by past evaporation at the soil surface, by death and decomposition of soil microbes (from past desiccation), and by the production (and delivery) of organic carbon in the form of forest litter (river red gum forests produce 2–6 tonnes of litter per hectare each year, by one estimate – O'Connell, 2003). As a result, microbial biomass increases rapidly and diversifies in soil and overlying water. This is a major potential carbon source for important parts of the food web that supports insect and fish communities, and species reliant on them. Wetland plant regrowth and seed dispersal is stimulated.

Persistence of floodwaters (the flooding period) initiates a productive succession which commences with the release of dissolved organic matter followed by blooms of micro-organisms and micro-invertebrates (e.g. microcrustacea, rotifers). As floodwaters recede, the wetlands have returned to maximum capacity. Depending on antecedent conditions, the degree of connectivity, and duration of inundation a diversity of fish communities may occur in isolated wetlands. As the floodplain dries post-flood, wetland ecosystems may increase in diversity, particularly amongst wetland plants and invertebrates. Increasing productivity may support terrestrial diversity and biomass notably amongst migratory birds, woodland birds, and bats. Depending on the degree and duration of connectivity and the diversity of hydrological condition (e.g. permanence/ephemerality), there will be significant differences in the species composition and biomass of fish assemblages amongst wetlands. As fish are high-order predators in these systems, these differences will result in substantial variation amongst other organisms. For instance, frog recruitment and diversity appear to be highly dependent on fish predation.

Wetlands that have supported more than 20,000 waterbirds occur in the Murrumbidgee-Lachlan confluence, Barmah-Millewa Forest, and Edward and Murrumbidgee River floodplains (Kingsford et al., 1996). A number of wetlands have been identified as having bioregional significance in the Riverina (ANCA 1996), including the Booligal Wetlands on the Lachlan River which have been recognised as a refuge for biodiversity in the bioregion (Morton et al., 1995).

The NSW Central Murray State Forests form the largest complex of tree-dominated floodplain wetlands in southern Australia. The site contains wetland types that are rare within the Riverina bioregion, particularly floodplain lakes and floodplain meadows and reed swamps (Eardley, 1999), and has supported more than 20,000 waterbirds following significant flood events (e.g. Mattingley, 1908; Barrett, 1931; Chesterfield et al., 1984).

Wetlands have numerous other properties, such as flood control, groundwater replenishment, sediment and nutrient flux and water purification, and act as reservoirs of biodiversity and have cultural significance (Scott, 1997).

4.5.4 Tree hollows

Tree hollows are semi-enclosed cavities in the main trunk or major branches that form in mature or senescent trees (primarily eucalypts) as a result of decay of heartwood, by fungi and invertebrates, and subsequent abscission of major limbs (Wilkes, 1982; Mackowski, 1984). Hollow entrances are more common in larger trunks and branches because damage is less likely to be occluded by growth of external sapwood (Marks et al., 1986). Thus hollow-bearing trees are usually the oldest and often largest members of the tree community, with some species taking up to 300 years to develop hollows (Wormington et al., 2003).

A dead tree that is still standing can continue to provide nesting and breeding hollows, perching places and forage substrate for birds and arboreal mammals (Lindenmayer et al., 1993). Dead fallen trees also continue to provide habitat for a range of ground-dwelling species (Mac Nally et al., 2002). A tree's diameter at breast height is a strong predictor of whether it is occupied by animals (Mackowski, 1984; Saunders et al., 1982; Smith and Lindenmayer, 1988; Gibbons et al., 2002) that use hollows for diurnal or nocturnal shelter sites, for rearing young, for feeding, for thermoregulation, and to facilitate ranging behaviour and dispersal (GHD, 2009). Numerous species use hollows for shelter, roosting and nesting, and for many species – including arboreal marsupials, bats, owls and parrots – this use is obligate (that is, no resource other than hollows can be used – Gibbons and Lindenmayer, 2002).

Like other inland eucalypt species, mature river red gums are known for developing tree hollows with age. They are also known to provide habitat for many native fauna species both as live and dead standing trees and as dead fallen logs. Studies in northern Victoria have found that hollows begin to appear in river red gums from a diameter at breast height of about 70 centimetres; that most of those with a diameter in excess of 100 centimetres have developed hollows; and that a median of five large hollow entrances occur in trees with a diameter of 120 centimetres (Bennett et al., 1994; Lumsden et al., 2002). GHD (2009) found an average of 25 hollow-bearing trees per hectare in unlogged river red gum forest, within the range of the documented 13–27 hollow trees per hectare in undisturbed temperate forests (Gibbons and Lindenmayer, 2002). As there are only a few undisturbed sites, tree hollow estimates may not be representative of the range of forest communities.

Occupancy of hollow-bearing trees is related to their position and spatial configuration in the landscape. Literature reviewed by Gibbons and Lindenmayer (2002) reported average occupancy rates of 43–57 per cent. Some fauna species prefer hollows near riparian habitat (Kalcounis-Rüppell et al., 2006) or foraging areas (Eyre and Smith, 1997; Kavanagh and Wheeler, 2004), although more mobile species may travel long distances from roost sites (Lumsden et al., 2002). Breeding behaviour can also govern the spatial suitability of hollows, with birds that nest colonially such as the superb parrot, or in clusters across the landscape such as the glossy black-cockatoo, requiring a local abundance of hollow-bearing trees (Gibbons and Lindenmayer, 2002; Cameron, 2006). Conversely, territorial species such as the pink cockatoo require an even distribution of hollow-bearing trees if all pairs are to breed (Rowley and Chapman, 1991).

Apart from nesting birds, which use a single hollow during breeding, many species move between hollows over time. Frequent movements between hollows may serve to reduce parasite infestation, minimise risk of predation, provide appropriate thermal microclimates and allow energy-efficient access to foraging areas (Lewis, 1995). The Australian owlet-nightjar shelters in up to six hollows over several months (Brigham et al., 1998); maternity colonies of bat species may switch between a network of hollow-bearing trees every few days (Lumsden et al., 2002); and brush-tailed phascogales may use up to 38 hollows over a year in south-west Western Australia (Rhind, 1998).

Expert opinion (Forests NSW, 2009a; Gibbons, P, ANU, pers. comm., 2009) suggests that numbers of habitat trees in unlogged river red gum forests are in the range of 6–25 trees per hectare.

4.5.5 Coarse woody debris

Coarse woody debris is dead woody material on the forest floor caused by natural tree fall or dropped limbs and branches. Coarse woody debris has been described by Kirby (1992) as 'one of the two or three greatest resources for animal species in a natural forest' and is highly important to the ecology of the river red gum forests. It is an important habitat resource for a large number of ground-dwelling species using the forests (Mac Nally et al., 2001), with species such as the yellow-footed antechinus observed to be limited in habitats where dead fallen timber is depleted (Lada et al., 2007; Lada and Mac Nally, 2008). Coarse woody debris is important for various woodland birds which use it as perching places or foraging substrate (Anton and Bennett, 2006). A recent experiment that manipulated the amounts of coarse woody debris in river red gum forests on Gunbower Island found that increasing the wood load also increased species richness of birds and abundance of several bird species (Mac Nally 2006; Mac Nally and Horrocks, 2007).

Coarse woody debris is often used by reptiles to hibernate or incubate eggs, and is pivotal to invertebrate ecology. It can protect native herbs from grazing by stock, provide micro-habitat for seed germination, assist in soil nutrient cycling, and enhance soil aeration and structure. Organisms such as termites, fungi and bacteria reassimilate macro-nutrients such as nitrogen from dead timber into living biomass and forest production. Coarse woody debris is a key functional component of the river red gum forests.

4.6 Endangered species and ecological communities

4.6.1 Matters of national environmental significance

Under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), an action requires approval of the Minister for the Environment is the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance.

The matters of national environmental significance are:

- listed threatened species and ecological communities
- migratory species protected under international agreements
- Ramsar wetlands of international importance
- the Commonwealth marine environment
- World Heritage properties
- national heritage places
- nuclear actions.

In this assessment, the primary matters of national environmental significance are:

- the Ramsar-listed wetlands of the Central Murray State Forests
- species protected under international agreements
- listed threatened species and ecological communities.

Chapter 3 outlines the Commonwealth's environmental management responsibilities and the importance of the Ramsar lisitng of the wetlands of the Central Murray State Forests.

Threatened ecological communities and species and migratory birds under international agreements are outlined below. **Table 4.5** identifies and outlines the habitat requirements of EPBC-listed fauna. **Table 4.6** identifies the EPBC-listed migratory species and **Table 4.7** identifies the EPBC-listed flora species.

4.6.2 Endangered ecological communities

Six endangered ecological communities (EECs) listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) are known to occur in the NSW Riverina:

- *Acacia melvillei* shrubland in the Riverina and Murray-Darling Depression bioregions
- *Allocasuarina luehmannii* woodland in the Riverina and Murray-Darling Depression bioregions
- inland grey box woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South bioregions
- myall woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions
- sandhill pine woodland in the Riverina, Murray-Darling Depression and NSW South Western Slopes bioregions
- white box–yellow box–blakely's red gum woodland.

Of these, three have been mapped as NSWVCA equivalents in State Forests in the NSW Riverina, including inland grey box woodland, myall woodland and sandhill pine woodland (**Figure 4.15**). White box–yellow box–red gum woodland also occurs in State Forest, but is not mapped.

The total area of inland grey box woodland, myall woodland and sandhill pine woodland in State Forest is 450 hectares, 140 hectares and 2,100 hectares respectively – a total of about 2,700 hectares, representing 1 per cent of the total area of State Forest. In contrast, river red gum and river red gum/box types cover 146,400 hectares of State Forest in the NSW Riverina, or 53 per cent of the total area.

Three of the above EECs are listed as threatened ecological communities under the EPBC Act. The EPBC listings are:

- the critically endangered white box – yellow box – Blakely's red gum grassy woodlands and derived native grasslands
- the endangered weeping myall woodlands
- the endangered buloke woodlands of the Riverina and Murray-Darling Depression bioregions.

Two aquatic EECs, as listed under the *Fisheries Management Act 1994*, also occur in the Riverina:

- the aquatic ecological community in the natural drainage system of the lower Murray River catchment
- the aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River.

These EECs include all native fish and aquatic invertebrates within all natural rivers, creeks, streams and associated lagoons, billabongs, lakes, wetlands, paleochannels, floodrunners and effluent streams (those that flow away from the river) of the Lachlan, Murray, Murrumbidgee and Tumut rivers, as well as all their tributaries and branches. These EECs have not been mapped in State Forests, although they are known to occur.

4.6.3 Threatened fauna and flora values of the river red gum forests

The river red gum forests support a rich diversity of fauna and flora (for example, Roberts, 2004; Webster et al., 2003). This includes various threatened species, populations and communities listed under the TSC Act and/or the EPBC Act, as well as a number of regionally significant species.

A total of 15 species are listed as either vulnerable or endangered under the EPBC Act and are considered to be matters of national environmental significance. Several freshwater fish species, including trout cod and murray cod, and a number of migratory birds are also listed under the EPBC Act and are matters of national environmental significance. There are also a number of threatened fish species listed in NSW under the *Fisheries Management Act 1994,* including Murray hardyhead, river snail, trout cod, Macquarie perch, southern pygmy perch, purple spotted gudgeon, silver perch and western population of olive perchlet.

A total of 50 terrestrial fauna species recorded in the NSW Riverina are listed under the TSC Act and/or EPBC Act as either vulnerable of endangered (**Table 4.5**). A further 18 migratory bird species or species groups are listed under the EPBC Act (**Table 4.6**). Both Tables 4.5 and 4.6 include data on the specific habitat requirements of listed species. Of the 68 species, species groups, or populations, the number that use major functional components of the forests are as follows:

- 17 use forest/wetland connectivity in the landscape, including black-chinned honeyeater, regent parrot, superb parrot, square-tailed kite, squirrel glider and southern bell frog
- 25 are dependent on permanent, semi-permanent and ephemeral wetlands, including 15 migratory species/groups. Species include Australian painted snipe, Australasian bittern, blue-billed duck, freckled duck, glossy ibis, Latham's snipe, large-footed myotis and sloane's froglet
- 33 use vegetation mosaics, including barking owl, black-breasted buzzard, Gilbert's whistler, glossy black-cockatoo, painted honeyeater, regent parrot and swift parrot
- 18 are dependent on hollow-bearing trees, including pink cockatoo, powerful owl, little lorikeet, purple-crowned lorikeet, superb parrot, brush-tailed phascagole, squirrel glider and yellow-bellied sheathtail bat
- 13 use dead fallen timber, including bush stone-curlew, chestnut quail-thrush, diamond firetail, speckled warbler, painted burrowing frog and western blue tongue lizard.

A total of 28 listed species are considered to be dependent on at least two of the major functional habitat components provided by the Riverina forests. To provide for the long-term security of listed and other species, the functional components on which they rely will need to be protected. The EPBC Act provides for recovery plans to be drafted for threatened species or ecological communities to address appropriate management of habitat. Recovery plans have been completed for five EPBC-listed fauna species in **Table 4.5** and are enforced by the Act. These recovery plans are for malleefowl, regent honeyeater, swift parrot, thick-billed grasswren and the northern hairy-nosed wombat, which is now presumed extinct from the Deniliquin region. A further seven recovery plans are under preparation.

Figure 4.15: Potential distribution of EECs within State Forests in the Riverina bioergion

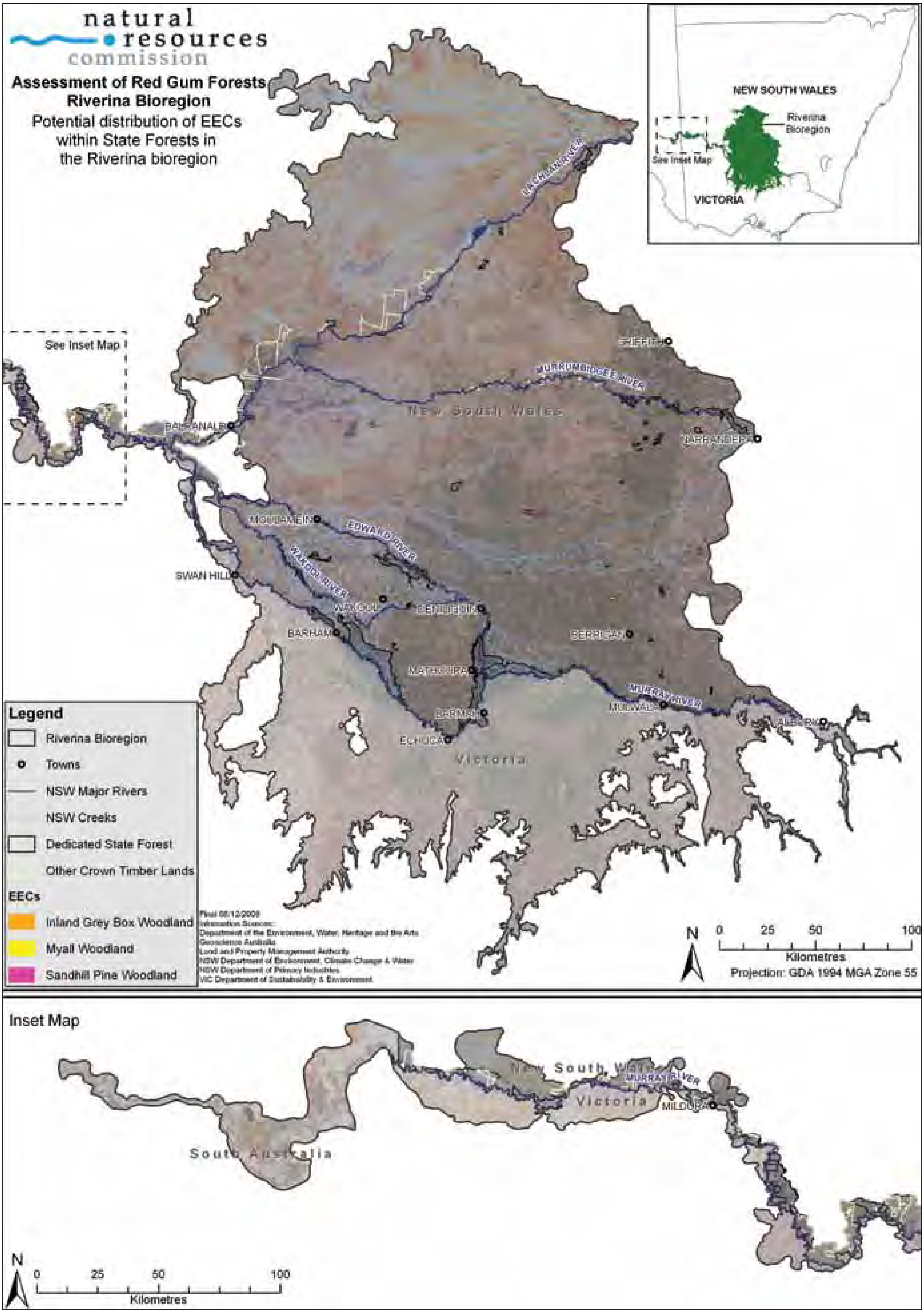


Table 4.5: EPBC-and TSC-listed fauna species of the Riverina, and their broad habitat requirements

		Status			Habitat feature			
Scientific name	Common name	TSC	EPBC	Connect-ivity	Wetlands	Vegetation mosaic	Tree hollows	Coarse woody debris
Amytornis textilis ssp *modestus*	Thick-billed Grass-wren (eastern subspecies)	CE	V	●				
Botaurus poiciloptilus	Australasian Bittern	V	-		●			
Burhinus grallarius	Bush Stone-curlew	E1	-					●
Cacatua leadbeateri	Major Mitchell's Cockatoo	V	-			●	●	
Calyptorhynchus lathami	Glossy Black-cockatoo	V	-			●	●	
Cinclosoma castanotus	Chestnut Quail-thrush	V	-	●				●
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	-			●	●	●
Crinia sloanei	Sloane's Froglet	V	-		●			
Dasyurus maculatus	Spotted-tailed Quoll	V	E	●		●		●
Falco hypoleucos	Grey Falcon	V	-		●	●		
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	V	-				●	
Glossopsitta pusilla	Little Lorikeet	V	-				●	
Grantiella picta	Painted Honeyeater	V	-			●		
Grus rubicunda	Brolga	V	-		●	●		
Hamirostra melanosternon	Black-breasted Buzzard	V	-			●		
Hylacola cauta	Shy Heathwren	V	-	●				
Lasiorhinus krefftii	Northern Hairy-nosed Wombat	Presumed extinct	E					
Lathamus discolor	Swift Parrot	E1	E			●		
Leipoa ocellata	Malleefowl	E1	V	●				
Litoria raniformis	Southern Bell Frog	E1	V	●	●			●
Lophoictinia isura	Square-tailed Kite	V	-	●		●		
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V	-	●		●		
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	-	●		●		
Myotis macropus	Large-footed Myotis	V	-		●	●	●	
Neobatrachus pictus	Painted Burrowing Frog	E1	-		●	●		●
Neophema pulchella	Turquoise Parrot	V	-	●		●	●	
Ninox connivens	Barking Owl	V	-			●	●	
Ninox strenua	Powerful Owl	V	-			●	●	
Nyctophilus corbeni	Greater Long-eared Bat (south-eastern form)	V	V				●	●
Oxyura australis	Blue-billed Duck	V	-		●	●		
Pachycephala inornata	Gilbert's Whistler	V	-			●		●
Pachycephala rufogularis	Red-lored Whistler	CE	V			●		
Pedionomus torquatus	Plains-wanderer	E1	V	●				

Table 4.5: EPBC-and TSC-listed fauna species of the Riverina, and their broad habitat requirements continued

	Status				Habitat feature			
Scientific name	Common name	TSC	EPBC	Connect-ivity	Wetlands	Vegetation mosaic	Tree hollows	Coarse woody debris
Petaurus norfolcensis	Squirrel Glider	V	-	●		●	●	
Petroica rodinogaster	Pink Robin	V	-			●		
Phascogale tapoatafa	Brush-tailed Phascogale	V	-	●			●	
Phascolarctos cinereus	Koala	V	-					
Polytelis anthopeplus monarchoides	Regent Parrot (eastern subspecies)	E1	V	●		●	●	
Polytelis swainsonii	Superb Parrot	V	V	●		●	●	
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V	-			●		
Pyrrholaemus sagittatus	Speckled Warbler	V	-	●		●		●
Rostratula australis	Australian Painted Snipe	E	V		●			
Saccolaimus flaviventris	Yellow-bellied Sheathtail bat	V	-			●	●	
Stagonopleura guttata	Diamond Firetail	V	-			●		●
Stictonetta naevosa	Freckled Duck	V	-		●			
Tiliqua occipitalis	Western Blue-tongued Lizard	V	-					●
Tyto novaehollandiae	Masked Owl	V	-			●	●	
Vespadelus baverstocki	Inland Forest Bat	V	-			●	●	
Climacteris affinis	White-browed Treecreeper population in the Carrathool LGA south of the Lachlan River and Griffith LGA	Endangered Population	-	●				●
Anthochaera phrygia	Regent Honeyeater	E1	E			●		

Flora species listed under the TSC Act and/or the EPBC Act are shown in **Table 4.7**. Of the 18 species, one (floating swamp wallaby-grass) is associated with swamp margins in river red gum forest and woodland, and is threatened by changed water regimes. An additional species (yellow gum) grows within river red gum forest and woodland along the Murray River. The remaining 16 species may have been recorded in river red gum types, but are generally associated with other vegetation communities. A recovery plan has been completed for one EPBC-listed flora species, the sand-hill spider orchid, while plans are being prepared for three others.

Table 4.8 presents the main habitat requirements of a subset of river red gum and wetland-dependent fauna and flora species known to be threatened by declining condition in the Murray, Murrumbidgee and Lachlan forests (**Chapter 9**). Many of these species are listed under the EPBC Act and are matters of NES. Habitat requirement data in **Table 4.8** are supported by relevant Australian and NSW Government recovery plans, species-listing profiles drawn from threatened species websites, and expert knowledge.

An indicative range for each species listed in **Table 4.8** is mapped in **Figures 4.16** to **4.21**. Each map includes known survey records. Indicative ranges have been delineated using expert knowledge, supported by national distribution maps drawn from species identification guides. They are very broad, but provide an indication of the likely range of key species in the Riverina bioregion.

It is observed from these figures that survey records for most species in the Riverina are closely associated with the location of the main channels and river red gum forests, indicating their importance in supporting these species. However, interpretation of the relative density of records across the region should be undertaken with some caution, due to a skewed distribution of survey effort. That is, an apparent concentration of records in one area (for example, Yanga National Park) may be as much to do with survey effort as relative species abundance, as other areas of river red gum in the Riverina are known to have been relatively poorly sampled.

Table 4.6: EPBC-listed CAMBA, JAMBA and ROKAMBA bird species of the Riverina

	Status				Habitat feature			
Scientific name	Common name	EPBC-listed migratory birds of the Riverina	JAMBA / CAMBA/ ROKA-MBA	Connect-ivity	Wetlands	Vegetation mosaic	Tree hollows	Coarse woody debris
Apus pacificus	Forked-tailed Swift	M	J, C, R					
Ardea alba	Great Egret	M	J, C		●			
Ardea ibis	Cattle Egret	M	J, C		●			
Calidris acuminata	Sharp-tailed Sandpiper		J, C, R		●			
Calidris ruficollis	Red-necked Stint		J, C, R		●			
Gallinago hardwickii	Latham's Snipe	M	J, C, R		●	●		
Haliaeetus leucogaster	White-bellied Sea-Eagle	M	C		●			
Hirundapus caudacutus	White-throated Needletail	M	J, C					
Hydropogne caspia	Caspian Tern	M	J, C		●			
Plegadis falcinellus	Glossy Ibis		C		●			
Rostralula benghalensis	Australian Painted Snipe	E, M	C		●			
Tringa nebularia	Greenshank	M	J, C, R		●			
Tringa stagnatilis	Marsh Sandpiper	M	J, C, R		●			
Anatidae (14 species in region)	Waterfowl	M	-		●			
Grus spp. (1 species in region)	Cranes	M			●			
Scolopacidae (5 species in region)	Snipe	M			●			
Recurvirostridae, Charadriidae (6 species in region)	Shorebirds	M			●			
Accipitridae (3 species in region)	Raptors	M				●		

Note: M, Migratory; E, endangered under EPBC Act; J, Japan – Australia Migratory Bird Agreement (JAMBA); C, China – Australia Migratory Bird Agreement (CAMBA); R, Republic of Korea – Australia Migratory Bird Agreement (ROKAMBA)

Hooded Robin – photo courtesy of DECCW (Michael Pennay)

Table 4.7: TSC-and EPBC-listed flora species of the Riverina

Scientific name	Common name	NSW status	EPBC status
Acacia curranii	Curly-bark Wattle	V	V
Amphibromus fluitans	Floating Swamp Wallaby-grass	V	V
Austrostipa metatoris	A spear-grass	V	V
Austrostipa wakoolica	A spear-grass	E1	E
Brachyscome muelleroides	Claypan Daisy	V	V
Brachyscome papillosa	Mossgiel Daisy	V	V
Caladenia arenaria	Sand-hill Spider Orchid	E1	E
Casuarina obesa	Swamp Sheoak	E1	-
Diuris pedunculata	Small Snake Orchid	E1	E
Diuris tricolor	Pine Donkey Orchid	V	V
Eucalyptus leucoxylon subsp. pruinosa	Yellow Gum	V	-
Kippistia suaedifolia	Fleshy Minuria	E1	-
Lepidium monoplocoides	Winged Pepper Grass	E	E
Maireana cheelii	Chariot Wheels	V	V
Philotheca ericifolia		V	V
Pilularia novae-hollandiae	Austral Pillwort	E1	-
Pultenaea humilis		V	-
Swainsona murrayana	Slender Darling Pea	V	V

Beyond the species listed under state or federal legislation and on international treaties, there are many other species that are supported by the river red gum forests. Some of these are known to be declining in the region, prompting the NSW Scientific Committee to reach a preliminary determination that they meet the criteria for 'vulnerable' under the TSC Act. These species are important regionally because of their breeding habitat and the numbers of birds congregating to breed, or because they are at the limits of their range with pressure on their habitat.

Opinions vary about the status of 'regionally significant' species; however, these species may include:

- azure kingfisher (*Alcedo azurea*) – declining
- flame robin (*Petroica phoenicea*) – preliminary determination
- inland carpet python (*Morelia spilota variegata*) – declining
- intermediate egret (*Egretta intermedia*) – important breeding
- little eagle (*Hieraaetus morphnoides*) – preliminary determination
- royal spoonbill (*Platalea regia*) – important breeding
- scarlet robin (*Petroica boodang*) – preliminary determination
- spotted harrier (*Circus assimilis*) – preliminary determination
- straw-necked ibis (*Threskiornis spinicollis*) – important breeding
- swamp wallaby (*Wallabia bicolor*) – limit of range
- tiger snake (*Notechis scutatus*) – declining
- varied sittella (*Daphoenositta chrysoptera*) – preliminary determination
- white ibis (*Threskiornis molucca*) – important breeding
- white-browed woodswallow (*Artamus superciliosus*) – preliminary determination
- white-fronted chat (*Epthianura albifrons*) – preliminary determination.

Table 4.8: Key species recorded in the river red gum forests of the Riverina

Common name	Scientific name	Status	Notes on distribution	Priority habitat	Main habitat requirements in the Riverina
Australasian Bittern	*Botaurus poiciloptilus*	V (TSC Act)	Wetlands of the Barooga, Murrumbidgee and Millewa forests	Wetlands in river red gum forests	Dense reed beds are its principal habitat type, but can be found in swamps, streams and estuaries. Preys on insects, crustaceans, frogs, fish and insects. Breeding and nesting usually take place on a platform of trampled weeds, rushes and cumbungi, usually near water level in heavy cover.
Barking Owl	*Ninox connivens*	V (TSC Act)	Barooga, Millewa, Murrumbidgee and Perricoota forests	River red gum forests	Primarily inhabits open forest and woodland, in warm lowland areas on gentle terrain (Ayers et al., 1996). Roosts by day in dense streamside woodlands and thickets of Casuarina and Acacia, as well as eucalypts, and forages in adjacent woodland; it is often associated with red gum species (Higgins, 1999). Are assumed to be sedentary, living singly, in pairs or family groups of three to five in permanent territories containing several roost sites. Requires hollow trees for nesting. They hunt nocturnally for a variety of mammals up to the size of a rabbit, primarily native gliders (Kavanagh and Bamkin, 1995). barking owl habitat is threatened by land clearance and feral honeybees, which can take over the owls' nesting hollows. Ecology of the barking owl is also analysed by Kavanagh et al. (1995), Kavanagh and Stanton (2009), Parker et al. (2007), Webster et al. (2003) and McGregor (in press).
Blue-billed Duck	*Oxyura australis*	V (TSC Act)	Lachlan and Murrumbidgee and Millewa forests	Wetlands in river red gum forests	Prefers habitats of permanent freshwater swamps, dams, lakes and larger rivers, usually with a cover of dense vegetation. Feeds upon a wide variety of seeds and leaves of freshwater plants as well as large numbers of midge, caddisfly and dragonfly larvae. Breeding and nesting take place in a cup-shaped nest constructed in rushes, reeds, sticks, cumbungi or lignum with a little down lining. Often a canopy of surrounding growth is pulled over it in cumbungi, rush, lignum or tea-tree, either over water or on the ground if on an island. Occasionally they will utilise the old nest of other waterfowl.
Brolga	*Grus rubicunda*	V (TSC Act)	Wetlands of the Barooga and Millewa forests	Open wetlands in river red gum forests	Typically prefers habitats that consist of shallow swamps and their margins, floodplains, grasslands, paddocks and ploughed fields, irrigated pastures, stubble and crops. Brolgas are omnivorous, with their diet consisting of grain crops, in particular sorghum and maize, as well as tubers. A variety of insects, spiders, freshwater and marine molluscs, crustaceans, small mammals and reptiles and frogs comprise the rest of their diet. Breeding and nesting usually take place in a nest constructed of grasses and plant stems, on small islands in swamps or in water. Occasionally eggs are laid on bare ground.
Bush Stone-curlew	*Burhinus grallarius*	E1 (TSC Act)	Murrumbidgee, Millewa, Barooga Wakool and Perricoota forests	Scattered occurrences in red gum forests and box woodlands	The habitat of the bush stone-curlew is eucalypt woodland with a dry grassy understorey. It is absent from both treeless areas and dense forests. The favoured habitat in western NSW is reported by Maher (1988) (cited in Smith 1991) to be black box *(Eucalyptus largiflorens)* woodland. It is a nocturnal species that forages the ground in woodland and in nearby open areas, including cropland and saltmarshes. The diet comprises seeds, fruits and other plant material along with insects and other invertebrates. Small reptiles and frogs also form part of their food source. Breeding and nesting take place on bare ground.

Table 4.8: Key species recorded in the river red gum forests of the Riverina continued

Common name	Scientific name	Status	Notes on distribution	Priority habitat	Main habitat requirements in the Riverina
Freckled Duck	*Stictonetta naevosa*	V (TSC Act)	Barooga, Millewa and Lachlan forests (also found in Lower Lachlan)	Wetlands in river red gum forests	Prefers heavily vegetated swamps, large open lakes and associated shores and floodwaters. Feeds by filtering and dabbling, which limits their foraging to aquatic habitats, especially shallow productive waters or soft mud at wetland edges. Breeding and nesting usually occur in a well-constructed bowl-shaped nest of stems and sticks in lignum or in overhanging tea-tree branch or flood debris close to water. It will at times utilise old coot nests.
Gilbert's Whistler	*Pachycephala inornata*	V (TSC Act)	Campbells Island Western and Millewa forests	River red gum forests and black box woodlands	Prefers mallee, often in association with spinifex, although it also utilises shrubby mulga or taller eucalypt woodlands, belah, riverine black box and lignum, or partly cleared country (Pizzey, 1980). Bimble box/pine and ironbark/pine woodlands also support this species, again when in association with a shrubby understorey. They construct a bulky cup nest made of bark strips, grass, twigs and leaves, lined with grass and rootlets and loosely bound with cobwebs, wool and vine tendrils, and may be well built or rather untidy (Pizzey, 1980). Nests are located in the dense upright fork in a shrub or low tree (up to 2 metres high), often among a heavy growth of vine, within a mistletoe clump, or on top of a stump among coppice. Feeds on invertebrates, seeds and plant material, predominantly taken from the ground but may also be gleaned from low trees and shrubs (Barker and Vestjens, 1990).
Glossy Ibis	*Plegadis falcinellus*	CAMBA (EPBC Act)	All forests	The margins of wetlands, swamps, lakes, irrigation bays	Glossy ibis is a migratory species inhabiting wetlands, swamps, lakes, irrigation bays, and other shallow water bodies where they congregate in small to large flocks. They forage for various invertebrates and frogs. A group of 10–20 birds will nest, often amongst colonies of other ibis and egrets. Their nest is situated just above the water level, and typically only one chick will fledge.
Great Egret	*Ardea alba*	JAMBA, CAMBA (EPBC Act	All forests	The margins of wetlands, swamps, rivers and lakes	The great egret is a solitary species that forages in shallow waters in search of frogs, small reptiles, fish, molluscs and other invertebrates. They form small flocks at night and breed in colonies, often with other species of egret and ibis.
Painted Snipe	*Rostralula benghalensis*	E, CAMBA (EPBC Act)	Murrumbidgee, Lachlan, Barooga, Millewa forests	Margins of wetlands and swamps	The habitat of the painted snipe consists of swamp fringes, dams, sewage farms and marshy areas that generally have a cover of grasses, lignum, low scrub and open timber. Their diet mainly consists of aquatic plants and seeds, insects, worms, molluscs, crustaceans and other invertebrates. Breeding and nesting take place in a well-made saucer of twigs, reeds and grasses which is often set on a small hummock above water level, usually in cover. The nest may also have a canopy of stems and grasses.
Powerful Owl	*Ninox strenua*	V (TSC Act)	Recent record in the Barooga forests	River red gum forests	Primarily distributed on the coastal side of the Great Dividing Range, they inhabit tall open sclerophyll forests, dense mountain gullies, coastal forests and woodland areas. In the Riverina it has been recorded infrequently in river red gum. A sedentary species which lives singly or in pairs within permanent territories containing several roost sites. Nests are located on decayed debris in large hollow tree limbs or trunks 10–20 m above the ground. Hunts nocturnally within more open forest types, their primary prey species being arboreal and semi-arboreal mammals, as well as birds, insects and terrestrial mammals. Requires access to large contiguous blocks of forest/woodland.

Table 4.8: Key species recorded in the river red gum forests of the Riverina continued

Common name	Scientific name	Status	Notes on distribution	Priority habitat	Main habitat requirements in the Riverina
Regent Parrot (eastern subspecies)	*Polytelis anthopeplus monarchoides*	E1 (EPBC Act) V (TSC Act)	Western forests	River red gum forests	Occur in a wide range of habitats, from river red gum forest, black box woodland to mallee woodland. Observed nesting in old river red gums downstream from the Wakool-Murray River junction. A typical nest tree is greater than 18 m high, 134–175 cm DBH (average), a crown diameter of 19 m and within 16 m of permanent water. Nest trees are often surrounded by other old trees with a DBH of 125 cm (Beardsell, 1985; Burbidge, 1985). Regent parrots eat a wide variety of seeds and fruits, though they feed mostly in mallee. Threatened by clearing of nesting and feeding habitat, trapping for the avicultural trade, road kills, pesticide applications on grains and accidental poisoning through consumption of baits (Webster, 1991). Requires living or dead trees with hollows larger than 5 cm in diameter within 1 km of water courses or billabongs.
Square-tailed Kite	*Lophoictinia isura*	V (TSC act)	Lachlan, Murrumbidgee Western and Millewa forests	Occurs in a range of forest types. Locally in river red gum forests	The habitat of the square-tailed kite consists of open forests and woodlands, timbered watercourses, rocky hills and gorges. Their diet mainly consists of passerine bird species, foliage, insects and sometimes small mammals and lizards. Breeding and nesting usually occur in trees where the nest is large and constructed of loose sticks.
Superb Parrot	*Polytelis swainsonii*	V (TSC Act)	Barooga, Lachlan, Millewa and Murrumbidgee forests	River red gum forests	Nests in river red gum forests and forages in adjoining box woodlands including yellow box (*Eucalyptus melliodora*) and other eucalypts, as well as stubble, pastures, sugar gum windbreaks and homestead gardens. Outside the breeding season birds move out of the riverine forests into dry woodland *(Calltiris* and *Eucalyptus)*. Diet consists of seeds of grasses, herbs, crops and weeds. It also feeds upon fruit and blossoms of eucalypts and acacias. Breeding and nesting usually occur in hollow eucalypt limbs. Typical nests are large, mature, healthy trees with many sprouts (though dead trees are also used). A typical nest tree is greater than 33 m high, 157 cm DBH (average), has a crown diameter of 11 m and is within 26 m of permanent water. Nest trees are often surrounded by other old trees with a DBH of 100 cm, typically located close to a watercourse (Webster, 1988).
Brush-tailed Phascagole	*Phascogale tapoatafa*	V (TSC Act)	Barooga, Millewa, Koondrook-Perricoota forests	River red gum forests	The preferred habitat of the brush-tailed phascogale is dry sclerophyll open forest with a sparse ground cover of herbs, grasses, scleromorphic shrubs or leaf litter. The small, mainly arboreal brush-tailed phascogale is an agile climber and individuals forage preferentially in rough-barked trees of 25 cm DBH or greater, where available (Soderquist, 1993). The species is nocturnal and carnivorous, feeding on invertebrates and arthropods (such as spiders, centipedes, beetles and cockroaches), nectar and occasionally small vertebrates. Individuals use their fingers to extract prey from crevasses under bark. The brush-tailed phascogale nests and shelters in tree hollows, utilising many different hollows over a short time span. Suitable hollows are 25 – 40 mm wide (Ayers et al., 1996), lined with leaves and shredded bark and covered with pungent faeces which serves as a territorial marker (Soderquist, 1995).

Table 4.8: Key species recorded in the river red gum forests of the Riverina continued

Common name	Scientific name	Status	Notes on distribution	Priority habitat	Main habitat requirements in the Riverina
Koala	*Phascolarctos cinereus*	V (TSC Act)	Recorded in the Barooga forest; known to occur in the eastern parts of the Millewa and Murrumbidgee forests	River red gum forests	Has an extensive but disjunct distribution from northern Queensland to southern Victoria (Strahan, 1995). Essentially arboreal, it is an extremely agile climber and leaper. Is restricted to eucalypt forest and feeds almost exclusively on the leaves of eucalypts, in particular in the Riverina, the river red gum (*Eucalyptus camaldulensis*) and bimble box (*E. populnea*). Breeding occurs in trees during summer. Although it lives predominantly in trees, it may travel for some distance on the ground in search of food.
Squirrel Glider	*Petaurus norfolcensis*	V (TSC Act)	Barooga and Millewa forests	River red gum forests with a silver wattle understorey	Inhabits a variety of wet and dry sclerophyll forests, including open forests, low open forests and woodlands, where it lives in family groups. Forages at night in the upper canopy feeding on nectar, invertebrates, pollen, lerps and sugary extracts from berries and fruits along with the occasional small bird and mouse. Glider habitat is threatened by clearing of woodland for agriculture, logging, grazing, predation by owls, foxes and cats, and loss of genetic diversity (Ayers et al., 1996).
Fishing Bat (Southern Myotis)	*Myotis macropus*	V (TSC Act)	Barooga, Millewa and Murrumbidgee forests (also found in Lower Lachlan)	River red gum forests	Associated with creeks, rivers and depressions where there is a reliable source of water and prey items (small fish). Roosts in caves, tunnels and man-made structures including culverts and bridges.
Sloane's Froglet	*Crinia sloanei*	V (TSC Act)	Millewa and other forests on Murray	River red gum forests	Occurs in the Murray-Darling Basin in grassland and woodland that are periodically inundated.
Southern Bell Frog	*Litoria raniformis*	E1 (EPBC Act) V (TSC Act)	Murrumbidgee and Western forests	Wetlands in river red gum forests	Largely aquatic species found among vegetation within or at the edges of permanent water such as streams, swamps, lagoons and dams. Has taken advantage of irrigation developments in the Coleambally and Murray districts, where it has been recorded in rice crops. An opportunistic feeder of invertebrates and other frogs. Destruction of permanent wetland habitats by hydrological changes, clearing of wetland vegetation and trampling by grazing stock, along with high pesticide concentrations and salination affect the habitat of this species.
Floating Swamp Wallaby-grass	*Amphib-romus fluitans*	V (EPBC Act) V (TSC Act)	All forests along the Murray, except the Western forests	Wetlands in river red gum forests	Recorded on the south-west slopes and plains of NSW, this threatened species occurs in permanent swamps (Harden, 1993).
Yellow Gum	*Eucalyptus leucoxylon* subsp. *pruinosa*	V (TSC Act)	Known from several localities along the Murray	River red gum forests	Occurs in well-watered sites, often on deep soils along the Murray River.

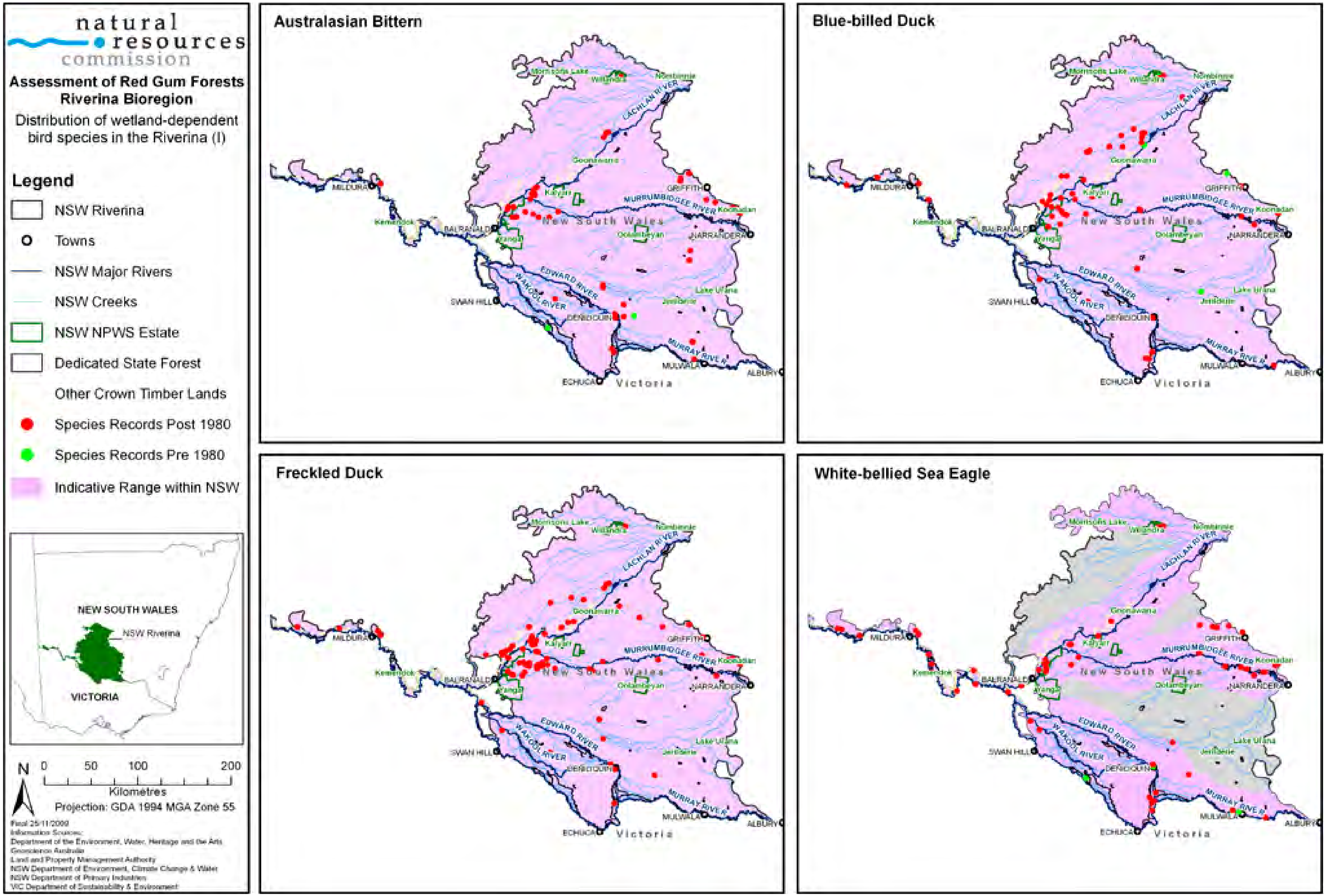
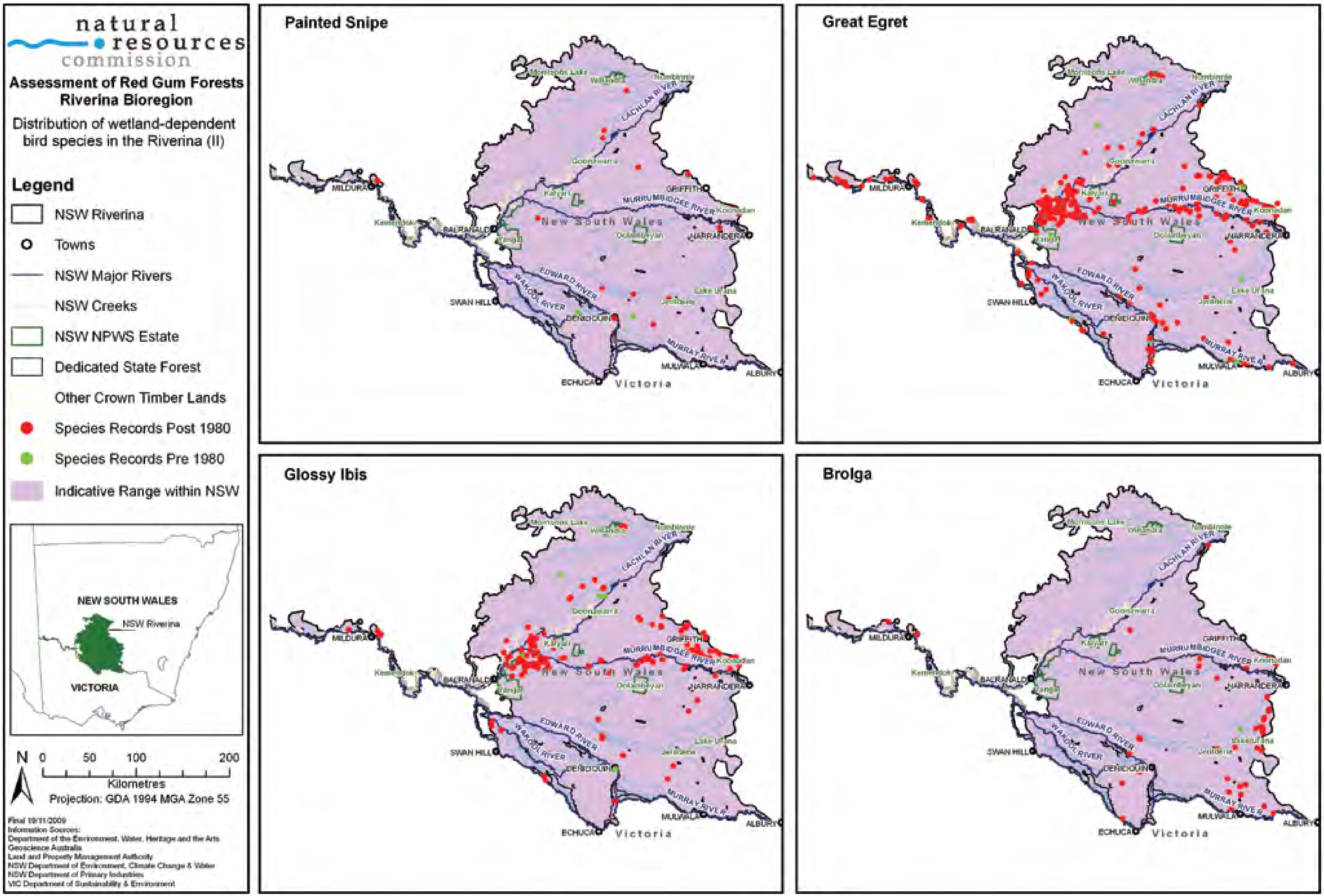


Figure 4.16: Distribution of wetland-dependent bird species in the Riverina (I)

Figure 4.17: Distribution of wetland-dependent bird species in the Riverina (II)



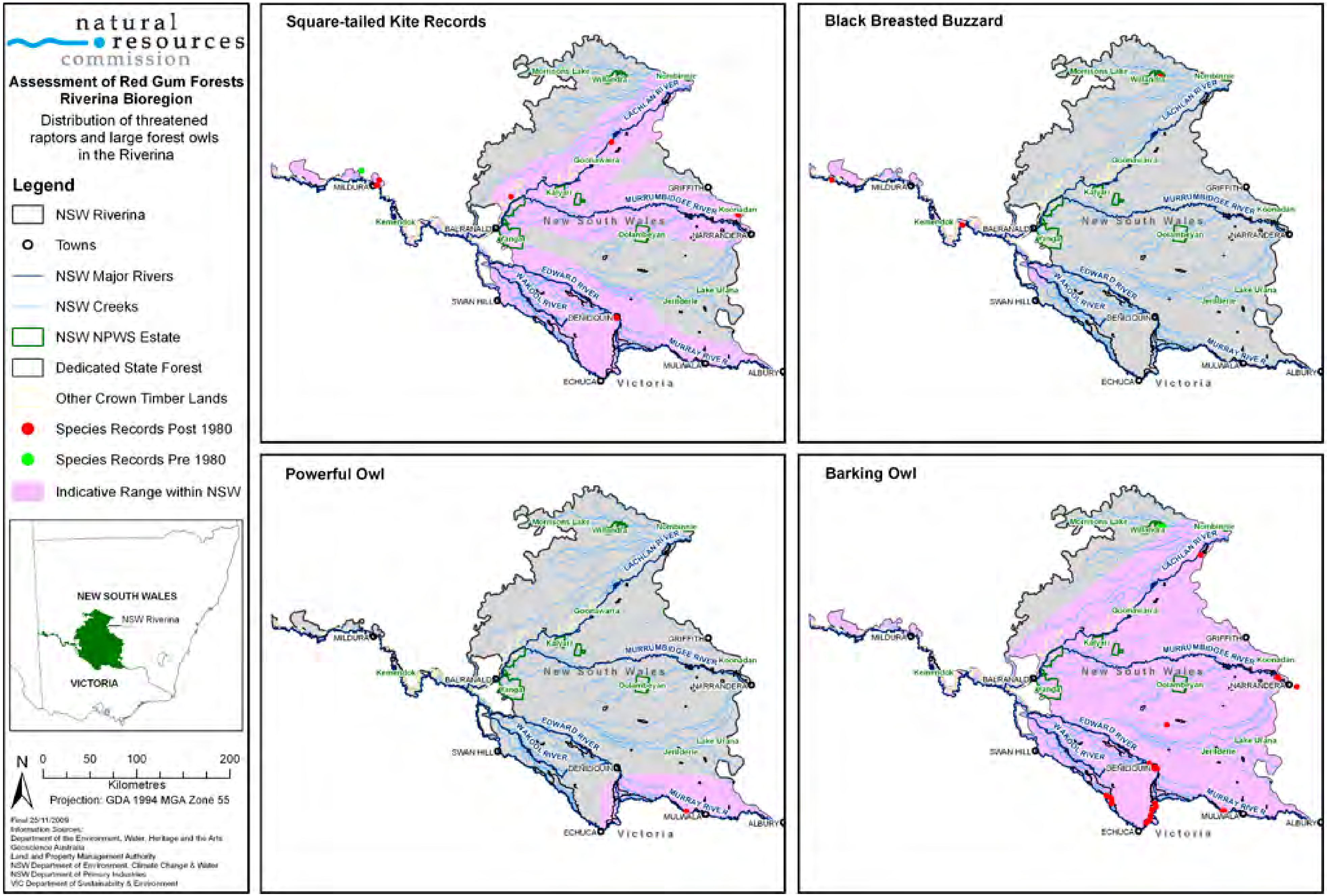
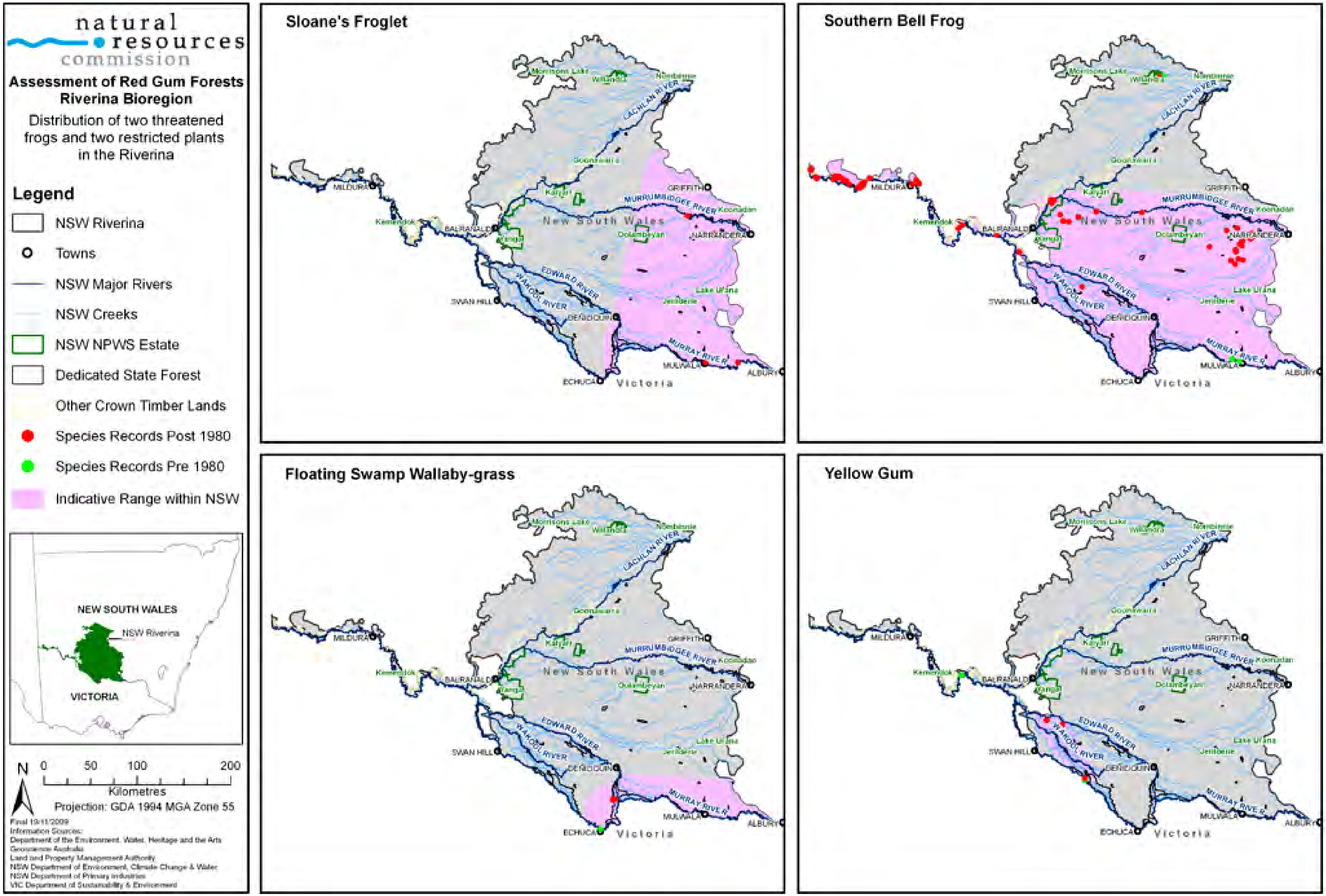


Figure 4.18: Distribution of threatened raptors and large forest owls in the Riverina

Figure 4.19: Distribution of two threatened frogs and two restricted plants in the Riverina



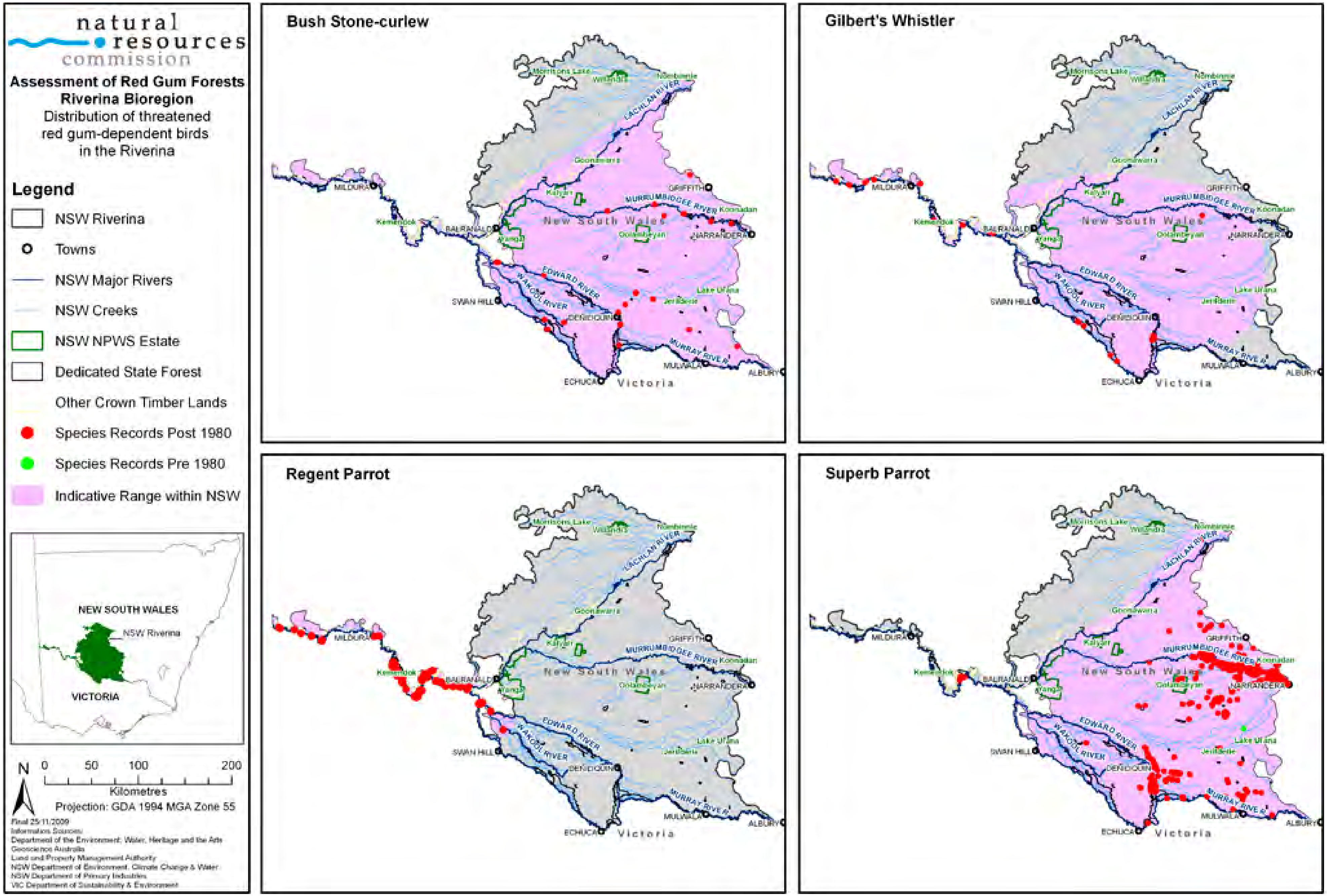
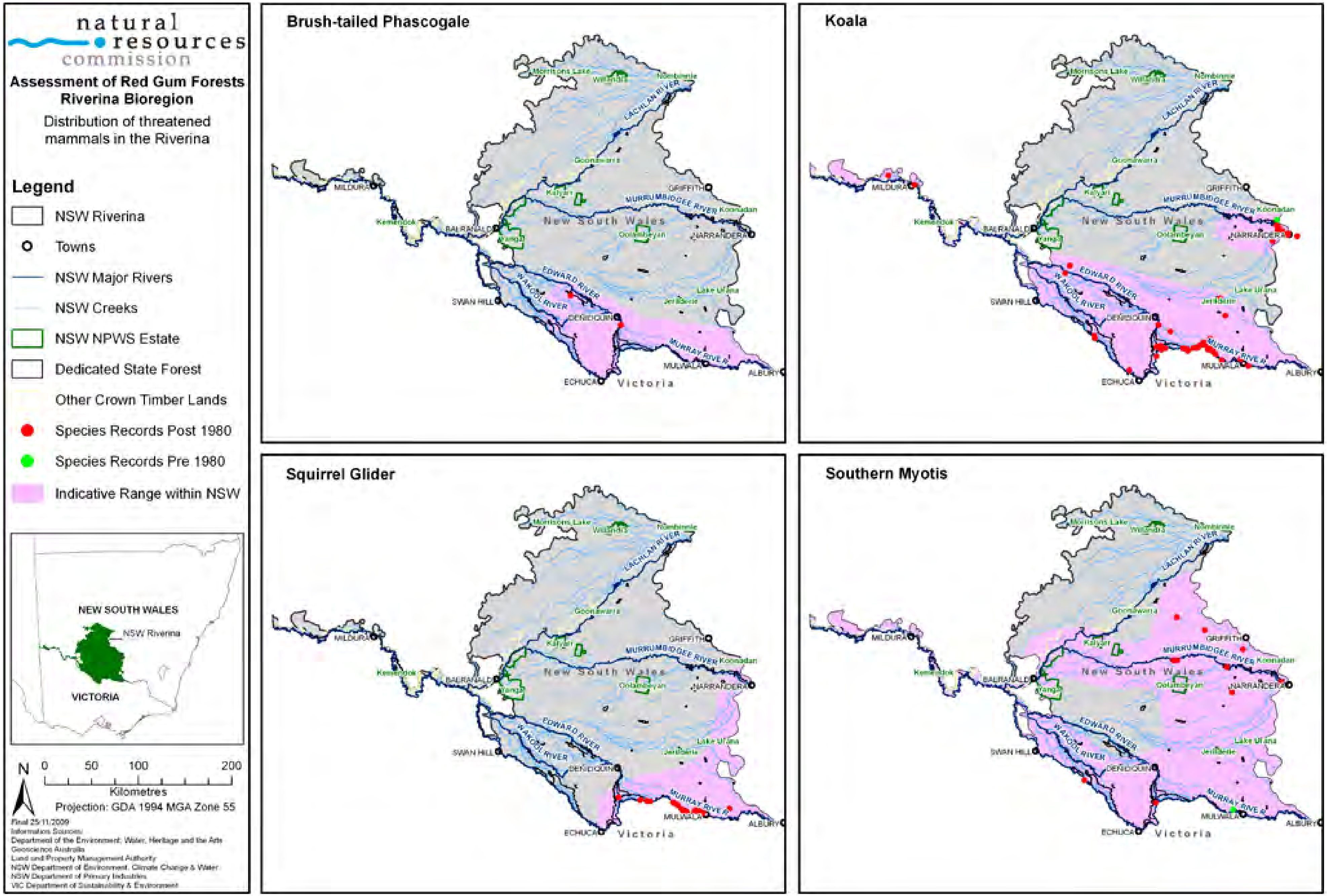


Figure 4.20: Distribution of threatened red gum–dependent birds in the Riverina

Figure 4.21: Distribution of threatened mammals in the Riverina



4.7 Ecological values by water management unit

In this section the flora and fauna are described for the forests associated with each water management unit (WMU) as defined in **Chapter 2**.

Millewa forests

The Millewa forests in the Central Murray State Forests, together with the adjacent Barmah group in Victoria, constitute the largest single stand of river red gum in Australia. They are part of the NSW Central Murray State Forests Ramsar site listed on the Directory of Important Wetlands of Australia, and are recognised as a significant ecological asset under The Living Murray program. The Millewa forests contain a mosaic of river red gum types, with a number of sand ridges supporting the EEC cypress type throughout. Yellow box (*Eucalyptus melliodora*) and inland grey box (*E. microcarpa*) often co-dominate the river red gum. The total area of forest in this group surpasses 43,000 hectares, of which about 39,000 hectares is river red gum–dominated. The forest is in relatively good health in contrast to other red gum forests, particularly those occurring to the west (for example, Pennay, 2009).

The Millewa forests are known to support a diversity of avifauna and have been identified by Birds Australia as an 'Important Bird Area'. They support barking owl (Moira, Barmah and Deniliquin State Forests) and superb parrot nesting sites (Gulpa Island and Millewa State Forests). The forests are important for threatened honeyeaters, with large numbers of black-chinned honeyeaters recorded, as well as records for painted and regent honeyeaters. They are one of the two known areas in the region supporting Gilbert's whistler and are habitat for the hooded robin. Other important bird species recorded in the Millewa forests include Australasian bittern, blue-billed duck, bush stone-curlew, crested shrike-tit, diamond firetail, grey-crowned babbler, southern whiteface, square-tailed kite, varied sittella and white-browed babbler.

These forests provide a habitat network for at least eight globally threatened fauna listed by the IUCN in 2000. The IUCN Red List (2000) lists the Australasian bittern, superb parrot, silver perch and flat-headed galaxias as 'vulnerable', and the regent honeyeater, swift parrot, Murray hardyhead and trout cod as 'endangered'.

Millewa forests support a high diversity of microbats, including the large-footed bat and the yellow-bellied sheathtail bat. The forests also contain brush-tailed phascogales and koalas, which are both at the western limit of their range. There is a large population of possums and gliders supported by a high density of tree hollows, providing a reliable source of food for arboreal predators such as barking and possibly powerful owls.

The Millewa forests also play a substantial role in the functioning of the Murray River, particularly in terms of hydrology, flood mitigation, water quality, sediment deposition and river health.

Koondrook-Perricoota and Campbells Island forests

The Koondrook-Perricoota forests incorporate the second-largest area of river red gum forest after Millewa. They form part of the NSW Central Murray State Forests Ramsar site, and are recognised as a significant ecological asset under The Living Murray program. They contain stands in good condition in the south-east and along the main channel. However, the majority of the forests are in poor condition (Pennay, 2009) and need relatively high flows to permit flooding. The majority of vegetation is river red gum tall open forest and woodland, with black box woodlands in the eastern section. Species listed in the *Threatened Species Conservation Act 1995* (NSW) in the area are the barking owl, gilbert's whistler, black-chinned honeyeater, hooded robin and yellow-bellied sheathtail bat. There are also historical records of the southern bell frog.

The Campbells Island forests are known to support Gilbert's whistler in the eastern section, which appears to be in relatively good health compared to the central and western sections (Pennay, 2009). The area is also important for regionally significant woodland birds such as the black-chinned honeyeater, diamond firetail, grey-crowned babbler and white-browed babbler.

The total area exceeds 36,000 hectares, of which 34,000 hectares is red gum dominated.

Werai forests

The Werai forests are supported by the Edward River, which is a main overflow channel of the Murray. The river red gum forests in Werai are an important site for inland forest bat, contain the westernmost record of brush-tailed phascogale, and are part of the NSW Central Murray State Forests Ramsar site and a Wetland of National Importance.

Murrumbidgee forests

A number of small State Forests connect a reach of the Murrumbidgee River downstream of the township of Narrandera. These forests are dominated by river red gum types, with some box woodlands on the outer floodplains and cypress pine on sandy rises in the eastern forests. Few surveys have been undertaken in the forests of the Hay area, so little data are available. However, the region is known to be a major breeding habitat for superb parrot, and contains records of other key avifauna including the Australasian bittern, barking owl, black-chinned honeyeater, blue-billed duck, brown treecreeper, bush stone-curlew, diamond firetail, freckled duck, grey-crowned babbler, plains wanderer (record in Wilbriggie State Forest), painted honeyeater, speckled warbler and turquoise parrot. The southern bell frog has been recorded in this area.

Plains Wanderer – courtesy Damon Oliver

Lachlan forests

The Lachlan forests support a diversity of vegetation types, including river red gum forest and woodland, river red gum–box woodland, riverine box woodland and mallee woodland. The area has been subject to a very low level of survey, so its fauna and flora values are largely unknown. However, superb and turquoise parrots have been recorded in these forests, along with blue-billed and freckled duck, pink cockatoo and square-tailed kite. Significant water bird breeding is known to occur in Moon Moon State Forest.

Upper Murray River riparian zone forests

The Upper Murray River riparian zone forests are known to be in good condition with a high diversity of old trees with hollows. These forests are the most eastern in the Riverina and consist almost entirely of river red gum. NSW Atlas records show that these forests support a diversity of eastern and western fauna. They have the only record of powerful owl in the Riverina State Forests, and are known to support Australasian bittern, barking owl, brolga and superb parrot. They are an important area for the koala and squirrel glider, and there is a record of brush-tailed phascogale. The forests contain a diversity of threatened birds including diamond firetail, freckled duck, hooded robin and magpie goose. Regent honeyeaters have also been recorded in nearby forests.

Wakool and Edward Rivers riparian zone forests

The Wakool forests along the Wakool River have been little surveyed. They comprise river red gum woodland, box–river red gum woodland and box woodland. The stand probably experiences infrequent flooding. A few threatened species such as speckled warbler, grey-crowned babbler and bush stone-curlew have been recorded, while two threatened grass species recorded in the vicinity include *Austrostipa metatoris* and *A. wakoolica*.

Lower Murray River riparian zone forests

The Lower Murray River riparian zone forests support a diversity of communities – river red gum forests, river red gum–box woodlands, mallee woodlands, lignum and semi-arid acacia woodlands. The area is a known breeding habitat for regent parrot (containing known nest sites), and supports the pink cockatoo and southern bell frog. The forests have the only record of western blue tongue lizard in the region, and a number of other species are unique to the Western group, including black-breasted buzzard, chestnut quail-thrush, greater long-eared bat, inland forest bat, malleefowl, purple-gaped honeyeater, redthroat and southern scrub robin.

Other forests and woodlands

A number of small and isolated State Forests are located within the semi-arid rangelands of the Riverina, outside the extent of river red gum and box woodlands. These forests often contain vegetation types which have been extensively cleared in the past, including the Inland Grey Box and Myall Woodland EECs.

Millewa State Forest on the Murray River

4.8 The application of reserve system principles

4.8.1 Reserve system principles

The possible future impacts of climate change and implications on the National Reserve System were investigated in a preliminary assessment undertaken by CSIRO (2008). This study outlined the potential impacts of climate change on biodiversity broadly and also at a regional level for 10 agro-climatic zones in Australia. The assessment identified eight key challenges to the management of the National Reserve System under possible future climate change, and discussed the implications for the development of reserves based on the Comprehensive, Adequate and Representative (CAR) system.

The 'Comprehensiveness' and 'representativeness' principles within the CAR reserve system focus on mitigating threats to species diversity. The system provides a basis for the development of a landscape based approach necessary to effectively and practically conserve species under the pressure of climate change. The authors recommend that additional emphasis should be placed on:

- maintaining landscape diversity
- conserving areas with high-habitat diversity
- conserving areas of known fire and climate refuges (CSIRO, 2008).

To ensure the viability of species under climate change, larger reserve areas and greater populations of species would be required (CSIRO, 2008). Four priority actions were recommended to address the issues identified in the study. Broadly, these actions were to:

1. understand how biodiversity will respond to climate change and the implications for conservation
2. protect more habitat and more diversity
3. manage habitat to reduce threats
4. manage landscape-scale issues.

4.8.2 Current reservation of river red gum types

NSW area estimates for the three river red gum groups (very tall forest, tall open forest, and woodland), the river red gum–box woodland and the black box woodland are shown in **Table 4.9**. These are linked to area estimates for individual NSWVCA types listed earlier. Combined area estimates for NSW and Victoria are included for context. These were derived by establishing equivalence between NSWVCA types **(Table 4.2)** and Ecological Vegetation Classes (EVCs) which are described and mapped in Victoria. These then drew on EVC extant and pre-1750 area statistics in Victoria (VEAC, 2008), and calculated the protected area of each EVC within all reserves in Victoria, including a number of recently gazetted reserves.

The estimated current area of river red gum dominant and co-dominant forest and woodland in the NSW Riverina is 401,000 hectares (from Benson et al., 2006; Benson, 2008). Of this, a total of 30,400 hectares is contained in 'protected areas', including:

- 27,400 hectares in national parks and nature reserves (DECCW unpubl. data)
- 2,600 hectares in Dedicated Flora Reserves in State Forest
- 300 hectares on lands managed as Indigenous Protected Areas, and
- 100 hectares on private lands over which a Voluntary Conservation Agreement or Property Agreement has been established.

As previously discussed, the 'protected areas' above do not include areas of State Forest categorised as Forestry Management Zone 3: Harvesting Exclusions and Special Prescription.

Areas of river red gum forest in State Forests, private land, and, to a lesser extent, western lands leases and travelling stock routes, are now the remaining areas of native forest and woodlands in the bioregion, totalling an estimated 401,000 hectares.

The estimated current area of river red gum dominant and co-dominant forest and woodland in the combined NSW, Victorian and South Australian Riverina bioregion is 582,400 hectares (from Benson et al., 2006; Benson, 2008; VEAC, 2008). Of this, an estimated 123,000 hectares is reserved in National Parks and nature reserves in NSW and Victoria.

There has been minimal land clearing of the high-productivity river red gum types along the Murray and adjoining channels and inner floodplains. This is most likely because the dominant land-clearing pressure in the bioregion has been for cropping and pastoralism, which are not viable on regularly inundated land. Less than 20 per cent of river red gum tall forest has been cleared in the past.

In contrast, the lower-productivity river red gum woodland and river red gum–box woodland on the higher floodplains have been cleared to a much greater degree. Almost 60 per cent of river red gum–box woodlands of the floodplains, which often contain river red gum as a co-dominant, has been removed for broad-scale agriculture.

The level of reservation of river red gum box stands in the bioregion has been enhanced by the recent Victorian reservation decision. Only 7.6 per cent of the current extent of all river red gum stands in the NSW Riverina have been reserved, largely in Yanga National Park and various Flora Reserves. Meanwhile 21.1 per cent has been protected in Victoria and NSW, when including equivalent types in Victoria. The black box floodplain communities are relatively poorly reserved throughout their natural range, with just over 5.4 per cent reserved to date in NSW and Victoria combined.

4.8.3 Current reservation of other woodland types

NSW area estimates for other woodland types are also shown in **Table 4.9**. Nearly all of the extensive woodlands of the semi-arid Riverina bioregion have had more than 50 per cent of their former extent removed, mainly for grazing, with some cropping in the south-east of the bioregion. Most impacted have been the:

- box–cypress woodlands dominated by yellow box (*Eucalyptus melliodora*) and inland grey box (*E. microcarpa*)
- acacia woodlands, most notably those dominated by myall (*Acacia pendula*)
- white cypress woodlands.

The overall level of reservation is about 5 per cent, considerably lower than that of river red gum forests and woodlands. The level is similar in NSW and Victoria.

4.8.4 Application of JANIS reservation targets to river red gum forests

The *Nationally Agreed Criteria for the Establishment of a Comprehensive Adequate and Representative Reserve System for Forests in Australia* are widely known as the JANIS criteria. The JANIS criteria form part of Australian and NSW Government policies for sustainable landscape management. They focus on retaining functioning areas of ecosystems and managing them responsively to reduce and minimise threats. The application of the JANIS criteria takes into account a range of regional priorities, including social and economic considerations. The criteria are guidelines rather than mandatory targets, designed to deliver good conservation as well as acceptable social and economic outcomes.

The JANIS criteria have a target of reserving at least 60 per cent of the remaining extent of vulnerable ecosystems. A vulnerable ecosystem is one which:

- has been reduced by about 70 per cent in area within a bioregional context and which remains subject to threatening processes
- is not depleted but is subject to continuing and significant threatening processes (Commonwealth of Australia, 1997).

An application of the 60 per cent target to all river red gum and black box types, using both NSW and combined NSW/Victoria statistics, is shown in **Table 4.10**. Greater than 200,000 hectares of river red gum forest and woodland, and 200,000 hectares of black box woodland, would be required to achieve a target of 60 per cent of the current extent of these types, whether or not Victorian data is included.

Setting conservation targets for river red gum is difficult because the current extent of healthy river red gum appears to be contracting as a result of river regulation and climate change **(Chapter 8)**. In order to protect the function of red gum forests and ensure the continued delivery of ecosystem services, a more strategic and dynamic approach to conservation planning is required. This should extend current practice by utilising various other conservation approaches, such as initiatives on private land (for example, the environmental stewardship programs and the Nature Conservation Trust).

The key benefits of a reserve system are the protection of refugia (that are more resilient to climatic change) and the maintenance of major functional corridors. To achieve this, it may be necessary to reserve areas across a range of climates (temperate to arid), where flooding regimes can be delivered with reasonable confidence in each case. As mentioned above, complementary private land initiatives will be an integral part of landscape-scale protection of the values of the river red gum forests.

Concerns about the implications of climate change are stimulating policy makers to put greater focus on future viability and resilience of conservation reserves (National Biodiversity Strategy Review Task Group, 2009). Recent work on reserve design to improve viability under changed climatic conditions advocates:

- a shift in objective from preventing ecological change to managing change in ways that minimise biodiversity loss
- greater emphasis on identifying and protecting significant functional connectivity, and linkages to improve species and habitat migration
- coordination of a wide variety of conservation programs across the whole landscape, including those on private land (CSIRO, 2008).

Hay State Forest

Table 4.9: Area statistics for river red gum and other woodland types

	NSW only					NSW and Victoria**				
Vegetation group	Pre-European	Current	Reserved*	% cleared	*** % reserved	Pre-European	Current	Reserved	% cleared	*** % reserved
River Red Gum Very Tall Forest	35,000	30,000	5,700	14.3	19.0	72,000	62,400	20,700	13.3	33.2
River Red Gum Tall Open Forest	115,000	94,000	3,800	18.3	4.0	162,000	134,000	23,500	17.3	17.5
River Red Gum Woodland	131,500	75,000	12,700	43.0	16.9	222,000	116,400	30,000	47.6	25.8
River Red Gum–Box Woodland	465,000	202,000	8,200	56.6	4.1	602,000	269,600	48,800	55.2	18.1
ALL River Red Gum types	746,500	401,000	30,400	46.3	7.6	1,058,000	582,400	123,000	45.0	21.1
Black Box Woodland	700,000	350,000	9,100	50.0	2.6	839,000	417,700	22,600	50.2	5.4
ALL	1,446,500	751,000	39,500	48.1	5.3	1,897,000	1,000,100	145,600	47.3	14.6
Other woodland types										
Box–White Cypress	1,400,800	188,200	900	86.6	0.5	1,518,000	202,400	1,700	86.7	0.8
Ironbark Shrubby	120,000	50,000	5,100	58.3	10.2	120,000	50,000	5,100	58.3	10.2
Mallee	500	240	100	52.0	41.7	2,000	700	200	65.0	28.6
Semi-arid Acacia	2,242,000	678,500	38,800	69.7	5.7	2,242,000	678,500	38,800	69.7	4.7
Semi-arid Oak	1,358,000	701,000	47,100	48.4	6.7	1,458,000	749,400	67,700	48.6	9.0
Slender Cypress	4,000	800	0	80.0	0.0	15,000	2,500	0	83.3	0.0
White Cypress	506,000	150,800	1,600	70.2	1.1	513,000	153,100	2,500	70.2	1.6
ALL	5,631,300	1,769,540	93,600	68.6	5.3	5,868,000	1,836,600	116,000	68.8	6.3

* Informed by the NSWVCA database (Benson et al., 2006 and DECCW unpublished data).
** Also informed by VEAC (2008) EVC area data. Includes draft proposal reservation areas in reserved extent.
*** Percentage of current extent.

Table 4.10: JANIS targets for river red gum types in the Riverina (assumes all types 'vulnerable'*)

Vegetation types	NSW-only area (ha)				NSW and Victoria combined area (ha)			
	Current	60% current	Reserved	New reserves to meet target	Current	60% current	Reserved	New reserves to meet target
River Red Gum Very Tall Forest	30,000	18,000	5,700	12,300	62,400	37,440	20,700	16,740
River Red Gum Tall Open Forest	94,000	56,400	3,800	52,600	134,000	80,400	23,500	56,900
River Red Gum Woodland	75,000	45,000	12,700	32,300	116,400	69,840	30,000	39,840
River Red Gum–Box Woodland	202,000	121,200	8,200	113,000	269,600	161,760	48,800	112,960
All River Red Gum types	401,000	240,600	30,400	210,200	582,400	349,440	123,000	226,440
Black Box Woodland	350,000	210,000	9,100	200,900	417,700	250,620	22,600	228,020
ALL	751,000	450,600	39,500	411,100	1,000,100	600,060	145,600	454,460

* Vulnerable does not mean listed under the TSC Act or EPBC Act.

Chapter 5

Economic and social values

5.1 Overview

The river red gum forests of the Riverina bioregion contribute to the local and regional economy through the primary industries of timber production, grazing and apiary. The multiple recreational opportunities provided by the forests also contribute to the local tourism industry. The future strength of the Riverina bioregion's communities – its economy and social fabric – depends on the health of its biophysical landscape, including the river red gum forests.

This chapter provides an overview of the economic and social values supported by the river red gum forests, and supports Step 2 of the analytical framework, by describing the:

- broader economic context of the Murray and Riverina regions
- structure and economic contribution of the red gum forestry industry reliant on public land
- current status of timber resources on public and private land
- current status of grazing and apiary within State Forests
- tourism values supported by public land within the bioregion
- towns within the bioregion which have close ties to the river red gum forests and the forestry industry.

The key findings of this chapter are:

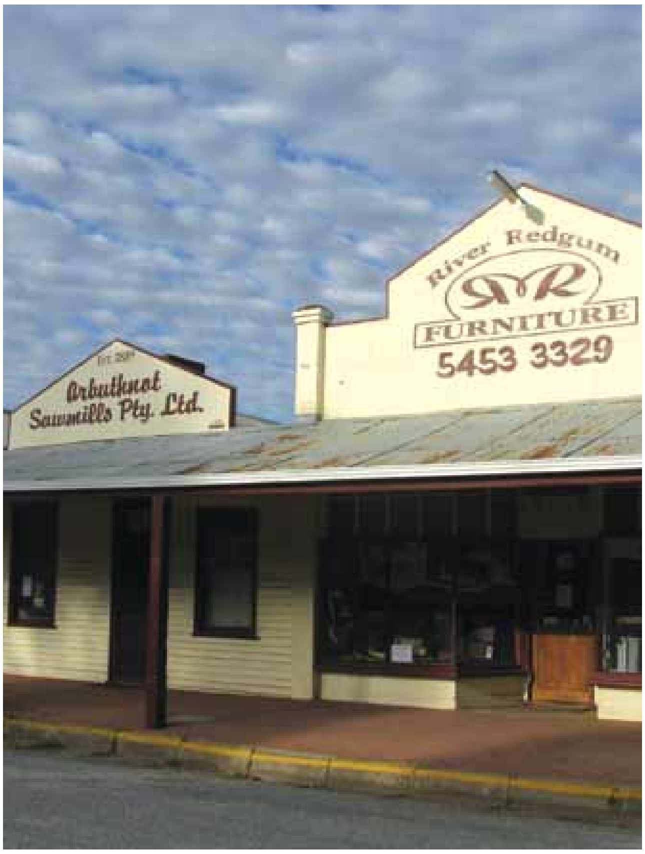
- The forestry industry related to red gum forests on public land in the bioregion makes a relatively small contribution to the NSW economy at a regional level (less than 1 per cent).
- However, it is a significant employer for several towns in the region, employing 304 full-time equivalent (FTE) staff directly related to timber from public land. Commercial operations with licences to harvest timber from public land employ 274 FTE employees and Forests NSW employs 30 FTE employees.
- Of the 274 FTE employed in commercial operations, 149 FTE staff work in mills which source higher-quality timber from public land. A further 43 FTE work with mobile mills which produce sleepers as a primary product. The remaining 82 FTE work in firewood operations.
- Seven towns within the region have close ties to the forestry industry reliant on public land. The twin towns of Barham-Koondrook have the highest number of forestry industry employees based on location of employment. Other commercial operations are located in the towns of Mathoura, Deniliquin, Merbein (in Victoria), Balranald and Darlington Point.
- In general, these towns are being impacted by the ongoing drought which is driving a decline in the agricultural industries which form the base of their economies.
- Grazing and apiary on public land provide an important source of additional income to farmers and beekeepers in selected years when grasses or flowering shrubs and trees are plentiful.
- State Forests and National Parks within the region support very different tourist activities, and tend to attract different types of visitors.

5.1.1 Definition of region

In conducting a socio-economic analysis the typical units for data collection follow human settlement and economic patterns, which differ from biophysical characteristics. Thus, this chapter incorporates the use of three distinct, but similar, definitions of 'regions', including the:

- biophysical region, namely the Riverina bioregion, including both NSW and Victoria
- regional economy, based on Statistical Local Areas, both NSW and Victorian, within the bioregion
- tourism region, covering the parts of the Murray, Riverina and Outback regions in NSW.

Maps outlining the location of each 'region' are included at points in the chapter where each definition of the 'region' is introduced.



Arbuthnot Sawmills and furniture shop at Koondrook

5.2 Economy of the Riverina bioregion

The gross product for the NSW Riverina regional economy[1] was estimated at $4.9 billion[2] in 2009. Employment in the region is dominated by agriculture, fisheries and forestry and related processing operations; education and training; and retail sectors. Total employment in the regional economy was 47,511 people, including full-time and part-time workers.

Agriculture, comprising grains, beef cattle, sheep and other agriculture (largely viticulture), constitute the majority of primary industry in the region. Secondary manufacturing is an important part of the bioregion's economy, contributing 28 per cent of regional product. This is primarily based on food manufacturing. As with most economies, the services sector constitutes the bulk of the tertiary industry. It provides 47 per cent of gross regional product and 63 per cent of employment.

Forestry makes a small contribution to the regional economy.

The major uses for irrigation water in the bioregion are on pastures or fodder crops for livestock (including dairying), and in rice production, with irrigated agriculture in the region including a mix of horticulture (grapes, citrus and vegetables) and broad-acre irrigation (rice, cereal, pasture and hay production). However, a recent decline in irrigated agriculture is evident due to low-security water allocations.

Figure 5.1 shows the boundary of the Riverina bioregion and the relevant Statistical Local Areas it covers. Two Victorian Statistical Local Areas were included to capture the economic value of forestry industry operations based in Victoria which draw from forests on NSW public land. The regional economy excludes the major regional centres of Albury and Wagga Wagga. It includes the towns of Narrandera and Griffith near the Murrumbidgee River. The southern part of the region includes areas of Victoria along the Murray River as far west as South Australia.

5.2.1 Contribution of the red gum forestry industry reliant on public land at different scales

The forestry industry reliant on river red gum wood from public land makes a relatively minor economic contribution at the regional and state level. However, at a local government level, the industry makes a significant economic contribution to the towns located near the red gum forests. While the red gum forestry industry reliant on wood from public land is a niche component of the overall forestry industry in NSW. it produces a range of specialised products for which other timber substitutes are not readily available.

Given the relatively small size of the river red gum timber resource, the forestry industry reliant on public land hardwood forests of the Riverina bioregion contributes less than 1 per cent of the region's economy, and by inference an even smaller proportion of NSW's economy. Compared with a gross product (or value-added) for the bioregion's economy of $4.9 billion, the forestry industry reliant on river red gum forests on public land makes a direct contribution of $23 million.[3]

These figures are based on regional input-output analysis, as discussed above. In the time available to conduct this assessment, the analysis was not able to be extended to examine the effect of possible changes in timber supply on the bioregion's economy. However, as the red gum forestry industry makes a relatively minor contribution to the economy of the Riverina and Murray regions, impacts as a whole can be assumed to be minor.

In contrast, at a local government scale, the red gum forestry industry reliant on public land is significant to seven towns in the Riverina bioregion. There are 32 businesses with licences to harvest timber from public land. When combined with Forests NSW operations, around 300 FTE employees are directly related to red gum forestry industry reliant on public land. A further 15 contractors and 17 employees of a downstream milling business were identified. Employees work primarily in the towns of Deniliquin, Barham-Koondrook, Mathoura, Balranald, Darlington Point and Merbein.

The red gum forestry industry of the Riverina bioregion is a relatively niche, self-contained sector of the forestry industry in NSW. Given the different type of timber produced, the red gum industry is not linked in to regional pulp, sawlog and plywood industry based around the softwood plantations near Tumut. The distinctive colour of red gum timber has facilitated the development of boutique furniture and veneer products (BIS Shrapnel, 2001) that are not easily substituted by other hardwoods.[4] Due to its durability, red gum timber is also used for timber railway sleepers and similar applications requiring durability, such as wharf timbers, in preference to other species.[5]

[1] For the purposes of this analysis, the NSW Riverina regional economy was defined to include the Statistical Local Areas in NSW of Wentworth, Balranald, Wakool, Murray, Deniliquin, Conargo, Murrumbidgee, Griffith and Berrigan. Two Statistical Local Areas in Victoria, namely Mildura Rural City Part A and Gannawarra, were included to capture the expenditure of mills located in these areas which source timber from river red gum forests in NSW.

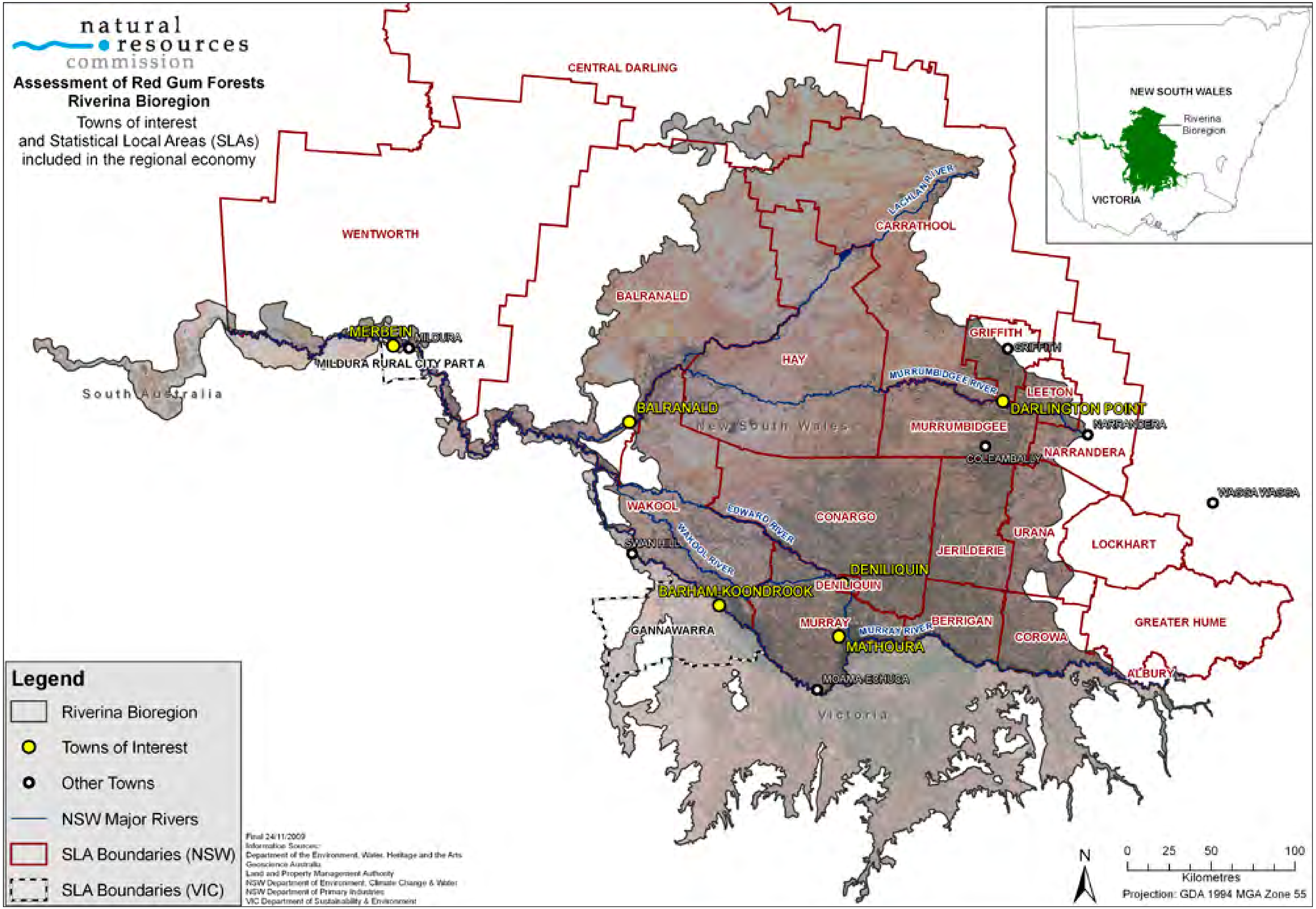
[2] Input-output analysis was used to examine the size and structure of the regional economy. This was based on ABS 2006 employment data and a 2005–06 model of the NSW economy developed by Monash University. Outputs were indexed to 2009 values. The indicators used to determine the size of the region's economy include gross regional output, gross regional product (value-added), income and employment. Gross regional product, rather than output, was chosen as the key indicator in this section because it avoids double counting associated with the purchases of intermediate products. **Appendix 9** provides the results of this analysis as well as a discussion of the analytical approach. The underlying assumptions and acknowledged limitations are also covered.

[3] When the indirect or 'flow-on' economic impacts of expenditure by the forestry industry (see **Appendix 9** for details on methodology and results) and its employees are included, the total contribution of the industry reliant on public land is estimated at $39 million or 0.8 per cent of the gross product of the bioregional economy.

[4] While some degree of substitution may be possible from other Australian native hardwoods (notably jarrah) or dark red hardwoods from South East Asia and South America, these products have a different colour and variously different properties to red gum. Also, as discussed in **Chapter 10** of this report, the availability of high quality red hardwood timber in Australia is increasingly constrained.

[5] While other types of timber are not used for sleepers, red gum timber does compete with concrete sleepers for new tracks. However, red gum timber is still used for repairs and maintenance on sections of track with existing timber sleepers (BIS Shrapnel, 2001).

Figure 5.1: Towns of interest and Statistical Local Areas included in the regional economy



5.3 Structure of the red gum forestry industry on public land

The NRC conducted a survey of the red gum forestry industry to collect primary data on the employment and financials of the forestry industry value chain and of typical businesses. The purpose of this survey was to understand the structure and size of the red gum forestry industry which sources timber from public land, and to assess its economic contribution to the regional economy. Results from the survey were supplemented by information provided by Forests NSW, drawn from their management and accounting systems.

In broad terms, the red gum forestry industry can be segmented into:

- large mills which focus on value adding to higher-quality logs
- mobile mills/operations which focus on railway and landscape sleepers, and
- smaller operations which focus on lower grade products such as firewood ('residue operations').

This report primarily considers those operations which source red gum timber from public land. Some of these operations also source timber from private land. Other operations which source timber entirely from private land are not covered in this report.

The key findings of the industry survey are:

- The 'red gum industry' is heterogeneous in terms of its constituent businesses; this diversity and the vertical integration of the larger mills ensure a high level of utilisation of the harvested resource.
- Each of the sectors of the industry (large mills, mobile mills/ operations and residue operations) appears to be profitable. However in general, operations which focus on sleepers and firewood appear to have higher returns on assets due to their lower cost structures and less asset-intensive operations.
- Total employment in the industry directly related to river red gum timber on public land is 304 FTE employees (this includes 274 employees of commercial operations with licences to harvest timber from public land and 30 FTE Forests NSW employees). The survey also indicated 15 contractors and 17 employees of downstream milling businesses have some reliance on timber from public land.

5.3.1 Forests NSW operations

In the Riverina bioregion, total royalties paid to Forests NSW for timber allocations are $4.3 million per annum. While information on the cost of Forests NSW operations in the Riverina bioregion was not available, the Auditor-General's 2009 report indicates that native forest operations across all of Forests NSW estate operated at a loss of $14.4 million in 2007–08 (Auditor-General of New South Wales, 2009). The Auditor-General was unable to conclude whether this was due to operational inefficiency or because prices do not reflect the true cost of meeting supply.

Timber supply is allocated to industry either by annual quotas or through parcel sale arrangements on a rolling one-year contractual basis. No long-term commitments are in place for river red gum timber from the Riverina bioregion; however, many of the allocations have been held for a number of years. A base allocation of quota grade sawlogs is made available to sawmills under annual licences. Sawmills and mobile mills also have annual licences for base allocations of ex-quota grade sawlogs. In addition to this, parcel sales of ex-quota grade sawlogs and firewood generated from the supply of quota allocations are sold by tender (BIS Shrapnel, 2001). Some sawlogs and firewood from silvicultural activities conducted for the purposes of improving forest health are also sold under contract arrangements.

Table 5.1 provides a summary of the different grades of resource that Forests NSW provides to commercial operators in the red gum forestry industry.

Table 5.1: Summary of forest resources utilised by the forestry industry

Resource	Description
Quota	Quotas are annual allocations of quality ('quota') sawlogs to Crown sawmills. Around 7% of quota sawlogs are considered to be very high quality and are referred to as HQ1 sawlogs; others that are still of good quality and size are referred to as HQ2 sawlogs. The renewal of a quota allocation is not automatic but is based on an annual review of a mill's performance. In the case of the red gum quota mills, quotas have been renewed each year without change in volume apart from minor adjustments because of small overcuts or undercuts. Transfers of quotas are subject to approval from the Minister for Primary Industries. Companies considering the sale of their quota must therefore make application to Forests NSW for approval to transfer. There has been only one sale of a red gum quota in the last nine years.
Ex-quota	Sawmills also use ex-quota sawlogs that do not form part of their quota allocation. This category includes logs that are of good quality but below size limits subject to further minimum limit for utilisation by the sawmiller. Ex-quota allocations are also reviewed annually and do not have the same tradeability considerations as quota allocations.
Residue	Residue includes those parts of the log not suitable for sawn timber that are utilised for landscaping, firewood or biofuel.

In regulating the industry's activity on public land, Forests NSW issues four different types of licence (**Table 5.2**).

5.3.2 Commercial operators

Industry structure

The forestry industry related to public land in the Riverina bioregion is concentrated among six large, vertically integrated mill operators that carry out activities along the supply chain from harvesting to manufacturing. Smaller businesses operate in parts of the value chain providing services to the larger integrated operations (e.g. by harvesting sawlogs for mills) and harvesting residues for lower-value products. A simple conceptual model of the red gum forestry industry supply chain is shown in **Figure 5.2**. Most of the larger, integrated mills conduct all operations from timber harvesting through to manufacturing.

There is a significant amount of horizontal integration between industry members and within mills. Inter-linkages between businesses have developed in response to the commercial imperatives imposed by large, multi-year contracts for sleepers, as well as economies of scale in marketing and operations. For example, Redgum Timber Producers (a collaboration of six mills) collectively supply around half of the sleepers purchased by Vic Rail under a single contract.

Businesses involved in the industry can be categorised based on the nature of their operations and the quality of timber they source. **Table 5.3** provides a summary of the different types of businesses in the industry that source timber from public land. In addition to these businesses, one significantly sized mill that relies on timber from private land was surveyed. Campbell's Mill at Balranald sources timber products from 13 other operators and from Redgum Timber Producers, some of which rely on public land for timber.

Gulpa Mill – Deniliquin

Table 5.2: Description of licences issued for industry activities on public land

Licence	Description
Timber Licence	Authorisation under the *Forestry Act 1916* that allows the holder to take timber (trees) as specified in the licence on Crown timber lands.
Products Licence	Authorisation under the *Forestry Act 1916* that allows the holder to take products (product of trees or shrubs) as specified in the licence on Crown timber lands.
Contractor's Licence	Authorisation under the *Forestry Regulations 2009* that allows a contractor who is employed by a holder of a timber or products licence to cut, obtain or remove timber or products.
Operator Licence	Authorisation under the *Forestry Regulations 2009* to be held by any person who is engaged or employed to cut, obtain or remove timber or products from Crown timber lands.

Figure 5.2: Forestry industry supply chain

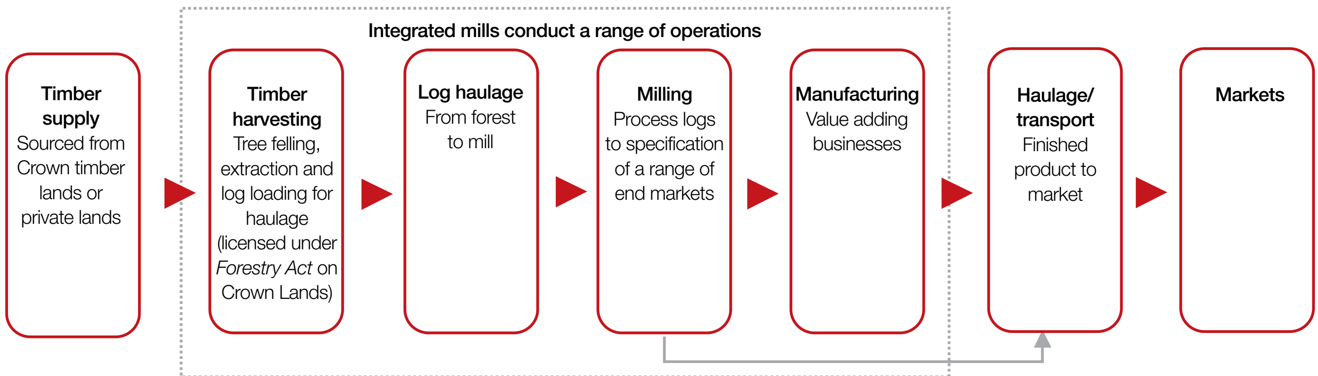


Table 5.3: Summary of business types

Business type	No. sourcing from public land	Description
Fixed location mill (Quota)	5	Larger mills with quota licences that are in fixed locations, usually in or near towns. These are generally integrated operations that conduct a significant proportion of their own harvesting operations and transport to the mill.
Mobile mill (Quota)	1	Mobile operations that source quota and ex-quota quality logs. These operations are located close to the timber source. Most of these operations also source residue material.
Mobile operations (Ex-quota)	8	Mobile operations that source ex-quota quality logs. Most of these operations also source residue material.
Mobile operations (Residue)	18	Mobile businesses that source residue materials, predominantly for firewood.

Table 5.4: Distribution of timber volumes from public land by business type*

Business type	Number of businesses	Percentage of total base allocation		
		Quota	Ex-quota	Residue
Fixed location or mobile mills** (Quota)	6	100	65	40
Mobile operations (Ex-quota)	8		35	11
Mobile operations (Residue)	18		35	49
TOTAL	32	100	100	100

* Base allocation information was provided by Forests NSW, based on their management and accounting systems..
** Five of the mills are fixed; one is mobile.

Table 5.5: Percentage of total timber sourced from public land

Business type	Number of businesses	Average percentage of total base allocation from public land
Fixed location or mobile mills (Quota)	6	74
Mobile operations (Ex-quota)	8	91
Mobile operations (Residue)	18	98

As **Table 5.4** shows, six quota mills account for the majority of quota and ex-quota timber volume from public land. Eight mobile operations account for 35 per cent of the ex-quota logs and 11 per cent of residue volume. Eighteen mobile operations source 49 per cent of the available firewood.

Some of the quota mills source timber from private as well as public land. **Table 5.5** shows the proportion of timber from public land for each type of business. The average for quota mills is skewed by two mills which draw a significant proportion of their timber from private land. The four other mills draw over 95 per cent of their timber from public land.

While it was outside the scope of this assessment to conduct a full survey of operations that rely on timber from private land, Campbell's Mill has a significant sleeper supply contract which is supplied from a mix of public and private land.

Location of businesses

The number and location of each of the businesses sourcing from public land are shown in **Table 5.6**. Two quota mills which source timber from public land in NSW are located in Koondrook and Merbein, close to NSW but on the Victorian side of the border. They have been included in this final assessment report to provide a comprehensive picture of the economic and social values supported by the river red gum forests of the NSW component of the Riverina bioregion.

Forests NSW manages the supply of timber to quota mills within three Management Areas to minimise the cost of transporting sawlogs. As **Table 5.7** shows, the six quota mills source timber from within the Management Area in which they are located.

Table 5.6: Number and location of operations

	Town of interest	Quota mills	Ex-quota mills	Residue operation	Total
Murray Management Area	Barham-Koondrook	3	2		5
	Deniliquin	1		2	3
	Mathoura		5	2	7
	Other Murray Management Area*		1	3	4
Subtotal		4	8	7	19
Murrumbidgee/Narranderra Management Area	Darlington Point	1			1
	Other M'bidgee/Narra-nderra Management Area**			2	2
Subtotal		1	0	2	3
Mildura Management Area	Balranald			5	5
	Merbein	1			1
	Other Mildura Management Area***			4	4
Subtotal		1	0	9	10
Total		6	8	18	32

* 'Other Murray Management Area' includes businesses based at Leitchville, Mulwala, Moama and Romsey which source timber from within the Riverina bioregion.
** 'Other Murrumbidgee/Narranderra Management Area' includes businesses based at Murrami and Leeton which source timber from within the Riverina bioregion.
*** 'Other Mildura Management Area' includes businesses based at Broken Hill and Pomona which source timber from within the Riverina bioregion

Table 5.7: Location of mills and sources of quota sawlogs*

Mill name	Location	Percentage of quota from each Management Area (MA)				
		Murray MA			Mildura MA	M'bidgee/ Narranderra MA
		Millewa Forest	Pericoota-Koondrook Forest	Werai Forest		
Bonum Sawmill (Rowes Timber Industries)	Barham-Koondrook	31	69			
Arbuthnot Sawmill	Barham-Koondrook	23	77			
O'Brien's Sawmill	Barham-Koondrook	51	49			
Gulpa Sawmill	Deniliquin	98		2		
Merbein Sawmill	Merbein				100	
Darlington Point Sawmill	Darlington Point					100

* Information was provided by Forests NSW on the volumes of quota timber sourced from each forest between 2004–05 and 2007–08. This information was drawn from Forests NSW management and accounting systems.

Products and key markets

A significant feature of the red gum forestry industry is its high utilisation rate of felled logs, achieved through the use of residue products for firewood, chips, mulch and sawdust. Fixed mills produce a wide range of products, from high-priced furniture grade timber or veneer, through to lower-priced products such as woodchips and mulch. Many mobile mills and operators derive a significant proportion of their revenue from firewood and residue products.

The major markets for river red gum products are metropolitan Melbourne and regional Victoria. Adelaide, regional South Australia, Canberra and, to a lesser extent, Sydney are also destinations for some products. A small amount of river red gum product is exported.

While relatively small in volume compared with the softwood plantation industry, red gum products are valued for the unique properties and distinctive appearance of their timber. The durability of river red gum timber makes it appropriate for use as structural timber as well as railway sleepers.

Table 5.8 provides a description of the different river red gum products and the key markets.

The estimated annual volume and range of unit prices for each product for surveyed quota mills is provided in **Table 5.9**. These estimates are indicative and are based on interviews with quota mills and other sources of market information. Given the variation in product mix between mills and over time in response to demand, they present an indicative picture of what a mill may produce.

The product mix produced by quota mills varies as product supply contracts change (reflecting changes in demand) and with variations in the quality of the available resource. Major contracts for sleepers are generally several years in length, with Vic Rail and the South Australian rail industry being the main customers. Markets for residue products of firewood, woodchips and mulch tend to be seasonal (BIS Shrapnel, 2001). As a result, firewood operations tend to cut timber when it is available and stockpile it for sale during winter.

Trends in the markets for red gum products over recent years vary depending on the nature of the product. Within the sleeper market, substitution of concrete for timber sleepers for major upgrades of freight rail lines has occurred in recent years. The other major market (by volume) of firewood appears to be strong and large enough to absorb increased supply of product (BIS Shrapnel, 2001). This is consistent with discussions held with the red gum forestry industry.

Employment

Employment directly related to the management, harvesting and milling of river red gum timber from public land in the NSW component of the Riverina bioregion is 304 full-time equivalent (FTE) staff. This includes:

- 274 employees of 32 commercial operations with licences to harvest timber from public land[6]
- 30 Forests NSW employees.

In addition, 15 contractors provide haulage services to the quota mills surveyed. A downstream milling business which does not have a licence to harvest timber from public land, but which sources timber from those who do, employs a further 17 staff.

Table 5.8: Description of river red gum products

Product	Description	Key markets
Furniture grade	Timbers for furniture and joinery	Melbourne
Veneers	Timbers for furniture and joinery	Melbourne
Weatherboards	Timbers for housing construction	Melbourne
Decking timbers	Timbers for housing construction	Melbourne
Sleepers	Replacement timbers for railways	Victoria and South Australia
Crossings timbers	Timbers for bridges and marine construction (both new and replacement)	Victoria and South Australia
Garden timbers	Landscape sleepers	National, Victoria and South Australia
Firewood	Split firewood	Melbourne, regional Victoria, Canberra, South Australia and Local
Woodchips	Residues used for landscaping	Local markets, Victoria and South Australia
Mulch	Residues used for landscaping	Melbourne, regional Victoria, South Australia
Sawdust	Residues for feedlots	Riverina

[6] A downstream milling business which does not have a licence to harvest timber from public land, but which sources timber from those who do was also surveyed.

Table 5.9: Estimated volume and range of unit prices (based on products from quota sawlogs)

Product*	Estimate of total volume	Range of unit prices
Structural, building, furniture and heritage grade	10%	$2,000–$2,500
Veneers	1%	$2,000–$2,500
Weatherboards	1%	$2,000
Crossings timbers	2.5%	$1,500–$1,800
Sleepers	25%	$600–$700
Decking timbers (green)	2.5%	$550
Garden timbers	12%	$390–$430
Firewood	35%	$100–$120/tonne
Woodchips	7.5%	$65–$100/tonne
Mulch	1%	$30
Sawdust	2.5%	$35

* Categories are aggregations across a range of products which have been grouped on the basis of price.

Table 5.10 shows the results of the forestry industry survey by type of business. Employment is dominated by the six mills with licences to source quota quality timber, which are responsible for over half the employees directly related to river red gum timber harvested from public land. The eight ex-quota mills employ around 15 per cent of the workforce and the 18 residue operators employ around 30 per cent.

Consistent with the terms of reference, this assessment has focused primarily on employment directly related to timber on public land rather than private land. Businesses surveyed covered 100 per cent of quota volume, 92 per cent of ex-quota volume and 70 per cent of residue volume from public land.

Where businesses were not able to be contacted or chose not to participate in the survey, an estimate of their employment was calculated on a pro rata basis using information on their licensed annual base allocation of timber.

The survey of those businesses with licences to harvest timber from public land identified a few businesses which provide contract haulage to the mills or conduct downstream milling. Employment in these businesses has been shown as separate items. Employment by other businesses which provide services (e.g. accounting, transport of finished products) to the forestry industry reliant on public land were not included in the survey.

Table 5.10: Employment in the red gum forestry industry reliant on public land (FTE) by business type

Employment category	Quota mills	Ex-quota mills	Residue operators	Total
Employees of commercial operations with timber licences				
Surveyed businesses	149	26	48	223
Pro rata estimate for businesses not able to be surveyed*	0	17	34	51
Subtotal employees	149	43	82	274
Forests NSW employees				30
Subtotal employees directly related to timber on public land				304
Contractors to businesses with timber licences				15
Employees of downstream milling business				17

* Employment numbers for businesses not able to be surveyed have been estimated on a pro rata basis. This includes two ex-quota businesses responsible for 8 per cent of ex-quota timber base allocations, and 11 residue operators responsible for 30 per cent of residue base allocations.

Some of the businesses surveyed are located in Victoria, but source timber from public land in NSW. These businesses employ 57 FTEs. As the location of employment for these employees are towns very close to the NSW border (Koondrook and Merbein), staff may live in either NSW or Victoria.

Employees of commercial operations with licences to harvest timber from public land have a mix of skills. **Table 5.11** shows the employment breakdown by category for those businesses that were able to be surveyed. The higher proportion of staff in management roles in ex-quota mills and residue operators, when compared to quota mills, may be due to the number of owner operators in these businesses.

Table 5.12 shows the location by town of employment of FTE employees of businesses with licences to harvest from public land. While some employees live in the town in which they are employed, some may live in nearby towns.

Numbers of FTE employees are based on the results of an industry survey. These were compared to total employment in the relevant urban locality (ABS, 2006) to estimate the percentage of employment in each town directly related to businesses with licences to harvest from public land. This demonstrates the high proportion of industry employment in Barham-Koondrook where three quota mills are located. Other quota mills are located at Deniliquin, Merbein and Darlington Point. Ex-quota mills are concentrated around Barham-Koondrook and Mathoura.

While residue operators are spread across a number of towns, there is a concentration at Balranald.

Table 5.11: Employment in surveyed commercial operations directly related to public land (FTE) by category

	Quota mills		Ex-quota mills and residue operators	
Category	FTE	% of total	FTE	% of total
Management	11.5	8	13	18
Administration	15.5	10	5	7
Bush operations	30	20	33	45
Milling	69	46	19	26
Other	23	15	4	5
Total of surveyed businesses	149		74	

Table 5.12: Employment in commercial operations directly related to public land (FTE) by town

Town	Direct employees of businesses with licences to harvest from public land (FTE)*	Estimated percentage of total employment in urban locality**	Number of businesses with licences to harvest from public land			
				Ex-quota mills	Residue operators***	Total
Barham-Koondrook (Vic)	119	16	3	2		5
Mathoura	31	14		5	2	7
Deniliquin	28	1	1		2	3
Merbein (Vic)	25	3	1			1
Balranald	24	5			5	5
Darlington Point	20	5	1			1
Other****	27	N/A		1	9	10
Total	274		6	8	18	32

* By location of employment.
** Based on comparing direct employees to ABS 2006 data for total employment in the relevant urban locality.
*** Some businesses licensed to harvest residue are included in the count of quota and ex-quota mills as these businesses have licences to harvest residue as well as quota or ex-quota timber.
**** Other locations include Leitchville, Mulwala, Moama, Romsey, Murrami, Leeton, Broken Hill and Pomona. Businesses located in these towns source timber from within the Riverina bioregion.

Table 5.13 shows employment by quota mills by length of tenure of employees. Over half the direct employees of quota mills have been employed for more than 10 years.

Table 5.13: Quota mill employment by length of tenure (FTE)

Length of tenure (years)	Direct employees of quota mills (FTE)	Percentage of total
0–1	11	7
1–5	33	22
5–10	24	16
10+	81	54
Total	149	100

Note: Percentages have been rounded.

The results of the NRC's survey provide confirmation of employment numbers directly related to the management, harvesting and milling of river red gum timber from public land in the Riverina bioregion. Other published estimates of employment in the red gum forestry industry have used different sources of data and have also included estimates of employment in businesses which source timber solely from private land. These estimates were based on a range of methodologies, scales and data sources that make direct comparisons between them difficult. A summary of these previous estimates and the reason for differences from the NRC's surveyed number is provided in **Table 5.14**.

Information on businesses sourcing timber solely from private land is limited. There is a concentration of residue and firewood operators around Balranald which rely on timber from private land. This was confirmed anecdotally by Forests NSW and discussions with the Forests Products Association (NSW).

Financials

Financial surveys were conducted of all quota mills and selected ex-quota mills and residue operators. The results of these surveys were used to estimate the contribution to the bioregional economy of the forestry industry reliant on river red gum sourced from public land, as discussed in **section 5.2.1** above. **Table 5.15** shows different measures of the direct contribution of the industry.

Information on assets was also collected for the quota mills surveyed. Total assets of $44 million are categorised as shown in **Table 5.16**. The valuation of assets is highly variable, as data included a mix of depreciation value, replacement value and insured value. Many businesses do not place a valuation on their quota licences so the total asset figure does not include their quota asset (which can be sold with approval from Forests NSW).

Separate to the analysis of the contribution of the forestry industry to the regional economy, the financial survey results were used to develop indicative discounted cash flow models for a typical quota mill, a mobile mill producing sleepers/residue and a residue/firewood operator.[7]

These models suggest that typical operations are profitable. However, mobile mills and residue/firewood operators operate with a lower overall cost structure and generate higher returns on assets. This is consistent with findings by BIS Shrapnel (2001).

Care should be taken in generalising these results to specific operations within the industry. The results of the discounted cash flow models are only indicative of a typical operation and do not take account of the varying supply volumes, product mixes and investment in equipment between businesses in the industry. As they are also based on aggregated data provided by a number of businesses with varying accounting practices it is possible that revenues for a typical quota mill have been underestimated and assets over-estimated.

Table 5.14: Previously published estimates of employment

Source	Estimate	Reason for difference from NRC-surveyed employment numbers
GHD (on behalf of Forests NSW (2009a)	183	Estimate based on assessment of ABS (2006) data and consultation with experts. Methodology not documented.
Forests NSW (2009a)	463	Includes 150 employees related to firewood operations which source from private land.
NSW Forest Products Association	537	Includes at least 150 employees of businesses reliant on timber resource sourced from private land.
ABS (2006)	1,008	Covers a broader region than the NSW portion of the Riverina bioregion which encompasses the softwood plantations around Tumut; includes forestry from white cypress, plantations, and on public and private land; includes job categories not directly related to red gum forestry industry.

[7] These models were constructed to reflect variations in the quality of timber used as inputs and the type of products produced by different operations. Given the range of different supply volumes, product mixes and status of equipment, judgement was applied to model businesses that were representative of the industry as a whole. See **Appendix 9** for a description of the methodology.

Table 5.15: Direct contribution of the red gum forestry industry reliant on public land (2009 dollars)

Measure	Direct contribution
Turnover (Gross output)	$48 million
Turnover less expenses (value-added through production activities)	$23 million
Income (wages paid to employees and imputed wages for business owners)	$11 million

Table 5.16: Breakdown of assets by category

Asset type	Estimated value
Property	$9.65 million
Buildings	$10.49 million
Machinery and processing equipment	$16.6 million
Mobile plant	$7.3 million
TOTAL	$44.04 million

5.3.3 Cost-benefit analysis

Cost-benefit analysis involves the identification and description of all costs and benefits at a state scale that may arise as a result of any change in public land management considered by the NRC. Cost-benefit analysis considers market values associated with industries that rely on them, as well as values that are not marketed. In the preliminary assessment report, cost-benefit analysis was considered as a possible method to provide an indication of the likely scale of net social benefits of the NRC's recommendations, but not as an analytical framework for decision-making.

While cost-benefit analysis can provide a useful indication of the relative value of market and non-market values associated with environmental assets, it has inherent limitations. These include issues related to how non-market values are estimated; the fact that 'real' costs are incurred at a local or regional level, whereas imputed benefits occur at a state level; and the fact that achievement of environmental outcomes may not be directly tied to policy recommendations.

The type of choice modelling that was used by the Victorian Environmental Assessment Council (VEAC) to estimate the non-market values, such as existence or protection values, of forests covered by the Victorian assessment, involves complex and lengthy research that could not be conducted for NSW in the time available for this assessment. The NRC decided against using the results of the VEAC assessment, due to the different context in which that research was conducted.

Therefore, the NRC has not conducted cost-benefit analysis, but has focused its attention on assessing the local market values associated with the forestry industry reliant on public land; the status of timber resources; the environmental values; the social, cultural and heritage values; and the requirements for ecologically sustainable management of the forests, all of which are discussed extensively in other sections of this report.

River red gum sleepers

5.4 Status of timber resources on public and private land

5.4.1 Resources of river red gum timber on public land

The *Forestry Act 1916* covers 'Crown timber land' comprising State Forests, leased Crown land and private land over which the government retains the right to take timber, as discussed in **Chapter 3** of this report. Timber licences to harvest timber from these public lands are granted by Forests NSW.[8]

In accordance with the first term of reference (**Appendix 1**), the scope of this assessment covers all public land, including all categories of 'Crown timber land'. However the primary focus is areas of State Forests.

Table 5.17 shows the total base allocation of river red gum timber per annum from the areas licensed by Forests NSW for harvesting. Actual volumes of quota and ex-quota logs harvested over the past 14 years have closely matched base allocations, with some inter-year variations. Volumes of residue, on the other hand, have steadily increased over this timeframe.

The areas licensed for harvesting are separated into three Management Areas. **Table 5.18** shows the breakdown of annual quota volumes by these Management Areas.

5.4.2 Resources of river red gum timber on private land

In contrast to timber on public land, the size and quality of the resource available from private land is highly uncertain. Widely quoted estimates that half of the total timber utilised by the forestry industry is sourced from private land are based on very high-level area estimates prepared in 2001 by Forests NSW and BIS Shrapnel. Available evidence suggests timber resources on private land are unlikely to provide the security of supply or quality of timber currently sourced from public land.

Harvesting of timber on private land is regulated by DECCW under the *Native Vegetation Act 2003* and *Native Vegetation Regulation 2005*. Private land is considered in this final assessment report to provide context for the total resource of river red gum timber available throughout the NSW portion of the Riverina bioregion, consistent with the first term of reference.

Forests NSW has estimated that volumes of river red gum timber harvested from private land (including areas outside the bioregion) are in the vicinity of the volumes harvested from public land (Forests NSW, 2001). A review by BIS Shrapnel in 2001 confirmed the magnitude of these figures, but was not able to usefully improve their accuracy[9] (BIS Shrapnel, 2001).

Commentary by BIS Shrapnel based on surveys of private landholders suggests that most of the river red gum timber on private land near major mills has already been heavily logged (BIS Shrapnel, 2001). The same report suggested that supply of quality logs from private land is likely to be highly variable, given the wide variety of the current condition (as at 2001) and management history of these forests.

Surveys of the major quota mill operators conducted for this assessment indicate that only two mills source significant volumes from private land, and these mills have a focus on producing lower-grade products from lower-quality timber. Other mills which have pursued a 'value-adding' strategy presumably would source high-quality timber from private land, were it available, but are not doing so.

There are notable exceptions to these generalisations, such as the long-term management of river red gum timber on private land by Merbein Sawmills, but the NRC's assessment is that they have been the exception rather than the rule.

In conclusion, the balance of available information suggests river red gum timber resources on private land are unlikely to match those on public land in volume or quality.

Table 5.17: Summary of base allocation of river red gum wood from NSW State Forests and Western Lands Leases*

Resource	Base allocation (per year)
Quota logs	31,010 m³
Ex-quota logs	28,107 m³
Residue log	101,548 tonnes

* Information as at August 2008–09 was provided by Forests NSW, drawn from their management and accounting systems.

Table 5.18: Base allocation volumes by Management Area*

Resource	Quota (m³/year)	Ex-quota (m³/year)	Residue (tonnes/year)
Murray Management Area	23,450	17,607	63,148
Mildura, Murrumbidgee and Narrandera Management Areas	7,560	10,500	38,400
Total	31,010	28,107	101,548

* Information was provided by Forests NSW, drawn from their management and accounting systems.

5.5 Other industries in the region's State Forests

5.5.1 Grazing

Grazing in State Forests has occurred for more than 150 years. The forests provide palatable species and water sources that are suitable for cattle production. While the forests provide a feed source to fill the winter feed gap, they provide a marginal additional value to graziers, rather than being a primary resource for the grazing industry.

Grazing is licensed by Forests NSW and guided by the Forests NSW Grazing Strategy. Graziers are issued either short-term grazing permits or annual occupational permits. Occupational permits describe the area able to be grazed; the time of the year when grazing is permitted; and management activities to be conducted, such as weed and pest animal control. Forests NSW estimates that the current occupation permits for grazing cover some 115,000 hectares out of a total of approximately 160,000 hectares of dedicated State Forests managed by Forests NSW. This supports an estimated 7,000 head of cattle (Forests NSW, 2008). **Figure 5.3** shows the broad distribution of grazing permits issued within the NSW portion of the Riverina bioregion.

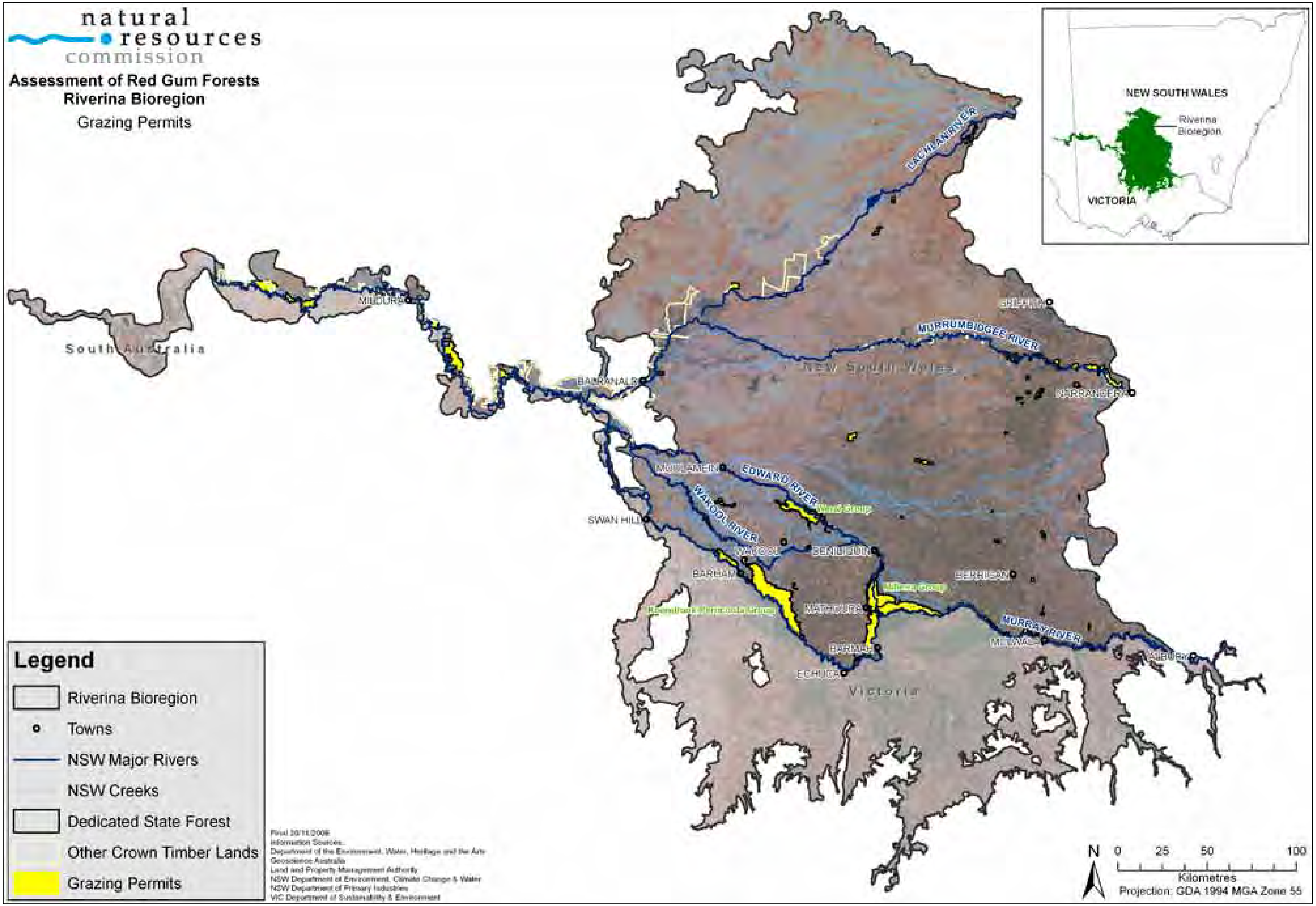
Livestock grazing

Stock gate in Euroley State Forest – photo courtesy of DECCW

[8] The Forestry Commission of NSW (currently trading as Forests NSW) is constituted under section 5 of the *Forestry Act 1916*. Section 27A of the *Forestry Act 1916* allows for the Forestry Commission to issue timber licences to take timber on Crown timber lands.

[9] This study compiled data from a range of sources on NSW river red gum forests on private land within the lower Murrumbidgee/Lachlan, Wakool, Edward, Koondrook and Millewa forest areas, and therefore included areas outside the bioregion. While acknowledging the limitations of available data on area and type of forests, the study estimated that approximately 136,000 hectares of red gum timber on private land was available for commercial harvesting.

Figure 5.3: Grazing p ermits



5.5.2 Apiary

State Forests are a valued resource for the apiary industry. The honeybee industry has used the river red gum forests in the Riverina bioregion for over 100 years. River red gum is a valued species for honey production and supports both NSW and Victorian apiaries. In addition, the State Forests provide rehabilitation areas, enabling apiarists to rebuild the strength and health of hives. Due to the availability of water, the forests are also useful drought reserves for the apiary industry.

Forests NSW issues permits that allow an apiarist to set down hives in a defined area. The permit generally covers a 1.5 x 1.5 square kilometre area. In 2005–06, Forests NSW issued 461 Occupation Permits to apiarists.

There are an estimated 600 sites within the assessment area that are suited for beekeeping. Further to this, submissions received by the NRC estimate that there are between 40 and 50 beekeepers who utilise the Millewa Forest and a further 15 to 20 in the Moira Forest area alone.

Pollination is usually short term (3–4 weeks); however, the presence of river red gums supports the hives for the remainder of the year. Flowering of river red gum is largely dependent on suitable flooding so, although this species can produce high-quality honey, significant production is relatively sporadic (VEAC, 2008).

5.6 Tourism

The State Forests of the Riverina bioregion have a long history of use by surrounding communities and visitors to the bioregion. Tourism values are connected to the river, beaches, trails and natural surroundings of the bioregion. The most popular sites are the weir pools and the white sandy beaches found at the bends of the Murray River, both having high aesthetic value. Many generations of families have spent time experiencing and enjoying visits to these areas and participating in the activities they support.

The Murray, Murrumbidgee, Edward and Lachlan rivers provide a focus point for many outdoor activities, while the adjoining State Forests provide access and complementary facilities. Good access, water and close proximity to urban areas have ensured the bioregion's continued popularity for tourism activities associated with the iconic red gums, rivers and wetlands.

5.6.1 Importance of tourism in the region

Tourism data are collated using LGAs which combine to make regions. The NSW portion of the Riverina bioregion includes parts of the Murray,[10] Riverina[11] and Outback[12] tourism regions. As shown in **Figure 5.4**, the Murray tourism region contains areas of high recreational value which are situated along the southern border of NSW (i.e. along the Murray River). The Riverina tourism region contains other areas of recreational value situated in the eastern central Riverina region.

The combined three tourism regions received 4.3 million visitors in 2008, with 6 million visitor nights. Holidays or leisure were the most common reason given for domestic overnight visits to these tourism regions; namely, 50 per cent for the Murray, 49 per cent for the Outback region and 31.5 per cent for the Riverina region. In the Murray and the Outback regions, the most popular accommodation option was 'Caravan or camping near road or on private property'. This reflects the holiday or leisure purpose of the visits.

Since 2005, domestic overnight visitor numbers have been on a downwards trend across all three regions. The Murray region has seen a 31 per cent decline in domestic overnight visitor numbers, and the Riverina region, a 28.5 per cent decline, while the Outback region experienced only a 3 per cent decline.

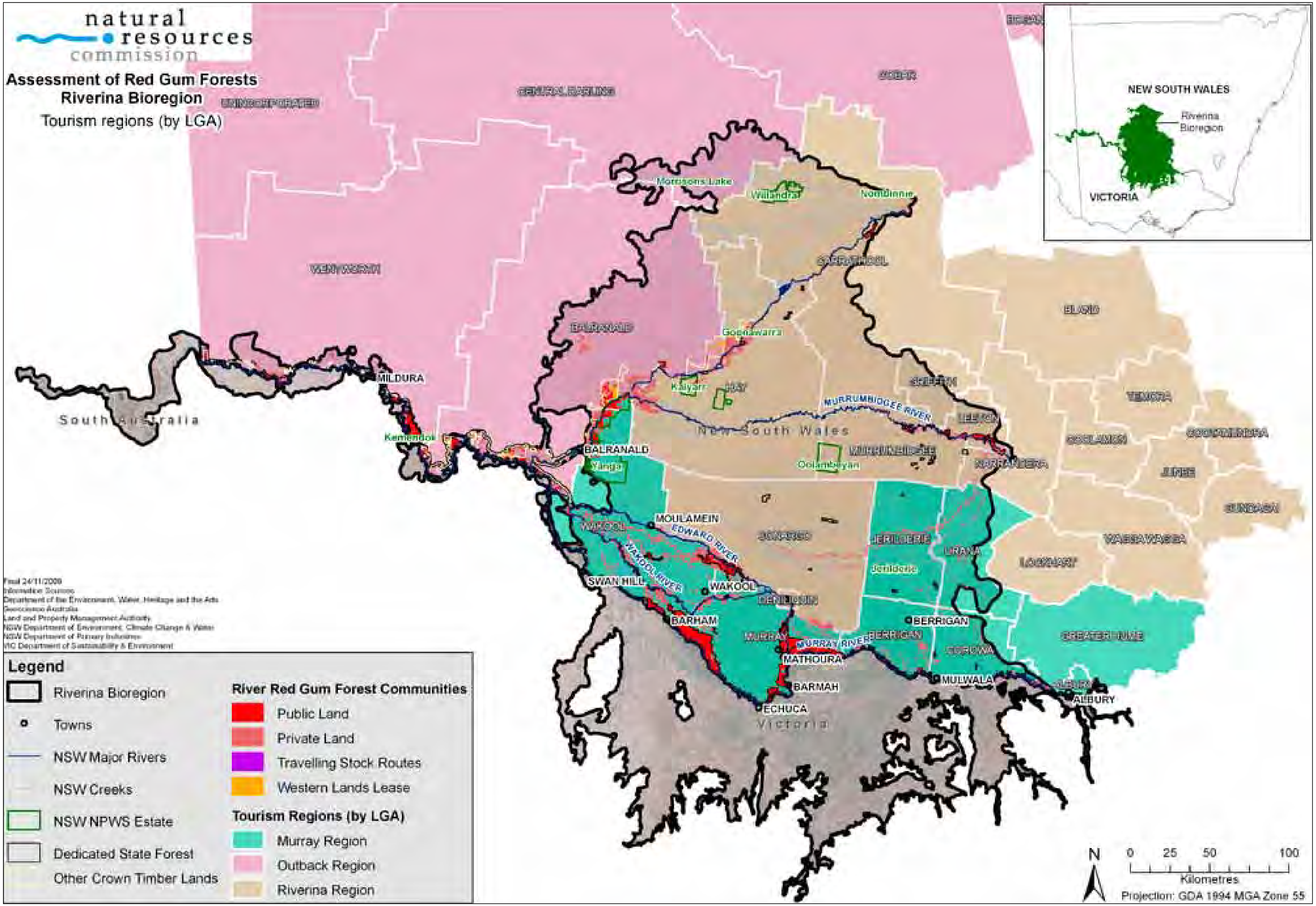
Fishing is a popular recreational activity

[10] The Murray region comprises the local government areas of Albury; Berrigan; Corowa Shire; Greater Hume Shire; Jerilderie; Murray; Urana; and Wakool.

[11] The Riverina tourism region covers the local government areas of Bland; Carrathool; Conargo; Coolamon; Cootamundra; Deniliquin; Griffith; Gundagai; Hay; Junee; Leeton; Lockhart; Murrumbidgee; Narrandera Temora; and Wagga Wagga.

[12] The Outback region covers the local government areas of Balranald; Bogan; Bourke; Brewarrina; Broken Hill; Central Darling; Cobar; Unincorporated Far West; Walgett; and Wentworth.

Figure 5.4: Tourism regions (by LGA)



The total annual tourism expenditure for these three regions in the year ending March 2009 was $1.197 billion (Tourism NSW, 2009a, 2009b, 2009c). **Table 5.19** provides an overview of the value of total tourism in the Murray, Riverina and Outback regions for the year ending March 2009. The three regions combined account for approximately 5 per cent of the total value of tourism to NSW.

Table 5.20 provides an overview of the source of visitors for each region. Anecdotal evidence from the NRC's tours of the bioregion indicated that the areas in the assessment in the Riverina and Outback regions also rely upon a majority of Victorian visitors.

Unfortunately, tourism data specific to the NSW river red gum forests in either State Forests or National Parks is very limited. However, Forests NSW estimates that the river red gum forests experience an estimated 500,000 visitor days per year (Forests NSW, 2008), bringing expenditure into local and regional areas (**Table 5.21**).

Yanga National Park has only recently opened. Currently there are no data on the social and economic value the park provides to the community, although there are ambitious projections for significant tourist numbers. The park has 13 caravan sites and 26 camping sites. There is not sufficient evidence to date of the economic impacts of transferring State Forests into National Parks.

Specific data for individual towns in the study area are limited; however, tourism data by LGA provides an indicator of the importance of tourism at a regional level.

Table 5.21 shows the number of visitors and estimated expenditure of visitors in the LGAs of towns of interest. Tourism numbers and expenditure associated with individual icon sites are obviously smaller than to the region as a whole.

Available data sources describe tourism activity as a whole and not specifically tourism that is connected to river red gum forests.

Table 5.19: Overview of total tourism in the region (Tourism NSW, 2009a, 2009b, 2009c)

Region	Expenditure ($)	'000 total visitors	'000 visitor nights	% of visitors to regional NSW
Murray	418	1,555	2,365	4.2
Riverina	523	2,019	2,014	5.1
Outback	256	702	1,660	2.8

Notes: Includes major regional centres such as Albury and Wagga Wagga. Expenditure values exclude airfares and long distance transport costs.

Table 5.20: Overview of the visitor source for each tourism region (Tourism NSW, 2009a, 2009b, 2009c)

Region	Murray Region	Riverina Region	Outback
Visitors from Victoria	62%	25%	22%
Visitors from regional NSW	19%	42%	39%
Visitors from Sydney	8%	20%	13%

Table 5.21: Visitor numbers and estimated expenditure in LGAs related to towns of interest (Tourism Research Australia, 2008a, 2008b, 2008c, 2008d)

Local Government Area (LGA)	Annual visitors to LGA	Estimated expenditure	Notes
Wakool Shire	80,000	$26 million	Includes the town of Barham
Ganawarra Shire (VIC)	62,000	$14 million	Includes the town of Koondrook
Deniliquin Shire	97,000	$25 million	
Murray Shire	78,000	$33 million	Includes Mathoura
Murrumbidgee Shire	-	-	Data not available
Balranald Shire	38,000	$7 million	
Mildura Regional Shire	465,000	$153 million	Includes the town of Merbein
Total	820,000	$258 million	

5.7 Socio-economic profiles of towns of interest in the Riverina bioregion

Seven towns within the region have close ties to the river red gum forestry industry reliant on public land. Consistent with the general trend in the rest of the Riverina bioregion, these towns are being impacted by the ongoing drought which is driving a decline in the agricultural industries which form the base of their economies. Socio-economic profiles of each of the towns are presented below, based on available statistical data and discussions with Local Councils in some towns. These profiles also draw on **Chapter 10** of this report, which used statistical indicators of economic, physical, human and social capital to assess the capacity of each town to adapt to changes in the industries most likely to be impacted by water scarcity, climate variability and climate change.

5.7.1 Barham-Koondrook (NSW/Victoria twin towns)

Barham (NSW) and Koondrook (Victoria) are twin towns on the Murray River, with a combined population of approximately 2,000. Barham is the largest town in the Wakool LGA, with other towns in the shire including Moulamein, Tooleybuc and Wakool. Koondrook is located in the Ganawarra Shire (Victoria), which includes the larger centres of Kerang and Cohuna. Swan Hill (75 kilometres), Deniliquin (98 kilometres) and Moama/ Echuca (90 kilometres) are the nearest larger service centres for the twin towns.

The towns have a number of local services, including a hospital, medical centres, schools, banks, post office and police station, as well as retail and dining businesses. Key local tourism attractions include river-based activities such as fishing, camping and river cruises, and sports and recreation (e.g. golf). The red gum industry, in addition to the forests themselves, is also a key tourist attraction.

The population of Barham-Koondrook increased between 1996 and 2006; however, the growth was predominantly in Koondrook on the Victorian side of the Murray River. Population growth on both sides of the river was primarily in older age groups, with an average age of 50 in 2006 (GHD, 2009). The proportion of retirees and unskilled workers in Koondrook is well above the regional average. The town has a very high proportion of adults with no post-school qualification (refer to **Section 10.5**).

Since 2006, the population growth trend is reported to have reversed, with working families migrating out of the area to seek employment. Higher levels of population mobility may be considered to reflect lower levels of social cohesion (refer to **Section 10.5**). This out-migration is believed to be a result of the intensifying drought (GHD, 2009). The drought has also seen major declines in the rice and dairy industries, with the number of dairies reducing from 27 to 2 in the last two years. Such declines are reported to have had significant consequences for employment, investment and spending (GHD, 2009).

Despite the drought there have been no recent closures of businesses or services, although one doctor has recently left town and the number of police has declined. Similar to other towns, the out-migration of working-age families has had negative flow-on effects to community organisations, with the SES unit and Country Women's Association struggling to maintain their activities (GHD, 2009).

Combined, the two towns have three major sawmills and two ex-quota mills which source timber from public land. Together these businesses employ 119 FTE employees, which accounts for 17.2 per cent of Barham's working population and 15.4 per cent of Koondrook's working population. This indicator alone – that one in six workers in the twin towns is employed by the forestry industry – suggests Barham-Koondrook is sensitive to any potential industry changes.

Township of Barham

Gulpa Mill at Deniliquin

The town also has two river red gum furniture businesses. The twin towns host the annual Red Gum Showcase – an event that highlights the importance of the industry to the local community.

There is a strong local connection to the forests of Koondrook-Perricoota and Gunbower.

Tourism Research Australia (2008d) estimates a total of 80,000 people visit the broader Wakool Shire area, and spend a total of $26 million each year. For the Ganawarra Shire (Victoria), which also includes the larger centres of Kerang and Cohuna, Tourism Research Australia (2008e) estimates a total of 62,000 visitors, with a total spend of $14 million per year.

5.7.2 Deniliquin (NSW)

Deniliquin, a town of approximately 7,500 people located on the banks of the Edward River, is the centre of the Deniliquin LGA. The Deniliquin LGA is small in area (approximately 140 square kilometres) and encompasses the town and its outskirts. Being the third-largest town in the Riverina bioregion, Deniliquin is a service town for a number of smaller towns in the region, including Wakool, Conargo, Berrigan, Finely and Jerilderie.

Key community services in Deniliquin include health, education (including primary and secondary schools, a community college and a campus of the TAFE Riverina Institute), commercial, government and social services. Deniliquin is the administrative centre of Murray Irrigation Limited, which provides irrigation infrastructure services to an estimated 1,200 farmers in the Murray Irrigation Area, and the town has an active chamber of commerce.

Deniliquin had strong economic, human and physical capital relative to the other towns in the analysis. Although it had lower rates of home ownership, it outperformed the regional average for most of the economic capitals. In relation to human capitals, Deniliquin appears to have similar results relative to the regional average. It was also the least remote of all of the towns, which indicates it has greater access to important services, such as health and emergency services (refer to **Section 10.5**).

Deniliquin's population has been in a state of decline over the last three census periods (with a 4.5% decrease between 2001 and 2006). The Deniliquin economy has historically relied on the irrigation sector (predominantly rice and dairy), although the drought has seen a significant decline in these industries. For example, the town's rice mill and abattoir have closed in the past three years and there has been a reduction in employment in the irrigation sector. An estimated 20.7 FTE positions were lost from Murray Irrigation Limited (Murray Irrigation Limited, 2009) and in 2007, Sunrice made an estimated 180 jobs redundant in the towns of Deniliquin and Coleambally with the closure of rice mills (ABC, 2007).

Increasingly both farm and town families in Deniliquin are moving to mining areas in West Wyalong, Queensland or Western Australia, or family breadwinners are moving to follow this work, while their families remain behind (GHD, 2009). The declining population in Deniliquin is having impacts on the social fabric of the town, with community clubs and other volunteer organisations struggling to maintain membership (GHD, 2009).

The forestry industry in Deniliquin is focused on the Gulpa Sawmill. The operation has recently invested in new buildings and has established a dedicated enterprise that is focused on providing high-quality building timbers. The mill is one of the largest employers outside of local government, health and education. In addition to this mill, there are also two major residue-processing operations. Together, these businesses employ 28 FTE staff.

Tourism in Deniliquin is focused on the region's natural attractions. State Forests are destinations for camping, biking and bird watching, and the Edward River attracts visitors for river-based recreation such as kayaking, swimming, fishing and water-skiing. The town is host to the Deni Ute Muster, a major annual event that attracts an estimated 5,000 people to the town each October. Tourism Research Australia (2008c) estimates a total of 97,000 people visit the region, and spend approximately $25 million each year.

5.7.3 Mathoura (NSW)

Mathoura, with a population of approximately 650, is located in the Murray LGA. The major town in the Murray LGA is Moama (and its twin town Echuca located in Victoria), which is approximately 42 kilometres away. Moama-Echuca is a major service centre for Mathoura.

Mathoura, the second-largest town in Murray Shire, has experienced limited population growth; however, there are an increasing number of retirees in the town, reflected in low labour force participation and unemployment rates. Its population is aging, with a high proportion of individuals aged over 65.

A multipurpose Visitor and Business Information Centre is the focal point for the delivery of services in the town. This centre houses a sub-branch of Bendigo Bank, access points for Centrelink and Medicare, tourism information and various business services. Other services in Mathoura include a primary school, post office and police station. There are two hotels and one club. Mathoura has an active chamber of commerce and a local newspaper.

Key industries in the town are timber, agriculture and tourism, as well as the service industries that support them. Mathoura has three secondary sawlog quality mills and two residue operations, which combined are estimated to employ 30 people. Between 2007 and 2009, several new business ventures in the Mathoura township have been established and failed.

Of the towns examined, Mathoura had the highest proportion of individuals with no post-school qualification. Mathoura also had weak economic variables relative to the other towns, given its very high proportion of low-income households and high rate of unemployment. Furthermore, only a third of the population has access to the internet, which is well below the regional average. However, It has a strong cross-section of community service and interest organisations and a high rate of volunteerism (25% of the population) (GHD, 2009).

There is a strong local connection to the nearby State Forests, including the Barmah, Millewa Moira and Gulpa Island State Forests.

The town is supported by five ex-quota sawmills – Carroll, Colturi, Crump, Hill and Crane – and two residue-processing operations which source river red gum timber from public land. Together, these businesses employ 31 FTE staff.

The Murray River and its forests are the focus of tourism in Murray Shire. Mathoura hosts several annual events that attract visitors, including the Mathoura Fishing Classic and the Cadell Country Fair.

5.7.4 Darlington Point (NSW)

Darlington Point is a small town of approximately 1,000 people located on the banks of the Murrumbidgee River in the north of the Murrumbidgee LGA. Coleambally, the other main town within the LGA, is approximately 30 kilometres away, and Griffith (38 kilometres) in the adjoining shire is a major service centre for Darlington Point. Darlington Point acts as a dormitory town to Griffith, and as such the viability of the economy of Darling Point is integrally linked to that of Griffith.

Key services in Darlington Point include a police station, post office, a primary school, community health service and swimming pool.

Population in Darlington Point increased by 17.5 per cent in 2006 and 12.7 per cent in 2001, due to significantly cheaper land prices attracting young first-home buyers and older retirees. This growth has slowed in recent years with a decline in the rice industry, including rice mill closures and cessation of rice production due to water shortages. Historically, irrigated agriculture and the processing of agricultural products especially rice have been key industries in Murrumbidgee Shire. The recent drought and low water allocations have resulted in a decline in production and income based on irrigated agriculture. Census data for 2001 and 2006 showed employment declines in agriculture, wholesale and construction, reflecting the loss of rice growing and processing industries, and a slowdown in local residential construction. Despite downturns in recent years, there is evidence of increasing prosperity, with several new businesses opening and the retention of services such as police station, primary school and post office, and sporting and community groups.

Darlington Point scored low compared to the regional average for most of the statistical indicators of economic, human, physical and social capital. This suggests it may be highly sensitive to change. It has just over 1,000 people and has experienced some population growth over the last census period (3.3%, compared with 12.7% between 1996 and 2001). Of the towns analysed, Darlington Point had the largest proportion of Indigenous residents (17.2% compared to the outer regional NSW average of 6.0%). Furthermore, Darlington Point had the highest level of employment in labour and related work (31.3% compared to the regional average of 14.6%), but a below-average level of unemployment (4.2%).

Of all the towns, Darlington Point also had the highest level of population mobility and the lowest level of volunteering, which together suggest there is likely to be less social cohesion within the community (refer to **Section 10.5**). Darlington Point has sporting, charity and community groups, and has a volunteering rate of 16.5 per cent of the population over the age of 15 (Forests NSW, 2009a).

Walking, camping, fishing and other water-based activities on the Murrumbidgee River is the focus of tourism activities in the district. Tourism data for Darlington Point and the broader Murrumbidgee Shire are not available.

The forestry industry in Darlington Point is focused on a major fixed mill (Darlington Point Sawmill), which employs 20 FTE staff. The mill is the only significant holder of quota within the Narrandera and Murrumbidgee Management Areas. The business is a highly integrated mill. As the mill has adjusted to lower timber supply volumes and quality it has extended its firewood enterprise through investment in additional machinery. The mill is one of the few secondary industries in a town dominated by service industries. Many people who reside in the town are employed in Griffith.

Frog sculpture Balranald Visitors Centre – photo courtesy of Wikipedia

5.7.5 Balranald (NSW)

Balranald, located on the Sturt Highway and on the banks of the Murrumbidgee River, is the main town in the the Balranald Shire. The total shire area is approximately 21,400 square kilometres, with a total population of 2,440 (ABS, 2006). Other towns and localities in the shire include Euston, Kyalite, Hatfield, Penarie, Clare and Oxley.

Key services in Balranald include retail (supermarkets, clothing); accommodation (motels, caravan park); registered clubs, hotels, restaurants and food outlets; health and emergency services (medical centre, pharmacy, hospital, ambulance, fire brigade and rescue service); and education (primary school). The regional centres of Swan Hill (a distance of 92 kilometres) and Mildura (158 kilometres) provide services not available in Balranald.

Relative to the other towns, Balranald had strong social capital related to its low population mobility, low cultural diversity and high levels of volunteering, and therefore may be in a better position to adapt to change.

Balranald's population has declined significantly since 1996. A high proportion of its population is Indigenous (8.1%). While agricultural employment was found to increase in the last census period, this gain is now thought to have been lost due to production slowing down and properties amalgamating. Since 2006, there has also been a reduction in an estimated 24 jobs in education as a result of the relocation of distance education services.

The Council is the largest single employer in the town, with 50 staff (GHD, 2009). Public administration, and safety and health care and social assistance have grown and continue to grow with the building of a new hospital.

The forestry industry in Balranald comprises a major wholesale timber company – Campbell's Sawmills – and smaller operations that supply Campbell's with sleepers and firewood, or source firewood to on-sell to other wholesalers or direct to consumers. Campbell's Sawmills operates a mobile mill which harvests timber from areas further afield than Balranald, and has recently operated around Lake Cargellico and Darlington Point.

The industry is generally reliant on timber resources sourced from private land. However, five residue operators are licensed to harvest timber from public land. Campbell's Sawmill also sources some timber (predominantly sleepers) from small operations and Redgum Timber Producers Pty Ltd, which source products from both public and private land.

Surveyed employment in the part of the red gum forestry industry with a reliance on public land indicates 24 FTE staff are employed by residue operators with licences to harvest from public land. Campbell's Sawmills, which does not have a licence to harvest timber from public land, but sources timber from those who do, employs a further 17 staff.

Recent investigations by Balranald Shire Council estimate that 109 people rely on the forestry industry on public and private land for their primary source of income, while an additional 49 have a secondary reliance. In addition there are local businesses that supply inputs such as fuel and tyres and services such as auto-electric and engineering to forestry industry businesses.

Balranald is the closest service centre to Yanga and Mungo National Parks. Camping and fishing on the Murrumbidgee River are the focus of tourism activities in the district. Tourism data for the Balranald LGA estimates that the shire receives 38,000 visitors, who spend a total of $7 million (Tourism Research Australia, 2008a).

Aerial view of Buronga and Gol Gol – NSW towns along the Murray River adjacent to Mildura

Balranald has a very high incidence of community volunteering (33.8%) with a new organisation, Balranald Inc, formed in 2007 to explore and enhance the future of the community and economy (ABS, 2006).

In relation to human capital, Balranald had higher proportions of retirees and individuals employed as labourers, compared to the regional average. Relative to the other communities of interest, Balranald also had weaker economic capital relating to its lower levels of home ownership and higher levels of unemployment (refer to **Section 10.5**).

5.7.6 Merbein (Victoria)

Merbein, located in Victoria, is a satellite town of the large regional centre of Mildura, which is approximately 12 kilometres away. Within the Mildura Rural City LGA, with a total population in excess of 60,000, Mildura is the primary service centre for residents and businesses in Merbein. As such, Merbein has a good range of facilities and services, with a greater range of services accessible in Mildura. Population growth was strong between 2001–06 (8.3%), with affordable land and housing attracting new residents (GHD, 2009). Merbein also experienced significant growth in its Indigenous population over the last census period (26.3%), with Indigenous youth accounting for 9% of the population aged less than 24 years (ABS, 2006).

Located within the Sunraysia region, Merbein is a centre of irrigated horticulture production, including the production of wine grapes, dried fruits and citrus. There has been some decline in horticulture in recent years with periods of low commodity prices and reduced water allocations. Two large processors, McGuigan's Wines and SDS Beverages, are major employers in the Merbein district.

Of the towns analysed, it had the equal highest unemployment rate (8.3%), as well as a high proportion of individuals who were labourers or related workers (refer to **Section 10.5**). In the 2006 census, the most common industries of employment were manufacturing, retail, and primary industries. There is one sawmill operating in Merbein, which employs 25 FTE staff who live in Mildura and Merbein. Merbein Saw Mill relies on timber resources from NSW – with logs and residue sourced from State Forests, Western Lands Leases and private land.

On all of the economic indicators of vulnerability, Merbein outscored the regional average. In particular, Merbein had a high proportion of low-income households and a low level of home ownership. Furthermore, Merbein exceeded the regional average on a number of human variables, which included having low levels of education and high levels of unskilled workers. In light of Merbein's high levels of economic and human vulnerabilities, it is likely to be sensitive to changes that impact upon employment (refer to **Section 10.5**). However, this analysis was undertaken on the town of Merbein only and did not capture the extensive range of services and employment opportunities available in nearby Mildura.

Tourism data are not available for the town of Merbein. Tourism Research Australia (2008f) estimates that, in total, the Mildura Regional LGA receives a total of 465,000 visitors who spend $153 million.

Chapter 6

Cultural and heritage values

6.1 Overview

The Riverina bioregion supports cultural and heritage values for both Indigenous and non-Indigenous people. The heritage of the Riverina region reflects the historical and continuing interactions between the forests and their surrounding communities.

Heritage is all the things that make up Australia's identity: our spirit, our ingenuity, our historic buildings and our unique living landscapes. Our heritage is a legacy of the past, a living, integral part of life today and the stories and places we pass on to our future generations (DEWHA, 2009a).

This chapter explores contemporary Indigenous aspirations, values and interests, as well as the non-Indigenous cultural and heritage values of the forests. It supports Step 2 of the analytical framework by:

- describing Indigenous values, uses and heritage, and suggesting options for improving the level of Indigenous involvement in land management
- outlining the results of consultations with Indigenous organisations
- describing the contemporary cultural and heritage values related to the river red gum forests.

The key findings of this chapter are:

- Indigenous communities have a strong spiritual connection to the forests. Access to the forests and the ability to visit special places, and continue practices such as hunting, fishing, collecting foods, and telling stories is critical for cultural survival. Like environmental flows, cultural flows are also highly valued by Indigenous communities.
- Local Indigenous communities highlighted that a role in forest management, supporting greater self-dependency and improving employment opportunities were their primary concerns. Irrespective of future land use decisions, it is important that the process of understanding the aspirations of Indigenous people in the Riverina bioregion continues.
- Non-Indigenous cultural heritage of the region is encapsulated in the connections between local communities, the timber industry and the forests, as well as the historical use of river red gum in river transport.
- For Riverina communities and towns, the river red gum forests are the areas where they live, work and play. The forests and the associated heritage form a strong part of people's connection to place and their personal identity.
- Future land managers, irrespective of tenure, need to continue to engage with Indigenous and non-Indigenous communities to better map cultural and heritage uses, values, aspirations and concerns.

6.2 Indigenous nations in the bioregion

Indigenous communities of many nations have occupied the red gum forests for at least 10,000 years (Yarkuwa submission, 2009) with records suggesting that the Murray region was one of the most heavily occupied before European arrival.

Indigenous people of the Riverina shaped and managed the environment in which they lived. Studies of traditional interactions between Indigenous people and the environment suggest that fire was used extensively. In 1883 Curr observed (as cited in Atkinson, 2005) both annual mosaic burning and the Yorta Yorta people setting fire to grass and trees as frequently as every five years, either accidentally or systematically, for hunting purposes. This burning is likely to have assisted woodland formation (as river red gum is a fire-sensitive species) and may have contributed to the maintenance of a forest-grassland boundary in some areas (Navin Officer, 2009) although the specific details around pre-settlement fire regimes is actively debated (e.g. Benson and Redpath, 1997; Bowman, 1998; Esplin et al., 2003; Jurskis, 2009).

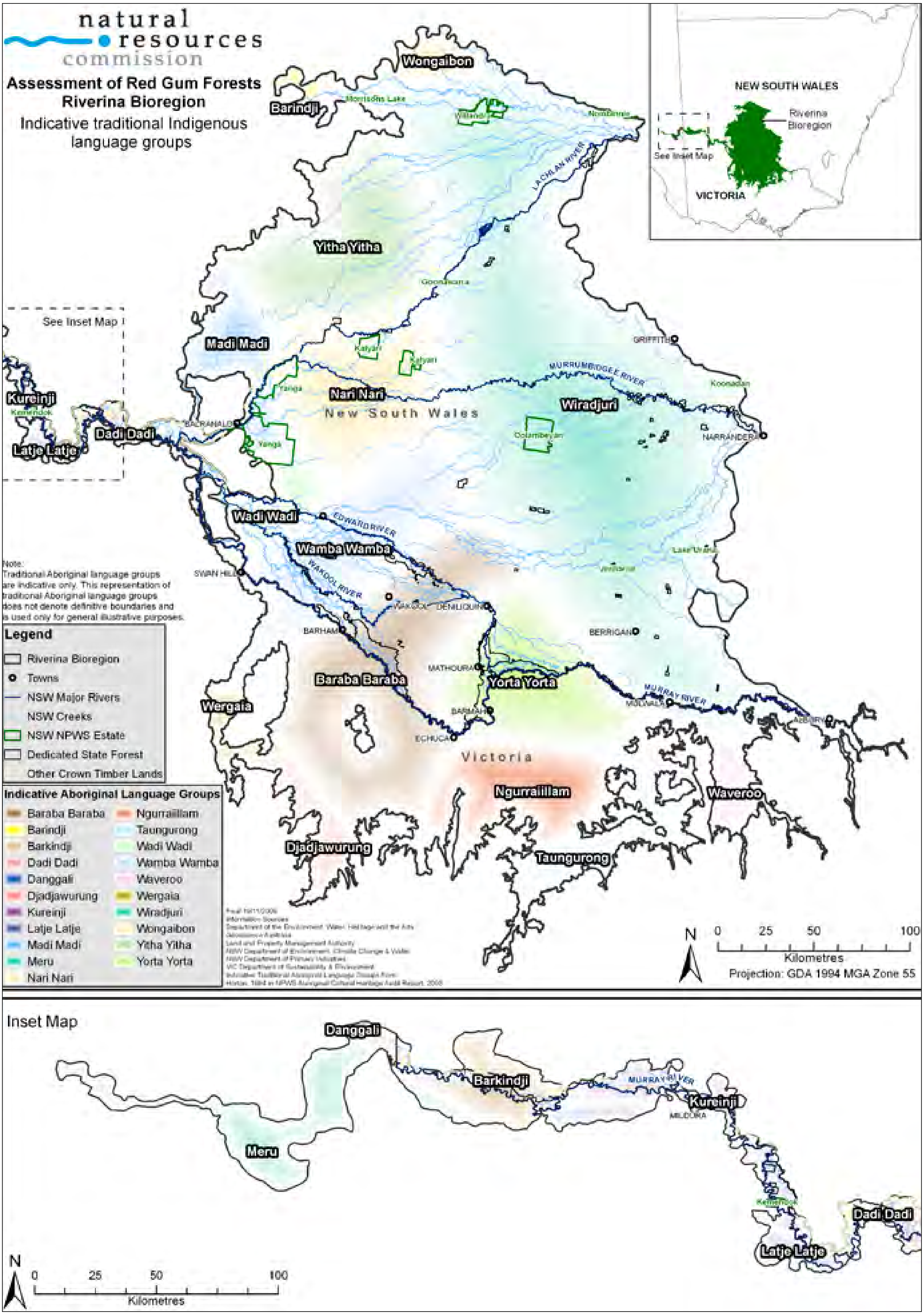
According to Tindale (1974) the traditional tribal groups or nations listed in **Table 6.1** were resident in the Riverina bioregion.

Figure 6.1 shows the general location of traditional Indigenous language groups in parts of the Riverina bioregion (information and map based on Horton, 1996). The bioregion is bisected by a number of traditional boundaries which are largely based on linguistic evidence. These boundaries can be misleading because the movement of the people varied seasonally and their settlement patterns were fluid. This is an indicative map only to reflect the general locale of nations and should not be used as the basis for any tenure or boundary decisions.

Table 6.1: Traditional tribal groups or nations of the Riverina bioregion

Local Aboriginal Land Councils in the bioregion				
Barapa Barapa	Barindji	Barkindji	Dadi Dadi	Danggali
Djadjawurung	Kureinji	Latje Latje	Madi Madi	Meru
Nari Nari	Ngurraiillam	Taunguong	Wadi Wadi	Waveroo
Wamba Wamba	Wergaia	Wiradjuri	Wongaibon	Yitha Yitha
Yorta Yorta				

Figure 6.1: Indicative traditional Indigenous language groups (not to be used for native title purposes)



6.3 Indigenous organisations in the bioregion

In NSW, Local Aboriginal Land Councils (LALCs), Indigenous nations, Aboriginal Community Working Parties, Traditional Owner groups and Elders' groups are the representative bodies for the interests, concerns and aspirations of Indigenous people.

Murray Lower Darling Rivers Indigenous Nations (MLDRIN) is a confederation of Indigenous nations and includes a number of Traditional Owners from the lower, southern part of the Murray-Darling Basin. Current delegates of MLDRIN come from the Barapa Barapa, Latji Latji, Mutti Mutti, Ngarrindjeri, Taungurung, Yorta Yorta, Wadi Wadi, Wamba Wamba, Wergaia and Wiradjuri Nations. MLDRIN was formed in 1998 during the Yorta Yorta native title case.

In 1977 the NSW Indigenous Land Council was formed as a lobby group for Indigenous land rights. Then in 1983, NSW enacted the formal creation of LALCs, under the NSW *Land Rights Act*, as a mechanism for compensating Indigenous people for loss of land. There are 121 LALCs across NSW, and along with other Indigenous organisations and DECCW they have responsibilities related to Indigenous cultural heritage.

Table 6.2 lists the LALCs that are either partially or wholly within the Riverina bioregion (see also **Figure 6.2**).

6.4 Indigenous heritage values of the Riverina bioregion

The Riverina bioregion supports a rich cultural heritage for Indigenous people. Indigenous cultural heritage relates to places with traditional significance. The resources, utilisation of the environment and the knowledge passed down through generations also suggest that the red gum areas were highly valued by Indigenous people for survival.

6.4.1 Indigenous heritage

For Indigenous people the Riverina bioregion is a cultural landscape with archaeological sites that have ongoing spiritual and cultural significance. The significance of sites is often tied to its context within the landscape or to stories of recent and Dreaming ancestors. Some sites may have significance independent of the landscape, but more often the significance of a site relates to its *context* within the landscape. Furthermore, broader landscapes and landforms may be culturally significant, relating to stories of recent ancestors or embodying the actions of Dreaming ancestors, even without evidence of physical sites.

The fabric of the land itself and its resources are also culturally important. For Indigenous people, cultural, spiritual, natural, physical and economic values are interlinked and heritage is only a subset of the overall values of importance. While the protection of archaeological sites plays a major role in the cultural heritage of Indigenous people, this alone does not reflect their social and economic aspirations in the 21st century (Ward, 2008).

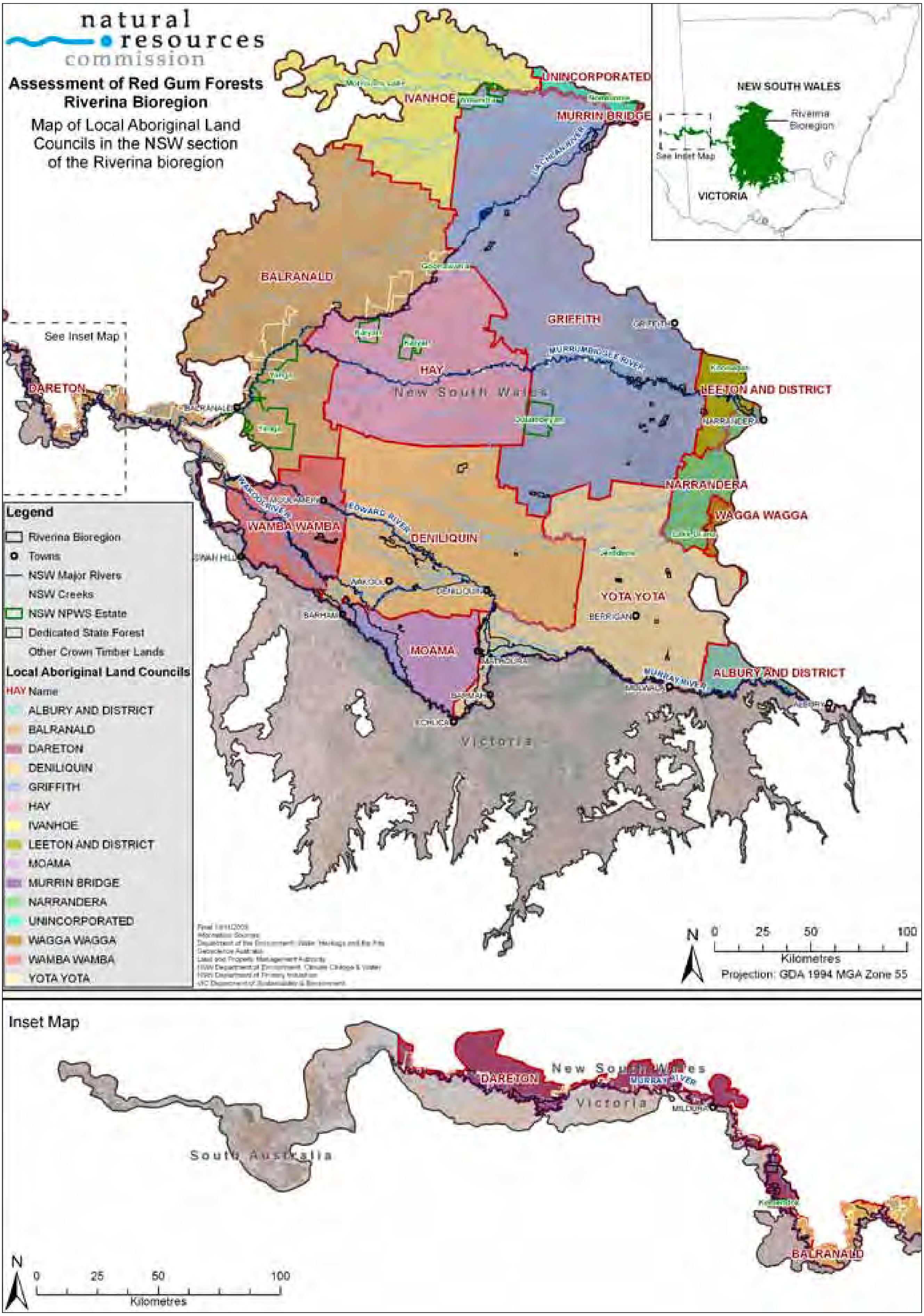
Indigenous cultural heritage is important because of its relevance in the present, and should not be misunderstood as relics of the past. Indigenous cultural heritage relates to places with traditional significance, places of mythology or stories, archaeological sites, post-contact sites (missions, fringe camps and stations) and the plants and animals associated with traditional and cultural values. While Indigenous cultural heritage tends to be divided between physical/conceptual and ancient/recent, there is an interrelationship between these different aspects and their relationship with the overall landscape.

Consultation with Indigenous representatives

Table 6.2: Local Aboriginal Land Councils in the Riverina bioregion

Local Aboriginal Land Councils in the bioregion			
Albury and District	Balranald	Cummergunja	Dareton
Deniliquin	Griffith	Hay	Ivanhoe
Leeton and District	Moama	Murrin Bridge	Narrandera
Wagga Wagga	Wamba Wamba	Yota Yota	

Figure 6.2: Map of Local Aboriginal Land Councils in the NSW section of the Riverina bioregion



While this assessment sought to understand the Indigenous cultural heritage of the region, the NRC recognises that this knowledge is the property of the local Indigenous people, and to provide a more detailed heritage assessment is not appropriate for this assessment nor necessary. For the purposes of this assessment the NRC sought to understand the depth of connection that exists between the local Indigenous communities and the surrounding landscapes.

Indigenous sites

There are comparatively few records of Indigenous history compared with non-Indigenous social and historical information held by the National Library database. The principal land use of the Riverina bioregion over the last 130 years has been sheep and cattle grazing. The 1880s and 1890s saw rapid land use change and large-scale agricultural developments. In this context the Indigenous heritage of the region has not been well assessed or conserved, with most of the area freehold and cleared (Pardoe and Martin, 2001). Land clearing for irrigation, usually involves laser leveling which removes evidence of landforms and sites from the landscape as noted by White (cited in Purcell, 2003).

A cultural heritage desktop audit from 2003 found that while information was scarce, a total of 993 Indigenous heritage sites were found across the Riverina bioregion. The table shows that a range of important sites exist. **Table 6.3** shows the number of sites from the Lachlan, Murrumbidgee and Murray fans subregions.

Estimates of Indigenous populations along the Riverina vary, but it is commonly believed that the Central Murray area may have been one of the most highly populated places in Australia, prior to European arrival (Webb, 1984). The Indigenous cultural heritage that exists in the Riverina bioregion includes oven (earth) mounds, artefact scatters, modified (scarred/carved) trees, hearths, rock art sites, shell middens, burials, potential archaeological deposits, ceremonial/Dreaming sites, fish traps, stone arrangements, resource and gathering sites, and stone quarries (Navin Officer, 2009).

Table 6.3: Desktop audit of Indigenous heritage sites in the Riverina bioregion (Purcell, 2003)

Site type	Lachlan	Murrumbidgee	Murray fans
Aboriginal place	0	1	1
Axe grinding groove	1	0	0
Bora/ceremonial	1	1	0
Burial	5	36	47
Contact, mission	0	2	1
Fish trap	0	1	1
Isolated find	2	4	4
Midden	2	19	15
Mound (oven)	1	87	248
Natural myths	0	0	4
Ochre quarry	0	0	1
Open camp site	13	105	21
Quarry	1	0	0
Scarred tree	18	147	199
Shelter deposit	1	0	0
Stone arrangement	0	1	0
Water hole/well	0	0	2
Total	45	404	544

Note: The above table is for indicative purposes only. Due to the date when this audit was conducted the exact size of the Riverina bioregion differs to what is used for this assessment, as the IBRA (bioregion) boundaries are different.

Box 6.1: Taroo (Lake Victoria)

Taroo or Lake Victoria, located on the western border of the bioregion is both a physically and culturally significant feature in the landscape. It is a shallow freshwater lake in southwestern NSW, close to the South Australian and Victorian borders which is significant to Indigenous people and the broader Australian community at a national level. Water regulation has contributed to the erosion of the lakeshore and the exposure of Indigenous cultural heritage, in particular burial grounds. The river red gum forests along the lakeshore is the most culturally significant feature and is now the subject of a landscape management plan.

Throughout 1841 the Indigenous people of Lake Victoria engaged in one of the strongest resistance campaigns against European invasion. For several months the Indigenous people were successful in their defense, until 27 August 1841, when combined forces and a police expedition from Adelaide resulted in what became known as the Rufus River Massacre.

The Lake is also connected to Dreaming stories about the creator of the Murray River and has special spiritual significance (MDBC, 2002).

Recorded history of traditional tribal groups

A significant aspect of Indigenous heritage sites in the Riverina is the high counts of registered burials. Further, Indigenous mound sites are unique to the Riverina region and the highest frequency of mound sites in Australia occurs here (Coutts, 1981). In the Werai Forest alone there are 12 traditional cemeteries.

Scar tree near Murrumbidgee River

Forests NSW's policies for cultural heritage management

Forests NSW has developed policies, plans and operational guidelines on how to identify and manage cultural heritage. These outline how Forests NSW works with Indigenous communities, how cultural heritage will be protected, and how cultural awareness will be promoted amongst staff.

To enable cultural heritage practices to continue Forests NSW Ecologically Sustainable Forest Management Plan outlines that Forests NSW will give favourable consideration to proposals from Aboriginal communities to use areas of State Forest. The NRC understands from discussions with local Indigenous communities

Table 6.4: Types of Indigenous archaeological sites found in the Riverina bioregion (Aboriginal Affairs Victoria factsheet)

Type	Description	Characteristics
Scarred trees	Trees where the bark has been removed for various purposes including: canoes, containers and shields.	Regular in shape, but varying in size. Slightly pointed or rounded ends. Used as landmarks or directional markers for navigation.
Burials	Evidence of human bones, exposed through disturbance or erosion.	Usually found in soft soils and sand.
Freshwater middens	Concentration of freshwater shells, the result of eating and cooking freshwater shellfish.	Size can vary greatly from 1m long to 1000 metres long. Found along river banks and floodplains.
Stone quarries	Outcrops of stone where Indigenous people collected materials for tools.	Evidence of flaking, crushing and battering of stones. Pits and trenches around the base of the outcrop. Often stone tool artefacts such as hammerstones, anvils and grinding stones.
Surface scatters	Accumulation of remains from Indigenous activities such as charcoal, animal bone, shell and ochre.	Frequently located near a reliable source of fresh water, exposed through disturbance or erosion.

around Deniliquin and Forests NSW staff that cooperative relationships have been fostered in recent years (Yarkuwa, Atkinson, K and Rodda, G, Forests NSW, pers. comm., 2009).

Forests NSW has programs to manage and encourage Indigenous involvement in State Forests. These include job creation programs, programs to investigate and develop joint/co-management arrangements (Forests NSW, 2009c). The proposal for an Indigenous Protected Area between Forests NSW and Yarkuwa Indigenous Knowledge Aboriginal Corporation is discussed later.

The operational guidelines prescribe restrictions for forestry activities. This includes controls to protect Indigenous sites, relics and places, such as the requirement of a 10–50 metre buffer around Indigenous sites. An Aboriginal heritage inspection and report should be completed for each compartment or operational area, prior to forestry operations commencing.

Forests NSW seeks to engage local Indigenous representatives in cultural heritage identification work and provides Indigenous cultural awareness training for Forests NSW staff to instill an operational culture that better understands cultural heritage (Forests NSW, 2006, Rodda, G, Forests NSW, pers. comm., 2009). Under the *National Parks and Wildlife Act 1974*, Forests NSW is required to manage the heritage values of State Forests and provide statutory protection for all Indigenous objects and places (Forests NSW, 2008).

Forests NSW management of Indigenous sites

Forests NSW maintains a database of known Indigenous heritage sites which draws on the Aboriginal Heritage Information Management System database maintained by DECCW, forest management records, and from consultation with Indigenous communities (Forests NSW, 2008). The Forests NSW EIS (Forests NSW, 2008) reports there have been 1,063 site recordings in the 120,050 hectares of the south-western State Forests, as captured below in **Table 6.5**.

The value and context that can be gained from these figures is limited and is a function of the scope and number of surveys conducted. Fewer sites does not equate to less significance as a larger survey would most likely reveal more sites. Nor does the data provide a degree of the significance of the sites. A comprehensive survey across the entire State Forest estate would most likely reveal the presence of more sites.

During consultations Indigenous people expressed concern that despite the development of these policies they were not being uniformly enforced.

6.4.2 Consultation with Indigenous organisations during the assessment

The NRC has sought to constructively engage with representative Indigenous bodies and concerned individuals in the region. Unfortunately, due to the timeframe for the assessment it was not possible to consult in all regions or with all nations or organisations. Subsequently a number of organisations and regions are not represented.

Table 6.5: Number of Indigenous heritage site recordings in State Forests with greater than 25 recorded sites (Forests NSW, 2008)

State Forest no.	State Forest name	Area of State Forest	No. of site recordings
90	Banangalite	1,294	39
384	Werai	9,454	349
398	Millewa	20,938	77
558	Gulpa Island	5,478	76
576	Moira	10,578	84
615	Campbells Island	3,812	38
625	Koondrook	15,140	291
773	Lake Victoria	4,397	29
Sub total		71,091	983
Total in Riverina bioregion		120,050	1,063

Note: This table is indicative only and should be considered in the context of areas that were actually surveyed for Indigenous sites. The actual number of sites is expected to be far greater.

Table 6.6: Indigenous communities consulted

Organisation
Barapa Barapa (MLDRIN representatives)
Culpra Milli Indigenous Corporation
Cummergunja Local Aboriginal Land Council
Deniliquin Local Aboriginal Land Council
Mutti Mutti (MLDRIN representatives)
Yorta Yorta Nation Aboriginal Corporation
Wamba Wamba (MLDRIN representatives)
Wiradjuiri (MLDRIN representatives)
Wadi Wadi (MLDRIN representatives)
Yarkuwa Indigenous Knowledge Centre Indigenous Corporation

The NRC met with groups to explain the focus, scope and background of the assessment and to hear and better understand the concerns and aspirations of the Indigenous people in the region regarding the river red gum forests in the Riverina. As part of the assessment the NRC consulted with the organisations listed in **Table 6.6**.

While the NRC did not meet with all the LALCs in the region, it met with representatives from the Deniliquin LALC on a number of occasions and discussed the assessment with the Cummergunja LALC. The NRC held a two-day workshop with MLDRIN in October 2009. The comments expressed during this process and in submissions received are included in the paragraphs below. The full report from this consultation can be found in **Appendix 8**.

The NRC found there was a diversity of views in terms of future aspirations and Forests NSW management. Many organisations and individuals were supportive of Forests NSW. They felt Forests NSW was a good land manager that conducted meaningful engagement with the community, while others were less positive.

The NRC found that more work towards a common understanding around who can speak for Country, and resolution around boundaries is needed. As the workshop facilitator Tony McAvoy observed, "the degree to which it [NRC's report] will make use of Indigenous options in the solution to this problem, will in part be limited by the Indigenous community's ability to resolve internal disputes".

6.5 Indigenous uses, values and concerns

As the first nations of Australia, Indigenous people have inherent rights to be involved in decisions that affect Country and their strong connection to it. Indigenous people are the original custodians of the land and waters and seek to maintain an ongoing connection with Country.

The Australian Government's recent endorsement of the United Nations Declaration on the Right of Indigenous Peoples (UNDRIP) establishes the Australian Government's commitment to the status given to Indigenous peoples.

6.5.1 Indigenous uses of the river red gum forests

Indigenous culture has evolved over time, adapting to new settings and contexts. While fishing and hunting may be regarded as recreational practices common to many people, for Indigenous people such activities also have cultural meaning, as they involve returning to Country and the associated spiritual connection. Some of the bush foods in the river red gum forests include fish, waterbirds, yabbies, mussels, turtles, possums, kangaroos, emus, cumbungi, reeds, water lily, dandelions, angled pig face, sow thistle and lerp (Pardoe, 1998).

Understanding by non-Indigenous people of the significance of red gum environments from an Indigenous perspective can be assisted by Use and Occupancy Mapping, a social science methodology which maps an Indigenous person's relationship with the land and waters. This type of mapping helps resolve the lack of visible evidence for contemporary cultural relationships.[1] 'Use' refers to activities such as hunting, trapping, fishing, gathering of medicinal and ceremonial plants. 'Occupancy' refers to areas Traditional Owners regard as their own through place naming, traditional stories, spiritual places or burial grounds.

Recent use and occupancy mapping was conducted to explore Indigenous people's connection to the Werai Forest (Yarkuwa, 2009). So far, more than 10,000 locations have been identified by current generations as areas where cultural activities have taken place, although mapping is not yet complete.

6.5.2 Indigenous values and concerns associated with the river red gum forests

The specific values of different Indigenous representative groups are described below. The high-level and common concerns expressed by MLDRIN include:

- access to the forests
- improved compliance in the protection of Indigenous cultural heritage sites in the forests
- cultural water flows
- economic self-determination.

The NRC also met with other Indigenous community members who expressed support for Forests NSW practices in terms of community engagement, land management and identification of cultural sites.

Cummergunja expressed strong support for Forests NSW. Kevin Atkinson informed the NRC that he believes forestry is important for the health of the forests and that the decline in forest health is the result of reduced water availability. He says Cummergunja have enjoyed good relations with Forests NSW who have undertaken cultural mapping with them and conducted meaningful community engagement (Cummergunja submission, 2009).

[1] In recognising that the values, aspirations and contributions of Indigenous people is integral to NRM, The Living Murray Initiative recently employed the use and occupancy mapping technique with the Yorta Yorta people in Australia (Ward, 2009).

Access

Country is at the core of Indigenous well-being. As described by Jackson (2005), "for Indigenous Australians, their personal, cultural and spiritual identity, their sense of belonging and sense of security, are inextricably linked to water and Country."

The health of Country, the ability to hunt and collect foods from the bush, and return to Country individually and with others were expressed to the NRC as fundamental needs for Indigenous people. While the NRC heard a diversity of views regarding the future of the forests, the ability to visit the forests, and to continue practices such as hunting, fishing, collecting foods, telling stories and visiting special places, was uniformly expressed across the Indigenous communities met with by the NRC. Access enables the survival of culture through the continuation and sometimes renewal of practices, stories and connections.

Cultural knowledge and practice is central to Indigenous peoples' sense of identity, culture and spirituality. As one Wiradjuri elder put it: "Continuing our culture is a matter of religious freedom. All Australians have the right under the Constitution to worship however they wish. Denying Indigenous people access to the forests is denying them their religion."

Box 6.2: Moonacullah Mission

The Moonacullah Mission is located northwest of Deniliquin on the banks of the Edward River. Between 12-14 families were settled there with a mission manager who was also the school teacher. To this day Moonacullah attracts large groups of families especially during the holidays and in the change of seasons.

People gather to tell stories of the past, spend time with each other, learn cultural practices and spend time in Country. The change of season attracts people because of the different food types available and to watch the landscape change.

It holds special historic and contemporary meaning to the local Indigenous people. Many of the Indigenous families in the region can trace their familial connection back to Moonacullah.

A burial site is located near the mission which has been fenced and protected by Forests NSW. Other burials are said to also exist in proximity to the mission (Taylor, S and Baxter, D, pers. comm., 2009).

Protection of Indigenous sites

While Forests NSW has comprehensive operational guidelines for management of Indigenous cultural heritage, some Indigenous people stated to the NRC that they were frustrated and upset that culturally significant sites such as scarred trees and burials, had been used for timber or damaged, albeit inadvertently, on public and private land. The MLDRIN representatives who met with the NRC expressed the grief caused by damage to their places of spiritual significance and heritage. While much of the damage may have happened many years ago, it still causes pain. The impact is that "people feel lost in their own Country" when scarred and other trees used as landmarks, are removed.

Cultural water flows

Central to an Indigenous worldview is the necessity of integrated custodianship between land and waters. Indigenous peoples' survival in Australia relied upon knowledge of the episodic and seasonal patterns (and reliability) of creeks, rivers, waterholes, wetlands, springs and soaks. Increasingly the value of traditional Indigenous knowledge and land management practices – in particular fire management and medicinal properties of plants – is being recognised.

In its submission to the NRC, MLDRIN highlighted that cultural water, beyond environmental water, is required so that Indigenous people are empowered to meaningfully fulfill their responsibilities to care for Country. MLDRIN noted that they have long understood the strong links between forest health and floods. They requested that future forest management be tied to adequate flows, especially where it involves increased partnership with local Indigenous communities.

The NSW *Water Management Act 2003* allows for cultural water access licences. While examples exist, the Indigenous communities in the region expressed a strong desire for increased cultural water flows to support a range of environmental, economic and cultural outcomes. The Culpra Mill Indigenous Corporation has been involved in the allocation of environmental water for river red gums along the Tarpaulin Creek Culpra Station and Malley Cliffs State Forest (Pearce, 2009).

Box 6.3: Cultural allocation – Murrumbidgee Regulated Water Sharing Plan

The Murrumbidgee Regulated River Water Sharing Plan contains a provision for a water allocation for cultural purposes, a sub-category of high-security access licences, and allows for water to be taken for Indigenous domestic and cultural purposes (NSW Office of Water, 2009). The Murrumbidgee Traditional Owners and Cultural Heritage Reference Group is working with DECCW and the Murrumbidgee CMA to develop a cultural watering plan that will identify sites/places where the 1,250 ML can be delivered to culturally significant areas (Murrumbidgee CMA, 2009).

Socio-economic determination, employment and training

The creation of employment opportunities and greater socio-economic determination, is a fundamental concern which was repeatedly expressed across the Indigenous communities met by the NRC. The goal of engendering greater self-responsibility is at the forefront of Indigenous aspirations.

As part of the Environmental Impact Statement, Forests NSW initiated a process to discuss the future of the forests in 2008, via a workshop held with MLDRIN.

As part of the assessment the NRC has made an initial attempt to start the process of better understand time constraint the goals of the Indigenous people in the Riverina. During the assessment the NRC heard not only of the long-term pain caused by exclusion, but also of the welcoming support for the attempt to be given a voice in the assessment process.

6.6 Land management with greater Indigenous involvement

While the percentage of land in the Indigenous estate across

2008). The ability of Indigenous people to connect with their traditional land and waters has deteriorated with the declining health of these systems (Ward, 2008). The local Indigenous communities who met with the NRC expressed a strong desire for greater involvement in the management of the forests.

The range of options discussed below may facilitate a process for greater Indigenous involvement in land management. This goal is also supported by the NSW State Plan which aims to provide greater opportunities for Indigenous people to take part in the management of Country, including joint management of National Parks (NSW Government, 2009).

While boundaries may not be resolved in the bioregion, all Indigenous representative bodies that the NRC met with, including Indigenous nations and LALCs, expressed the interest and desire to look after "River Country". In their view, greater land management responsibilities would provide multiple benefits such as: employment opportunities for local Indigenous people, the ability to continue cultural practices, increased broader community understanding around Indigenous values, and training opportunities in conservation and employment in land management for local Indigenous people.

6.6.1 Indigenous Protected Areas

Indigenous Protected Areas (IPAs) are owned and managed by Indigenous communities for the protection of their significant natural and cultural values. IPAs make a significant contribution to biodiversity conservation and make up 23 per cent of the National Reserve System (DEWHA, 2009a). Inside IPAs Indigenous communities develop a plan to manage the natural and cultural values of the landscape, and are provided support to manage threats such as weeds, pests and bushfire (DEWHA, 2009a).

Yarkuwa Indigenous Knowledge Centre Indigenous Corporation, in partnership with Forests NSW and the Australian Government, is currently exploring options under the IPA program for joint management of the northern part of the Werai Forest. This project is unique in that it incorporates traditional environmental and ecological knowledge with forestry practices under the IPA progam.

The initiation of this program between Forests NSW and Yarkuwa Indigenous Knowledge Centre demonstrates the goodwill and sense of partnership that has been fostered by both sides. Such collaborative work is a positive step for greater Indigenous involvement in land management.

Box 6.4: Toogimbe Indigenous Protected Area

Toogimbe Indigenous Protected Area is a pastoral property spanning about 460 square kilometres near the town of Hay in the Riverina bioregion. Toogimbe is owned and managed by the Nari Nari Tribal Council and was declared an IPA in March 2004.

The property dates back to when farming was introduced in the bioregion. The features of Toogimbe include flat former pasture lands, eucalypt-lined creeks and wetlands. The Hay area was a major trade route for Indigenous people, supporting a vast social and cultural network.

The IPA activities involve protecting the scarred trees, campsites and burial mounds, reconnecting Indigenous people to their land, wetland flooding, replanting vegetation and controlling weeds and feral animals. Toogimbe's wetlands are home to totem animals and traditional medicines and the traditional life of the Nari Nari people centres around these wetlands.

The Nari Nari Tribal Council aims to continue timber harvesting for community use in a sustainable manner. The revegetation is a major undertaking. In 2005, 2.5 kilograms of local seed was collected and 8,500 seedlings planted. The Nari Nari Tribal Council has also constructed a bush tucker garden and bird hides in the wetlands.

6.6.2 Joint management of National Parks

Joint management is where the Department of Environment, Climate Change and Water share responsibility for park management with Indigenous communities. This arrangement is recognised through a formal agreement such as a Memorandum of Understanding, an Indigenous Land Use Agreement or Aboriginal Ownership and leaseback under Part 4A of the *National Parks and Wildlife Act 1974*.

Both DECCW and the Indigenous communities seek benefits from joint management. For DECCW the aims include better management and protection of the natural and cultural heritage of the parks. For the Indigenous communities the benefits may include greater socio-economic outcomes through employment, training and capacity building and a connection to Country.

The different requirements for the range of options for joint management between DECCW and Indigenous communities is described below.

6.6.3 Memorandum of Understanding

A Memorandum of Understanding is a voluntary agreement between DECCW and the Indigenous communities. It formalises the arrangement but is not legally binding, nor is it a recognition of native title rights.

6.6.4 Indigenous Land Use Agreements

An Indigenous Land Use Agreement (ILUA) is with native title holders or claimants and addresses the exercise of native title rights. An ILUA must follow the process set out in the *Native Title Act 1993*. In the past the NSW Government has only entered into an ILUA if there has been a native title claim over the land (DECCW, 2009).

6.6.5 Aboriginal Ownership and lease-back

For Aboriginal Ownership or leaseback the park must be a land claim under the *Aboriginal Land Rights Act 1983* and identified for nature conservation by the Government or listed on Schedule 14 of the *National Parks and Wildlife Act 1974*. Schedule 14 is the list of parks and reserves of significance to Indigenous people. It is necessary for the Aboriginal Land Council(s) and the Government to agree on the lease arrangements. Ownership of the park is transferred to the Local Aboriginal Land Council(s) and leased back to the NSW Government for joint management.

The *National Parks and Wildlife Act 1974* sets out the legislative requirements for parks to be listed on Schedule 14, the list of parks which can be returned to Indigenous ownership (DECCW, 2009).

6.7 Non-Indigenous cultural values

The non-Indigenous cultural values of the river red gums centres around historical and contemporary connections with the forests, and their role in the economic development of the region. Given the long history of interaction between local communities and the forests, for many residents the forests form a key part of their identity – either through their own connections, their family history or the history of the towns in which they live. This section explores the non-Indigenous cultural values and heritage of the region.

6.7.1 Contemporary non-Indigenous cultural values

River red gums are Australian icons. They are immortalised in Australian art, poetry and song. For visitors to the Riverina, and the people who live there, the river red gum forests are an intrinsic part of the landscape they love.

Visitors and locals alike talk about their enjoyment of the leisure opportunities the forests provide. Locals talk about the businesses they have built up, sometimes over generations, on income generated from the forests. They might talk about the history of the region, linked heavily to the rivers and their floodplain forests, or they might focus on the recreation and cultural values of the forests. Many rejoice in the sense of freedom they have through camping or fishing in the forests.

The Murray and its tributaries, with their floodplain forests, are dominant in the landscape. They are a dominant cultural backdrop to the communities that have grown along their floodplain boundaries. Not only are they major features in a physical sense, they are an intrinsic component of the human geography of the region. It is no more possible to separate the river red gum forests from the towns than it would be to separate beaches from coastal communities (Teese and Wright, 2000).

Spending time in these forests, or in the towns of the Riverina, and talking with locals or people who visit regularly provides a sense that the river red gum forests have a deeper, more spiritual place in the lives of locals than is first apparent.

The livelihood of people in river towns was intrinsically linked to the river and many current residents hold memories of this generational link to the river. Many of the current day timber industry owners and operators are descendants of early settlers or mill operators. Most of the mill operators, such as the Rowe and Dankert families, have lived in and contributed to the region for generations.

Sketch courtesy of RW Arnott

Current generations feel that same close connection to this landscape as their great-grandparents did. They want the same sense of 'place' for their children and they want to see viable, secure and rewarding futures for future generations in their home towns.

For all the communities that live in the proximity of the river red gum forests, such as Koondrook-Barham, Barooga, Balranald, Darlington Point, Deniliquin and Mathoura, these forests are their playgrounds. They are places to relax and spend time with family and friends (Teese and Wright, 2000). The forests are also a destination for people from outside the region, in particular visitors from Melbourne. For more information about the economic value of tourism see **Chapter 5**.

These forests are changing, through a combination of human intervention and a variable and changing climate, and the communities in the Riverina will feel these losses. They will feel the changes in their economy, but also feel the impact on their personal and community values and the identity and culture of their towns.

6.7.2 Recreation activities

For local residents, the forests support a diverse range of non-commercial values, including access for fishing, swimming, boating and collection of domestic firewood.

Visitors to State Forests engage in a wide range of activities, including organised events and tours and individual activities. Entry to the State Forests is free for most individual visitors while groups are required to take out special purposes permits to undertake organised activities (Forests NSW, 2005).

Camping

Campfires and barbecues are some of the most traditional aspects of recreation in the State Forests of the Riverina. Camping in State Forests is popular because:

- it is free
- people are not restricted to designated spots; they can camp in large groups
- they can have campfires in some locations (outside of fire ban periods)
- they are not required to notify anyone or use booking systems.

Anecdotal evidence from the NRC's tours of the region indicates that campers enjoy the freedom of dispersed camping in State Forests, where people are free to camp where they choose and are not confined by allocated camping sites. The open and flat terrain of the Riverina region also encourages a high degree of dispersed camping. Typically dispersed camping does not include facilities, such as toilets, drinking water or fireplaces.

Another appeal of camping in State Forests is that holidaymakers are permitted to bring their dogs, although restrictions may apply in some areas. This is an important value as many pet owners make decisions about where they holiday based on whether their dogs are permitted. People living in the region also enjoy walking their dogs in the area, while enjoying the scenery.

A number of camp sites in the bioregion provide facilities such as bush toilets, tables, water supply and fireplaces.

The bioregion also offers something for those seeking a more remote camping experience, where camp sites are located away from tracks, requiring users to arrive on foot or by boat. People participate in numerous activities whilst camping such as swimming, picnics, day walks, drinking, touring and travelling to local towns.

Water-based activities

Boating, water-skiing and wake-boarding are common recreational activities in the Riverina bioregion and are supported by a small number of boat ramps (largely confined to the Murray Irrigation Area).

Canoeing and kayaking are popular ways to access shallow areas and provide good transport for bird-watching. Houseboats are another popular way to relax and explore the region and can be hired out of most major centres along the Murray River.

Recreational fishing is an increasingly popular activity, appealing to individuals and families alike. The rivers in the region are home to native species such as freshwater crayfish, golden perch and Murray cod, and introduced species such as redfin, trout and European carp. Recreational fishers may access the river by four-wheel drive, boat or from the riverbank.

A NSW fishing licence is required to fish in the Murray River. In addition, there are closed seasons and size and bag limits for many species, including the Murray cod. There are many fishing clubs that organise social fishing competitions and some clubs actively stock the rivers with native fish, in addition to fish stocking programs run by the Department of Industry and Investment.

Vehicle-based activities

The extensive network of roads and trails in the State Forests allow for active forms of recreation. Car touring, cycling, mountain biking, horse riding and hiking are all popular pursuits. There are a number of designated forest drives in the river red gum forests for use by four-wheel drives and trail bikes (Forests NSW, 2004). These trails are also shared by walkers and horse riders.

Four-wheel driving is a popular activity which gives participants access to remote areas of the State Forests of the Riverina bioregion. The extensive network of roads and fire trails in the area provides diverse opportunities both for short trips or extended tours.

Many people enjoy motorbike and trail riding as it gives them a way to see areas that many other people do not get to see. Mountain biking is also popular.

Camping is a popular recreational activity

Hunting in State Forests

Recreational hunting of feral pigs and goats, foxes, rabbits and hares, wild deer and wild dogs is permitted in some State Forests in the Riverina under the *Game and Feral Animal Control Act 2002*. Hunting for game species, such as some species of deer, ducks and quail, is also permitted but during open seasons only. The Game Council of NSW (2009) suggests that people generally hunt feral animals to be in the outdoors, to socialise, to help reduce feral animal species, for food in some cases, or in pursuit of trophies such as skins.

People wishing to hunt feral animals in State Forests must hold a current Restricted NSW Game Hunting Licence (R-Licence) issued by the Game Council of NSW. The R-Licence is only available to hunters who have completed the mandatory training and accreditation program as members of Game Council–approved hunting organisations. They must also have written permission from the Game Council of NSW, obtained through a booking system (Game Council of NSW, 2009). Hunting is not permitted in National Parks.

Walking activities

Bushwalking is a popular activity in the State Forests of the Riverina bioregion, with both day walks and extended and overnight trips available. Many of the walking tracks, board walks and bird hides are within easy access to main towns.

Walking trails wind their way along the creeks and rivers and are some of the many recreational facilities provided within the Riverina bioregion. Forests NSW also maintain map boards, signposting and interpretative signage providing walkers with an opportunity to learn about the birdlife, wetlands and red gum forests (Forests NSW, 2008). Walkers in the State Forests of the Riverina bioregion have access to designated walker-only tracks and camps, although they are also permitted to use vehicle tracks and to camp at sites that are also accessible by car.

There are a number of Indigenous walking trails and educational walks in the bioregion. In addition, Forests NSW's regional staff members conduct a variety of interpretive tours for local and visiting industry, naturalist and academic groups (Forests NSW, 2008).

Nature-based activities

The State Forests of the Riverina provide for a number of passive recreational activities such as picnicking, painting, photography and bird watching. The State Forests include a number of bird habitats giving visitors the opportunity to observe many different bird species. There are also a number of purpose-built bird hides in the bioregion.

Cockatoos, robins, parrots and kingfishers are some of the birds commonly found in the forests. The lakes and lagoons in the wetland areas also support populations of waterbirds including swans, pelicans, ibis, cormorants, spoonbills and many types of duck.

There are a number of Tourist and Visitor Information Centres to provide groups and individuals with the opportunity to learn more about the surrounding area, including the heritage and ecology of the region.

Organised events

Major events and organised activities are held in the State Forests every year, attracting tens of thousands of visitors. These events are authorised by special-purpose permits.

Events range from car rallies, festivals, fishing tournaments, boat races and athletic events through to more unusual pursuits such as sled-dog racing, rogaining and carriage driving.

The Peaches and Cream Festival is held biennially around the second or third weekend in January. It is Australia's longest running festival, with a town parade and music festival located at Thompson's Beach, the largest inland beach on the Murray River.

The 'Southern 80' is an annual high-speed 80-kilometre ski race held on the Murray River in the border towns of Echuca (Victoria) and Moama (NSW) in February. The Southern 80 ski race has been going for over 40 years and attracts over 400 competitors and over 40,000 spectators (Moama Water Sports Club website), many of whom camp along the river.

Recreational experiences in National Parks

In addition to the recreational experience of visiting State Forests and Western Lands Leases, there are also existing opportunities for people to enjoy National Parks in the bioregion.

The largest National Park in the bioregion, Yanga provides opportunities for walking, cycling, drive tours, wildlife observation and canoeing. Significant investment has been channelled into developing tourist interpretation centres at the Yanga homestead and woolshed. These centres depict the park's natural and cultural values.

6.8 Non-Indigenous heritage

European cultural heritage is related mainly to the historical connections between the river red gum and woodland forests and the development of the Riverina region. While relatively few significant sites and structures remain as testament to this history, modern day communities have long-standing connections with the river red gum forests that form part of the cultural heritage of the region.

Bird hide in Moira State Forest – photo courtesy of DII

6.8.1 Development of the bioregion and the associated heritage

The river red gum and woodland forests of the Riverina bioregion have been an important resource for communities along the Murray River since the first European settlers arrived in the 1820s. Due to the significant modification of landscapes across the region, cultural heritage items in the Riverina bioregion are limited to the remaining sites and structures, such as the Echuca Wharf, and the natural heritage of the forests themselves.

Red gum timber has been used extensively, especially across Victoria. It is a red, hard, durable timber, resistant to decay and termites. Its slow-rotting character has meant that it has been widely used for building foundations, railway sleepers, wharves and fences. In the 1920s it was chosen as the emblem for the National School of Forestry at the Australian National University in Canberra, demonstrating its timber value and iconic status.

6.8.2 Development in the bioregion

The development history can be categorised into early exploration and settlement up to the late 1800s, intensification of river red gum use and regulation through to 1980, followed by an increasing focus on balancing environmental and use values in more recent decades.

John Oxley first explored the region in 1817, following the Lachlan River near Booligal (Eardley, 1999). Twenty years later he was followed by Thomas Mitchell who explored the junction of the Murrumbidgee and Lachlan rivers in 1836. Charles Sturt then explored the Murrumbidgee and lower Lachlan between 1828 and 1831.

During the 1850s to late 1800s the expansion of river trade and introduction of railways led to increased cutting of river red gum timber. River red gum was used in river transport, to fuel the paddle-steamers and the timber was fast becoming a major item of trade. Steamboats or paddle-steamers were introduced to the Murray River in 1853 for commercial trade and operated principally between Goolwa and Echuca.

Ports with associated infrastructure were established at Echuca, Swan Hill, Albury and Wahgunyah. The wharf at Echuca in Victoria was built entirely from red gum timber and is listed as an item of National Heritage (DEWHA, 2009a). Towns such as Darlington Point emerged as suppliers of river red gum timber to fuel the river steamboats (HO and DUAP, 1996).

In 1915 the historic Murray Waters Agreement was signed, establishing 26 weirs and locks, paving the way for increased regulation of the Murray River, central to the irrigation development of the area. In 1912, the Murrumbidgee Irrigation Area started diverting water from the Murrrumbidgee at Narrandera. Construction of the Hume, Burrinjuck and Blowering Dams proceeded in 1936, 1928 and 1968 respectively. The Riverina region became known for its large-scale rice industries, dependent on water security (Eardley, 1999).

Historical phases of river red gum timber

Intensified use and recognition of the value of river red gum from the late 1800s led to more formalised forestry management. By the end of the 1800s, concern over widespread uncontrolled logging led to most of the remaining forests being reserved as forest lease or timber reserves. In the early 1900s many of these leases and reserves were dedicated as State Forests under the *Forestry Act 1916* (GHD, 2009). Some living trees or 'ringers' remain as survivors of the organised ringbarking practices carried out during this period.

Due to its durability, strength and resistance to water and insects, red gums timber was, and still is, highly valued for railway sleepers. The economic use of the red gum forests was expanded to supply timber to the Melbourne market and to export markets of the British colonies which were heavily engaged in railway and wharf building (Forests NSW, 2008).

From the 1980s, the environmental and cultural heritage values as well as timber production values were increasingly recognised. Forests NSW worked with timber operators, NGOs and community groups as well as other government agencies to develop policies to promote and support these non-use values. Permanent reservation areas for flora reserves and cultural heritage sites, retention of hollow habitat trees for fauna and the recognition of the Central Murray State Forests as Wetlands of International Importance are some example of Forests NSW's practices that reflect ecologically sustainable management (GHD, 2009). For more about recent forestry management practices and the impact on environmental values see **Chapter 11**.

6.7.3 Non-Indigenous heritage sites and items

The historic Yanga Station, timber jinkers and the Echuca Wharf are some tangible links to the heritage of the region that is inextricably tied to the river red gum. In addition to Lake Victoria's significance to Indigenous people because of the Rufus River Massacre, it is also important to other Australians because of its use in World War II.

The early steamer navigators William Randell and Francis Cadell are remembered by the adoption of street names in their honour across many towns along the Murray, Murrumbidgee and Darling rivers.

Yanga Station

In the 1840s the region was settled by cattle graziers, and by the 1860s sheep had become the primary stock. The historic Yanga Station heralds back to this era of prosperous grazing. Yanga is located near the town of Balranald and covered around 80,000 hectares. The explorer William Charles Wentworth leased Yanga in 1847. At the time it was gazetted to run 1,500 beef cattle and 30,000 sheep. According to Yanga's website, it was originally called Tala and renamed Yanga in 1862, which means 'mother' in the local Indigenous language (www.yanga.com).

The homestead was built using a 'drop log' construction in white cypress, otherwise known as Murray pine. It is claimed that the first telephone in Australia was installed at Yanga Station. The woolshed could accommodate 3,000 sheep and 40 shearers, testament to the strength of the wool industry at the time. From 1919 to 2006, the Black family ran Yanga Station. The Black family had a strong stewardship ethos, restoring and protecting the heritage (NPA website). In 1998, Yanga employed Bes Murray as the cultural heritage coordinator to ensure that both Indigenous and other Australian cultural heritage is respected and protected.

In 2006 the NSW Government bought Yanga Station creating a National Park, with interactive tourist centres that depict the cultural heritage of the Yanga homestead and woolshed.

Timber jinkers

Timber jinkers, otherwise known as log buggies, were constructed from red gum and used to transport timber from the harvest locations to the sawmills. They were hauled by a team of horses or bullocks. Bullocks were used in slow and difficult terrain. The proximity of the jinker illustrated above to the Berry Jerry Forest suggests it was used to transport red gum from the forest to the sawmill or from the sawmill to the Murrumbidgee River. The jinker is rare, with only a few examples remaining in museums. It is a representative example of the animal-drawn log trolley used on the sandy soils and riverbanks of inland NSW and Victoria, providing a link to the early clearing and milling activities of the Riverina (Migration Heritage Centre, 2009).

A timber jinker – Jindera c.1900 – source Museum of the Riverina collection (www.migrationheritage.nsw.gov.au)

Echuca Wharf

In the late 1800s Echuca Wharf was an important site on the busy Murray River (DEWHA, 2009a). It is testament to the major role of river trade in the pastoral boom and the rapid economic growth and development of the colonies during this time, which ultimately led to Federation. Today, the wharf is a major tourist attraction of the region. It is still operational with three tourist cruising paddle-steamers leaving from the wharf daily.

Echuca Wharf was built in 1864, almost entirely of locally felled and milled river red gum timber. The original wharf was 333 metres in length and built at 15 metres above low-flood level. This ensured it could unload goods year round, in times of both low-water level and flood. Cranes, wool press and bond stores were accommodated on the uppermost level.

After the Second World War, all but 75 metres of the wharf was demolished to provide for Melbourne's domestic firewood. In the 1960s the local historical society moved to restore the wharf. Today, the remaining structure is part of the central section of the original wharf. As a National Heritage–listed structure, original red gum timber is used in all maintenance and upgrades of the wharf.

Since the 1960s, the wharf and paddle-steamers have found new life, servicing the tourist industry. Echuca now boasts the largest number of paddleboats in the world.

In the Second World War, Lake Victoria was used as an air-to-ground gunnery range for the Royal Australian Airforce's Mildura-based training unit. There were a number of crashes at the lake. Remnants of spent ammunition have been found around the shores of the lake and some of the aircraft has been salvaged. Remains of some aircraft along with the remains of some of the aircrew are still in the lake.

Heritage sign at Echuca Wharf

Box 6.5: Early steamer navigation of the Murray River

William Randell and Francis Cadell were two Murray-Darling navigation pioneers. In 1853 they completed construction of steamers for use on the Murray River; Randell, the *Mary Ann* and Cadell, the *Lady Augusta*. The *Mary Ann* began its voyage on 15 August 1853, it reached the Darling junction on 3 September and the Murrumbidgee junction on 14 September, where it was overtaken by the *Lady Augusta*. Over the next few days it was a tight race, with the boats passing and re-passing each other. On 17 September 1853 the *Lady Augusta* reached Swan Hill four hours before the *Mary Ann*. The *Mary Ann* continued up the river and reached Moama on 24 September 1853. In their honour many towns along the Murray, Murrumbidgee and Darling rivers have named streets after them (MDBC, 2003).

A river paddle boats at Echuca

Chapter 7

Climate variability and predictions for future climate change

7.1 Overview

The NRC has used the best-available science and knowledge to assess the future climate variability and climate change in the Riverina bioregion. This science is telling us that the Riverina bioregion is likely to receive less rainfall and surface run-off, increased temperatures and a general increase in climate variability. These effects are expected to impact on water availability and future flooding regimes in the region, which will in turn have impacts on the functioning of river red gum forest ecosystems.

This chapter supports Steps 3 and 4 of the analytical framework by:

- outlining the current understanding of climate variability and climate change in south-eastern Australia
- outlining implications for planning within the uncertain trajectories of climate change
- defining the climate change scenarios used in the remainder of this assessment.

Chapters 8, 9 and 10 explore the potential implications of climate variability and climate change on water availability, flooding regimes and the economic, social and environmental values of the river red gum forests.

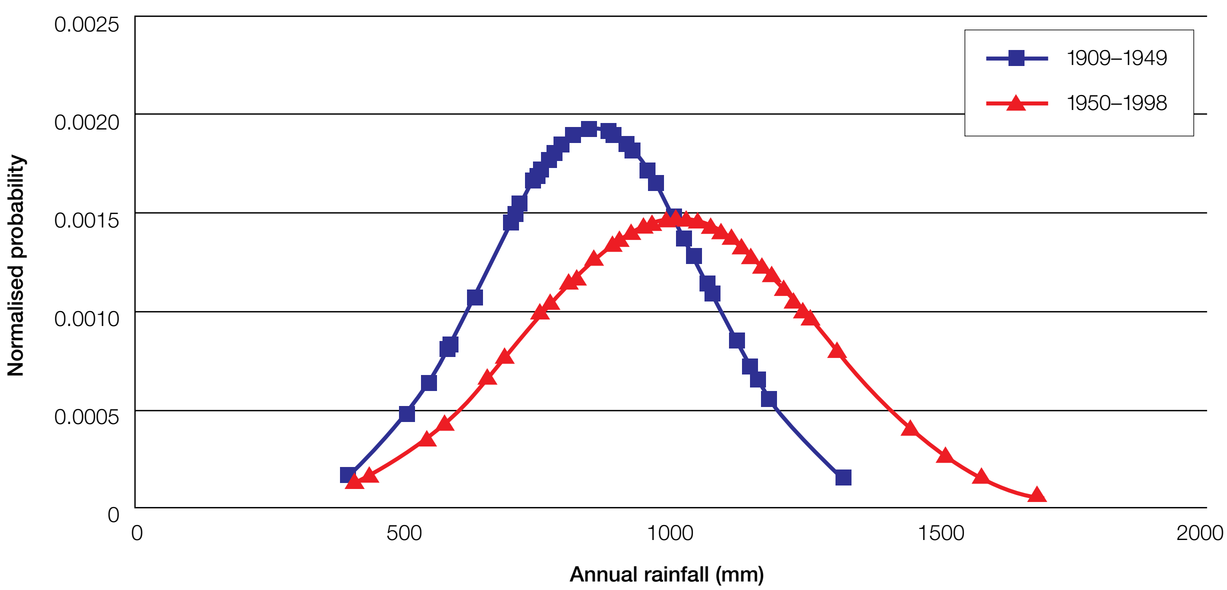
The key findings of this chapter are:

- The long-term rainfall and river flow records for south-eastern Australia show a major climate shift after 1950 to wetter conditions. There is strong evidence that the climate has shifted again over the past decade to conditions of much lower rainfall than the long-term average. This has been accompanied by increasing temperatures.
- There has been a dramatic decline in average inflows to the Murray system compared with the long-term average, although there were periods during 1900 to 1950 where river flows were also very low.
- Reduced rainfall and runoff and warmer temperatures are predicted under climate change scenarios in the south-east of Australia. Climate change may contribute to both a change in average conditions and an increase in variability. These changes can affect catchment hydrology more significantly than the projected changes in average conditions might indicate.
- Climate change is a significant threat to biodiversity, ecosystem functioning and ecosystem resilience. Climate change is likely to cause landscape-scale changes, markedly different hydrological regimes and the transformation of ecosystems and ecosystem function.
- Under a best-estimate (median) prediction of climate change by 2030, average surface water availability for the Murray region would fall by 14 per cent. Under a scenario with continuation of the recent drought, average surface water availability for the Murray region would fall by 30 per cent (CSIRO, 2008a).
- Current water reforms and approaches to water resource planning are seeking to address over-allocated systems and account for the effects of climate variability and climate change. Successful implementation of these reforms is critical to making water available for the river red gum forests. Management arrangements are being developed to respond to dynamic ecological states under different hydrological regimes.

The assessment for this section has drawn on work from well-respected international and Australian scientific institutions including the Intergovernmental Panel on Climate Change and the South Eastern Australian Climate Initiative, a collaborative partnership between the Murray-Darling Basin Authority, Australian Bureau of Meteorology, CSIRO, Australian Government Department of Climate Change, Victorian Department of Sustainability and Environment, and the Managing Climate Variability Program.[1]

The NRC strongly supports initiatives such as these that generate new knowledge and help us to reduce uncertainty and manage risks. This knowledge will be critical in supporting adaptive approaches in managing the future landscapes of the Riverina bioregion.

Figure 7.1: Normalised distribution of annual rainfall at Burrinjuck Dam (Khan, 2008)



7.2 Climate variability

South-eastern Australia has a highly variable climate. It can have inter-decadal shifts in both rainfall and temperature that can last for 40 or 50 years.

In south-eastern Australia, a major shift to a wetter period took place around 1950. For example, in the upper Murrumbidgee River catchment mean annual rainfall and rainfall variability increased after 1950 (see **Figure 7.1**).

As a consequence of this shift, annual flow volumes for the Murrumbidgee River at Wagga Wagga increased from 3,350 GL to 4,700 GL per year[2] (see **Figure 7.2**). This increased 'wetness' at the later part of the 20th century may have led to the over-allocation of surface and groundwater resources in many parts of Australia.

High rainfall in the second half of last century resulted in average surface water availability of 16,500 GL per annum in the Murray-Darling Basin. By comparison, during the first half of the century, water availability was less at only 13,500 GL per annum (**Figure 7.3**).

There is evidence that the climate has again shifted to lower rainfall and higher temperatures than the long-term average.

In the past decade we have seen weather patterns shift, with a dramatic decline in run-off (**Figure 7.3**). The average annual inflow between 1998 and 2005 of 10,500 GL is similar to the 10,300 GL experienced in the Federation drought of 1897–1904, and 10,550 GL in the droughts of 1938–45.

European history of Australia is marked by repeated references to periods of drought. Pigram (1986) found that widespread droughts occurred in Australia in 1864–68, 1880–88, 1895–1903, 1911–16, 1918–20, 1939–45, 1957–58, 1965–68 and 1979–83. Khan (2008) explored similarities between past and present droughts in the Murray-Darling Basin and found that the most severe and prolonged drought in earlier times was between 1895 and 1903. This was the 'Federation drought' which affected most of Australia. The current drought appears to have some similarity in pattern to that of the Federation drought.[3]

Many agencies are working to identify whether the observed rainfall and run-off patterns are part of an extended drought, or a shift to a lower average pattern similar to that which has occurred in the past. This form of climate shift is also known as a climate 'step change'.

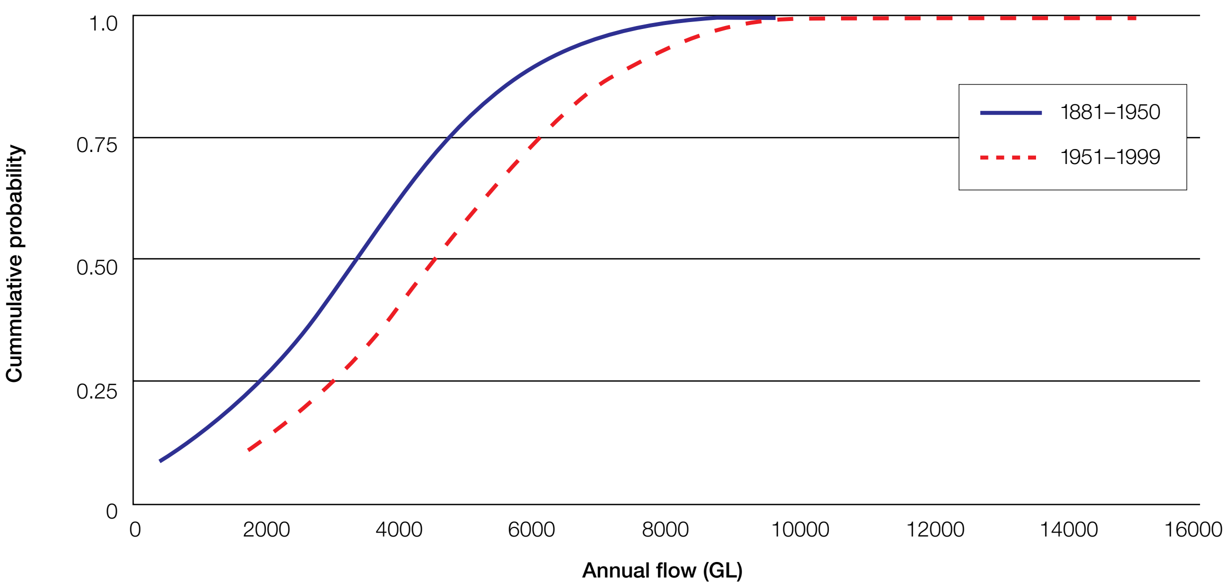
Over the past seven years, rainfall was predominantly very much below average throughout the Riverina bioregion (**Figure 7.4**).

This extended period of low rainfall has had significant impacts on catchment run-off and consequently river inflows.

The MDBA issues regular *Drought Updates*. Issue 21, November 2009, stated that:

As a result of the recent rain, Murray System inflows for the first five months of the 2009–10 water year were 2,200 GL which is significantly better than for the same period during each of the last 3 years, but remains well below the June to October long term average of 6,390 GL. The current water year is tracking as the 17th driest in 118 years of records. (www.mdba.gov.au)

Figure 7.2: Cumulative probability of flows in the Murrumbidgee River at Wagga Wagga (Khan, 2008)

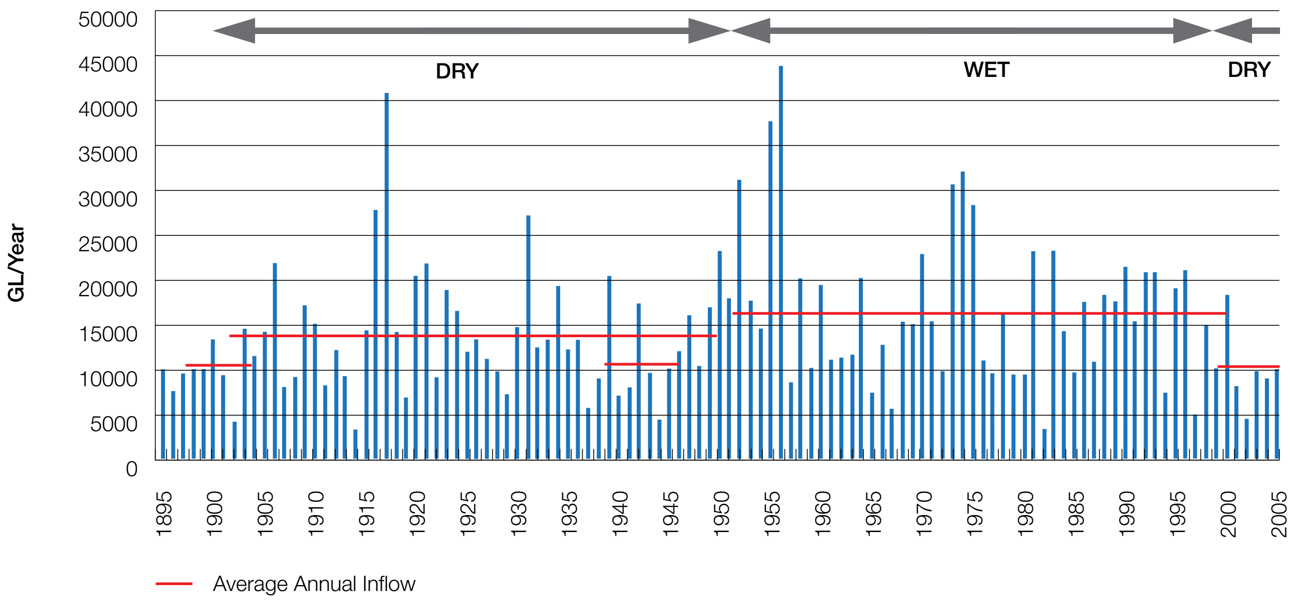


1 A program set up by the Australian Government, research institutions and agriculture sectors to help Australian farmers manage climate risk on-the-ground and providing tools to incorporate weather and climate information into farm business decisions.

2 Even discounting for the 500 GL contributed to the river by the Snowy Mountains Scheme, when the eastward flowing Snowy River was diverted inland, the increase was still around 850 GL.

3 However, the economic impacts of the current drought have been more severe due to Australia's large irrigation sector, and the greater basic needs of a much larger population, coupled with rising temperatures attributed to the onset of climate change.

Figure 7.3: River Murray inflows 1895–2005 (Wentworth Group of Concerned Scientists, 2008)



Note: Data was estimated by the modelling of historic climate and current development for the period 1895 to 2005.

Figure 7.4: Rainfall deciles for the Murray-Darling Basin, for seven years from 1 January 2002 to 31 August 2009 (adapted from www.bom.gov.au)

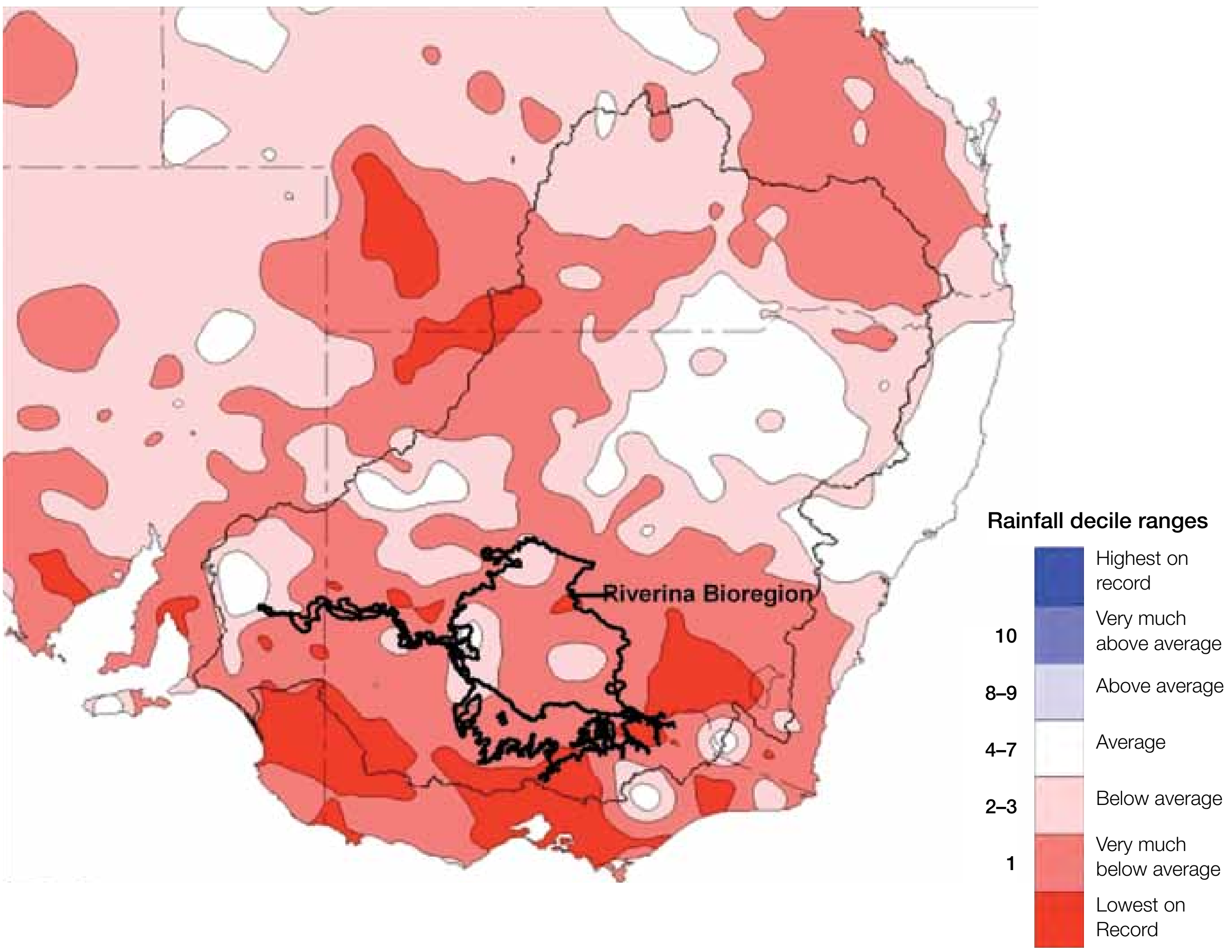


Figure 7.5 shows the substantial decrease in average inflows to the Murray system in recent years compared with the long-term average. It is important to note that the long-term average has within it periods of climate shift and periods of 5–10 years with very low flows (as illustrated in **Figure 7.3**).

Recent temperatures have also shown a sequence that is unprecedented in the historical records. During the 1950s to 1980s, the annual average temperature rise was around 0.1°C per decade.

However, since 1990 annual average temperature rises have been about 0.5°C per decade. Between 1997 and 2007 all years were warmer than average. For NSW as a whole, 2007 was the warmest year on record, and 2005 the third warmest. Since the turn of this century, all years have recorded an annual average mean temperature of more than 0.5°C warmer than the climatological average, with 2007 a record 1.1°C above average.

Figure 7.6 shows the annual mean temperature anomalies for Australia relative to the 1961 to 1990 reference period. This data set clearly highlights the recent sequence of above-average annual temperatures across the country, with many of the warmest years on record having occurred during the 1980s and 1990s.

Figure 7.5: Murray system inflows, excluding Snowy and Menindee inflows (www.mdba.gov.au)

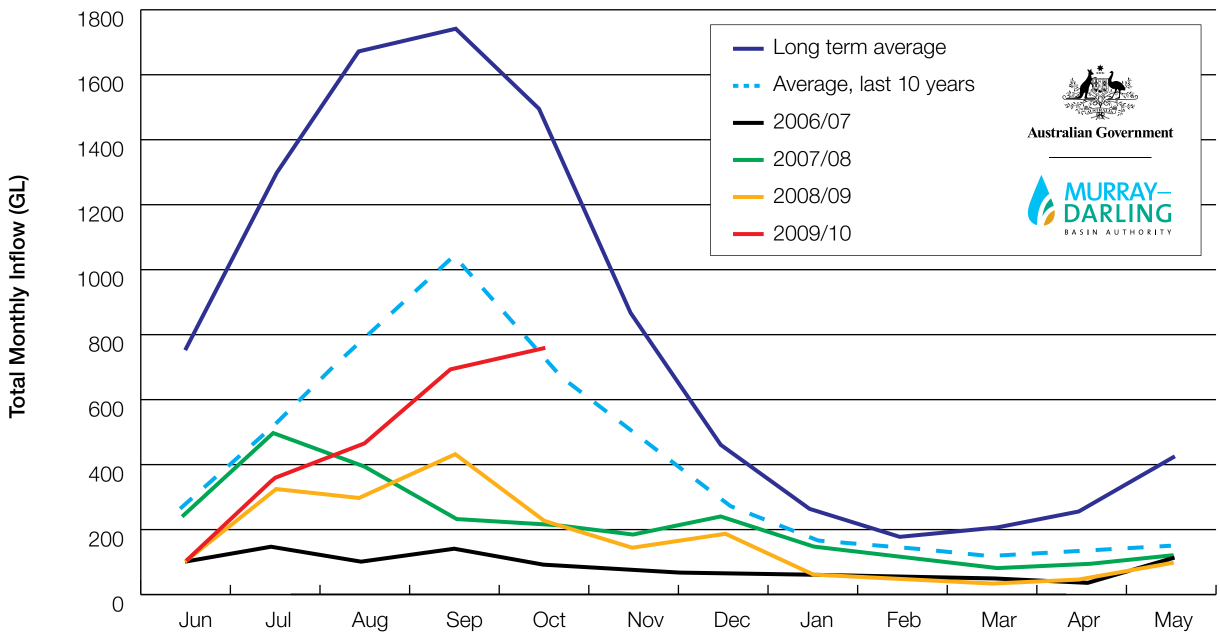


Figure 7.6: Annual mean temperature anomalies for Australia (BOM, 2009, www.bom.gov.au/climate/change/amtemp.shtml)

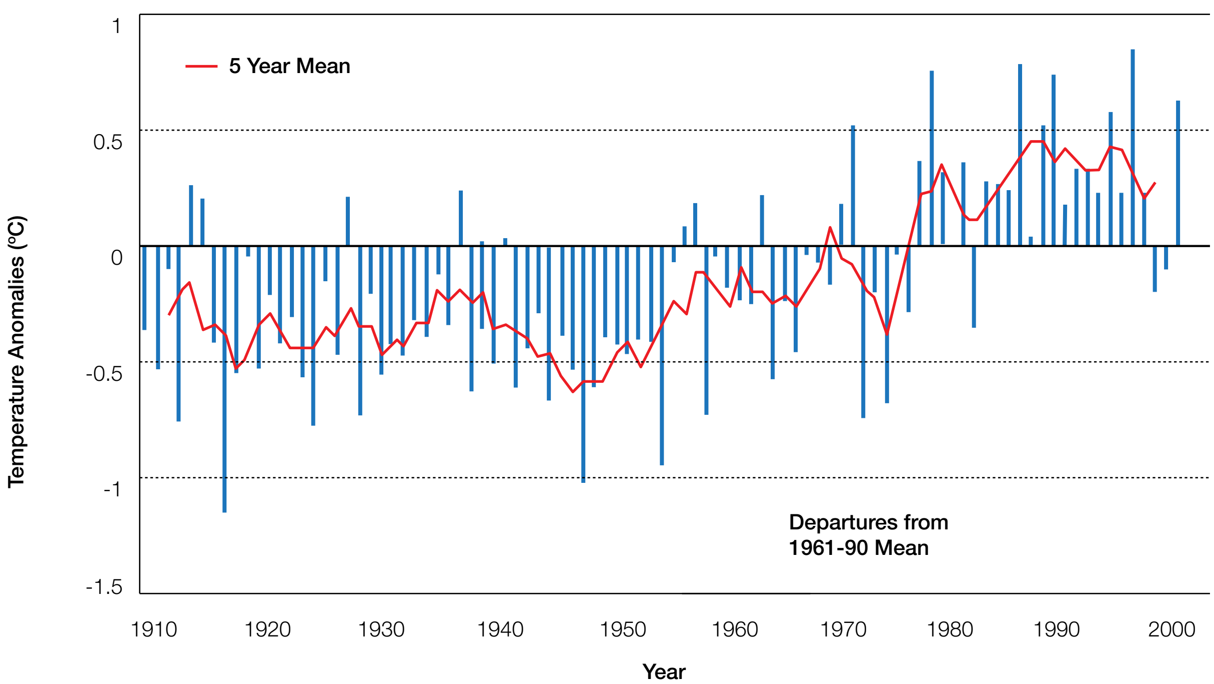


Figure 7.7: Relationship between means and extremes for previous climate and new climate (IPCC, 2007a)

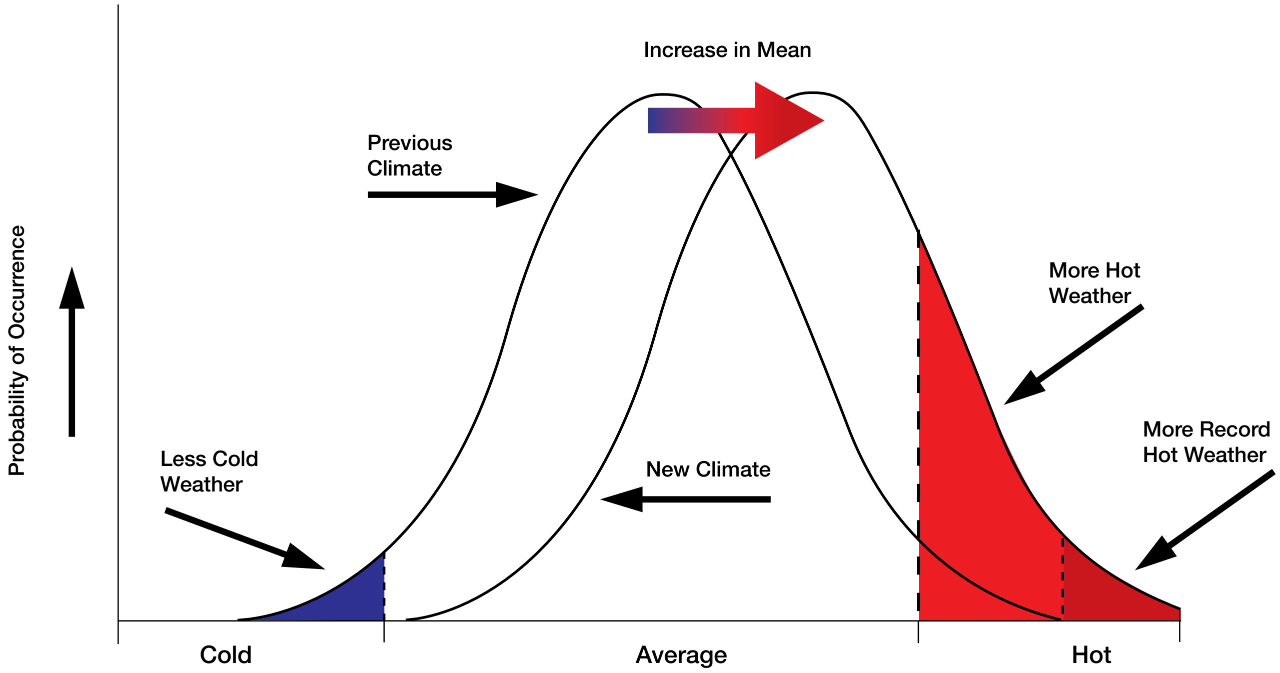
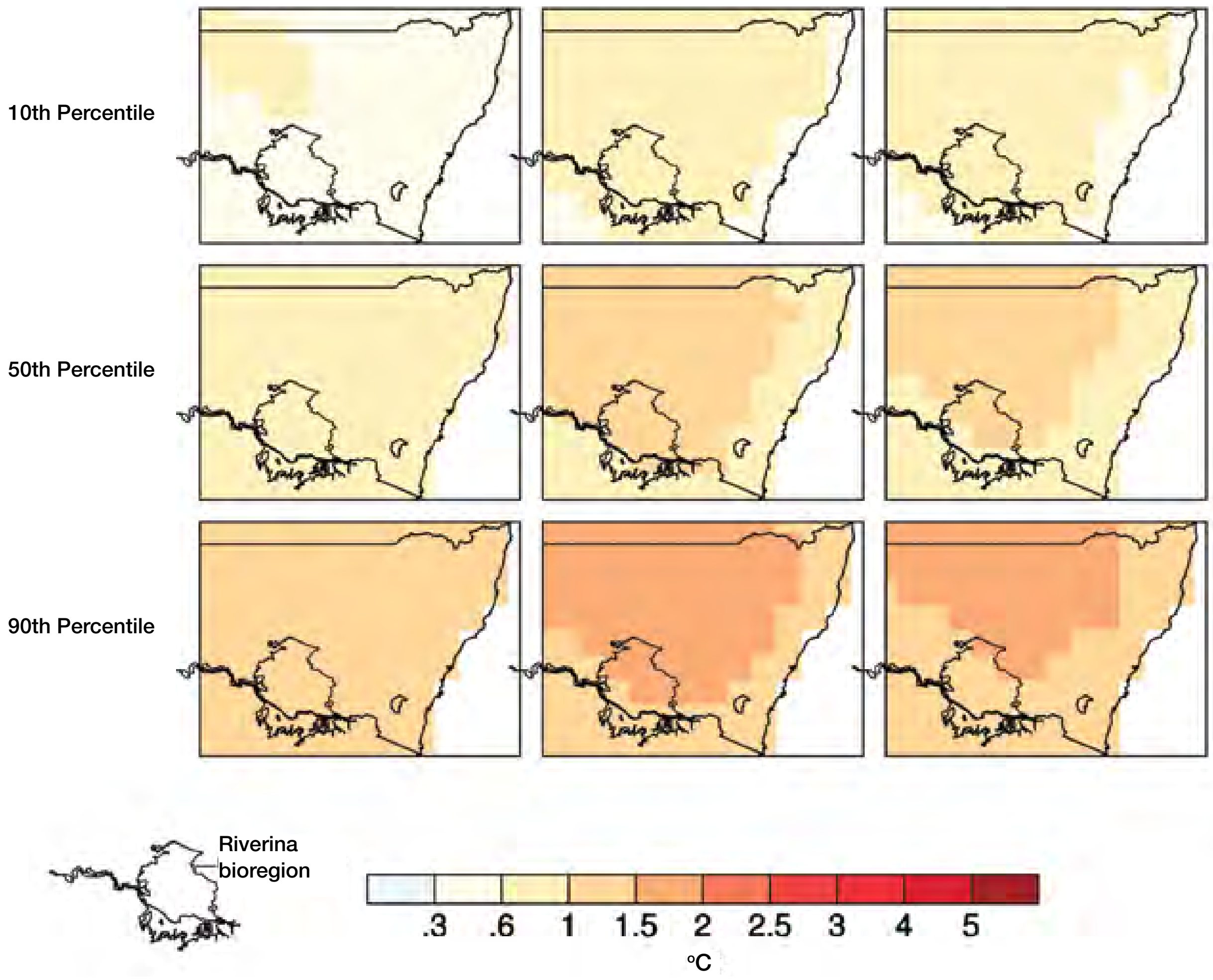


Figure 7.8: Forecast NSW/ACT temperature change 2030 summer. Emissions scenarios are from the IPCC Special Report on Emission Scenarios (adapted from www.climatechangeinaustralia.gov.au)



When examining historical changes to the NSW climate, a cool or even exceptionally hot month or year is less important than a multi-decadal trend. Current climate trends indicate an accelerating increase in average annual temperature in NSW.

Based on the latest climate science published by the IPCC (2007a) and shown in **Figure 7.7**, while there is a precedent for the current hot and dry conditions in the previous climate record, these conditions are likely to be far more prevalent in the new climate record. The arrow shows that hot weather, similar to that currently being experienced, occurs in both climates (previous and new). However, while only a small proportion of events in the previous climate occur in the 'hot zone', a significant proportion of all occurrences in the new climate record occur in the 'hot zone'. In addition, extreme hot events occur that were not observed in the previous climate.

7.3 Predictions for climate change in the bioregion

In 2007 the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment report (IPCC, 2007), concluding that:

- warming of the climate system is unequivocal
- humans are very likely to be causing most of the warming that has been experienced since 1950
- it is very likely that changes in the global climate system will continue well into the future, and that they will be more significant than those seen in the recent past.

These changes have the potential to have a major impact on human and natural systems throughout the world, including Australia.

The South Eastern Australian Climate Initiative (SEACI) is a three-year, $7 million research program investigating the causes and impacts of climate change and climate variability across south-eastern Australia. Launched in 2006, SEACI is a partnership involving government and industry, and is managed by the MDBA. CSIRO and the Bureau of Meteorology are research partners. SEACI has stated that the growing evidence of lower rainfall and reduced runoff in the south-east of Australia is linked to global warming (SEACI, media release, 1 May 2008). Predictions for the future include warmer temperatures and reduced rainfall and runoff.

Figure 7.8 shows the forecast summer temperature change across NSW, including the Riverina bioregion. The temperature is forecast to increase by 1–1.5°C for the projected 2030 summer across the NSW portion of the Riverina bioregion for the 50th percentile, the mid-point of the model results, which provides a best-estimate result.

Figure 7.9 shows forecast changes in rainfall across the NSW portion of the Riverina bioregion. A significant loss of winter rainfall and small increases in summer rainfall are forecast. The forecast changes are possibly outside of historical variation.

The IPCC has developed a range of emissions scenarios to project future climate change. It is difficult to make plans based on such a large variation in the projections. For instance, temperature in south-eastern Australia is projected to rise by 1.1 to 60°C by 2100 (IPCC, 2007).

Figure 7.9: Forecast rainfall changes based on A2 climate-change 2050 scenario (adapted from DECC, 2009b)

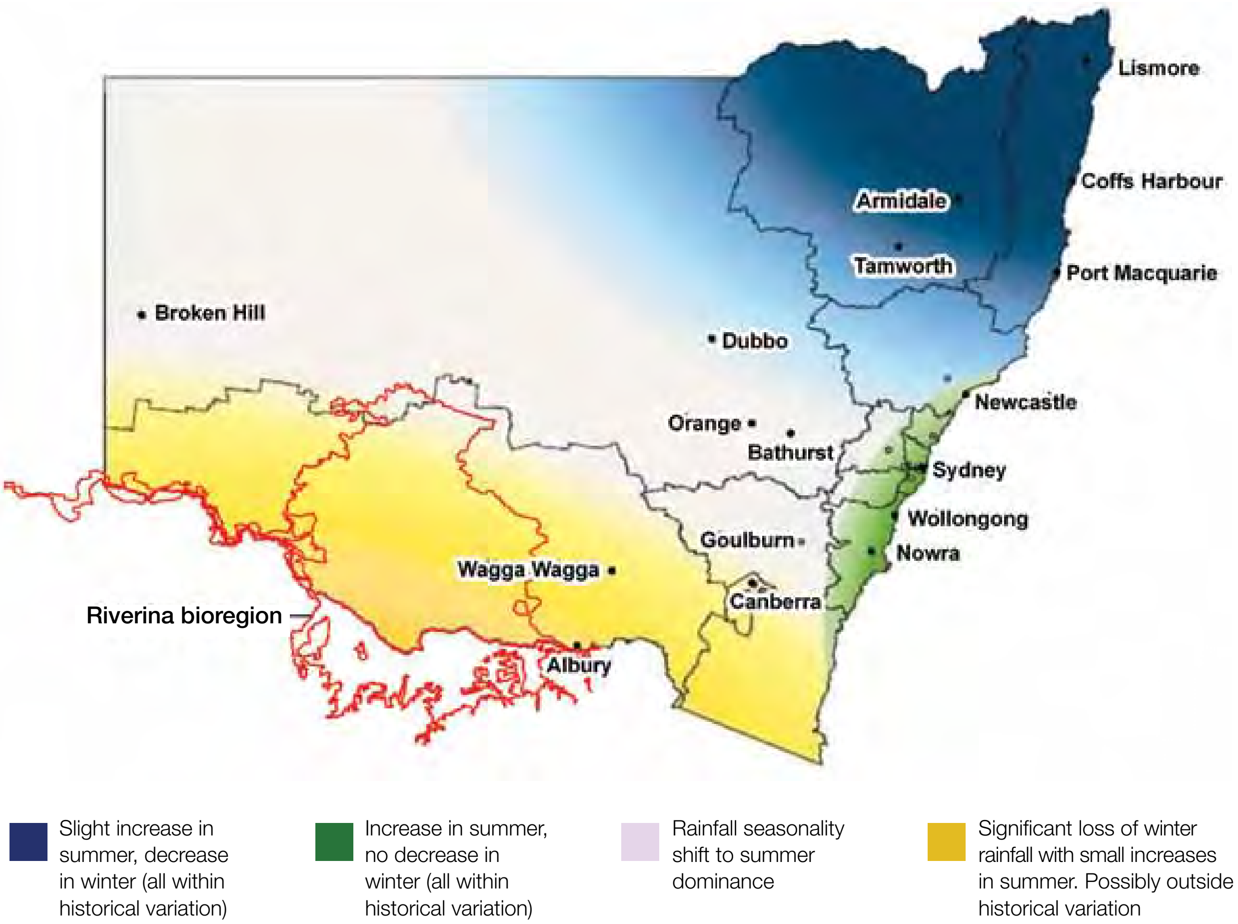


Table 7.1: DECCW expert panel assessments of likely changes in biodiversity

Impact	Comment
The structure, composition and function of ecosystems are likely to change	All ecosystems in NSW, even the most hardy and resilient, are expected to alter in response to climate change. The structure of ecosystems will be influenced by changes in fire regimes and hydrological flows. Changes in species' distributions and abundances will alter the composition of ecosystems.
Distributions of individual species are likely to change	The distribution of individual species is likely to shift in latitude and altitude in response to increased temperatures. Drier conditions over much of the west of NSW, as well as a shift in seasonal patterns of rainfall in the south-west are likely to cause range contraction in a number of species.
Changes in fire frequency and intensity are likely to have widespread impacts	Larger and more intense fires are likely to extend in the future into infrequently burnt wet forests and refuges such as canyons that are protected by their topography, changing forest structure and composition. Species that are highly sensitive to fire are likely to disappear, while those that depend on old or dead hollow-bearing trees and woody debris are likely to have fewer habitats. Small patches of fire-sensitive ecosystems in a matrix of extensive drier vegetation are most at risk. More extensive fire combined with drought stress is likely to decrease the flowering of plants such as banksias and eucalypts in dry forests and heaths, impacting on nectar-feeding animals.
Changes in invertebrate populations are difficult to predict but likely to be substantial	Invertebrates have many functions in ecosystems – for example as pollinators, predators, herbivores, detritus feeders, disease vectors, biological controllers of pests and food for other organisms. Invertebrate ecology and population dynamics are likely to change greatly, with consequences that are likely to be substantial but are generally hard to predict from current knowledge. Changes are already apparent in some of the better known and more significant invertebrates, such as the plague locust *Chortoicetes terminifera*. Breeding adults of this species were observed as early as July in 2008, and it is expected to benefit from warmer and wetter summers and warmer night-time temperatures.
Rainfall decline and reversed seasonality are likely to cause major changes in the Murray Valley	The Riverina and Murray Valley are very likely to suffer major ecological changes as a result of reduced annual rainfall, a shift in rainfall seasonality from winter to summer dominance, declining overall river flows and a loss of spring snow-melt (DECC, 2009b). Species adapted to 'Mediterranean' conditions (wet winters and hot, dry summers) are likely to be displaced or lost. Floodplain and wetland species that have already declined dramatically over the past decade are likely to decrease further. Many ecosystems are likely to collapse.
Species and ecosystems that are stressed by other factors are less likely to resist climate change	Many Australian ecosystems and species have evolved in highly variable climates and consequently are likely to have some capacity to resist expected climate changes. However, many ecological communities and species in NSW have declined severely because of land clearing, water extraction, habitat fragmentation, grazing and introduced pests. Species and ecosystems that are stressed by non-climatic factors are less likely to be resilient to climate change impacts.

The rate of global emissions growth since 2000 has been greater than for the most fossil-fuel intensive of the IPCC's emission scenarios. The Garnaut Climate Change Review concluded that all of the IPCC's emissions scenarios may under-estimate the future growth in emissions in the early 21st century (Garnaut, 2008). Analysis of global mean surface temperatures also shows that the rate of warming is in the upper range of the IPCC's climate projections.

7.4 Planning for climate variability and climate change

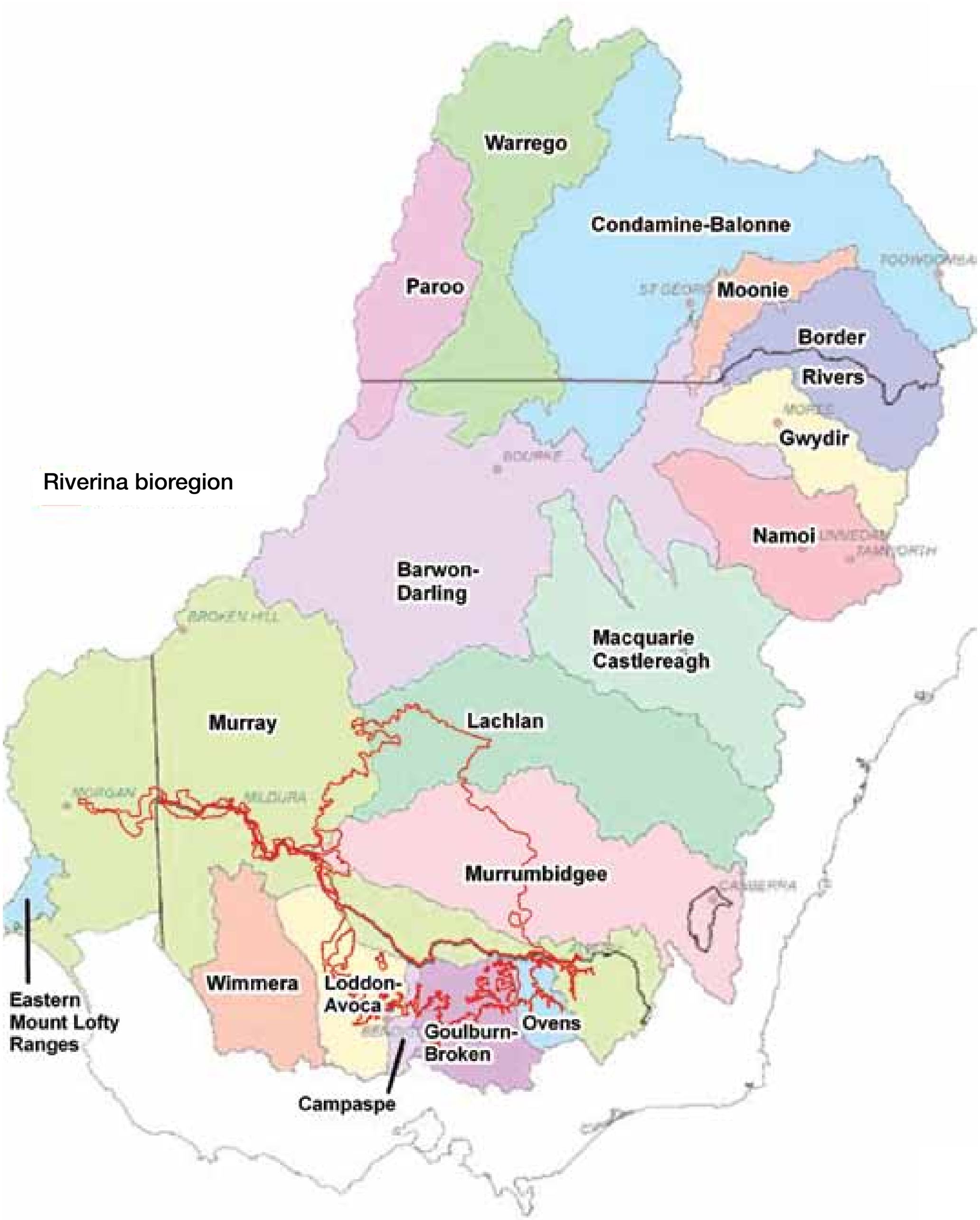
Future climate variability and climate change, and the corresponding effects on water availability, is expected to impact upon the future health of river red gum forests of the Riverina bioregion. Planning the management of the forests will require planning for an uncertain future.

7.4.1 Possible changes in biodiversity from climate change

The impacts of climate change on Australia's biodiversity are already discernible at the genetic, species, community and ecosystem level. The threat to Australia's biodiversity is expected to increase sharply through the 21st century and beyond due to the growing impacts of climate change, the range of existing stressors on biodiversity, and the complex interactions between them (Biodiversity and Climate Change Expert Advisory Group, 2009).

In 2009, the NSW Department of Environment, Climate Change and Water (DECCW) held expert panel assessments of the likely changes in biodiversity as a result of projected climate changes in NSW. The expert panel identified a number of potential impacts on biodiversity and ecosystem function (**Table 7.1**). The predicted impacts on the river red gum forests of the Riverina bioregion are outlined more fully in **Chapter 9**.

Figure 7.10: Assessment and reporting regions within the Murray-Darling Basin (CSIRO, 2008)



7.4.2 Predictions of future water availability

Climate change may contribute to both a change in average conditions and an increase in variability. These changes in turn can affect catchment hydrology more significantly than the projected changes in average conditions might indicate. The current drought and future climate variability will also likely reduce water availability for the majority of red gum stands across the bioregion.

Various scenario modelling exercises indicate a substantial reduction in the magnitude, frequency and duration of floods, particularly large floods.

A considerable amount of work has been completed in recent years assessing likely water availability under future climate scenarios. The most recent and comprehensive of these assessments is CSIRO's Murray-Darling Basin Sustainable Yields Project (MDBSY Project) completed in November 2008. The MDBSY Project is the world's largest basin-scale investigation into the impacts on water resources from:

- catchment development
- changing groundwater extraction
- climate variability, and
- climate change (CSIRO, 2008a).

The findings of the MDBSY Project are presented for 18 reporting regions within the basin (**Figure 7.10**). Some of the key findings from the MDBSY Project relevant to future water availability in the Riverina bioregion are:

- a very substantial decline in surface water availability is possible in the south of the Murray-Darling Basin
- in volumetric terms, the majority of the impact of climate change would be borne by the environment rather than by consumptive water users.

The Murray, Murrumbidgee and Lachlan regions are of particular relevance to the Riverina bioregion. For the Murray region, average surface water availability is 11,162 GL/year (CSIRO, 2008). If the recent (1997-2006) climate were to persist, average surface water availability for the Murray region would fall by 30 per cent; average diversions in the Murray region would fall by 13 per cent; and end-of-system flows would fall by 50 per cent. Under the best-estimate (median) prediction of climate change by 2030, average surface water availability for the Murray region would fall by 14 per cent; average diversions in the Murray region would fall by 4 per cent; and end-of-system flows would fall by 24 per cent.

A range of other factors were also assessed as part of the CSIRO's MDBSY Project work, including groundwater extractions, the expansion of commercial forestry plantations and increases in the total capacity of farm dams. The CSIRO assessment found:

- Current groundwater use is unsustainable in seven of the 20 high-use groundwater areas in the Murray-Darling Basin and will lead to major drawdowns in groundwater levels in the absence of management intervention. Parts of the Lower Lachlan, the Upper Lachlan, the Mid-Murrumbidgee and the Upper Murray are all listed as having unsustainable groundwater use.
- 'Best-estimate' projections of commercial forestry plantations and farm dams indicate only very minor impacts on the total runoff reaching rivers across the Murray-Darling Basin.

The MDBSY project outlines climate projections beyond 2030 (**Figure 7.11**). This work allows some indication of the reduction in run-off that can be expected under two climate change scenarios and how these compare with the reductions in run-off from the 1990 mean (approximately 40 per cent over 1997 to 2006) in the southern Murray-Darling Basin. The reduction over that period is similar to the extreme dry estimate for 2030 (43 per cent under the high global warming scenario) and a greater reduction than the median estimate for 2070 (from the medium global warming scenario).

Under the medium global warming scenario, the reduction in run-off for the southern Murray-Darling Basin is estimated to be approximately 11 per cent in 2030, 17 per cent in 2050 and 27 per cent in 2070. These projected reductions for a medium global warming scenario are less than the 40 per cent reduction experienced over 1997 to 2006. However, under the high global warming scenario, the 1997 to 2006 run-off reduction would be outweighed by the estimated median runoff change in 2070.

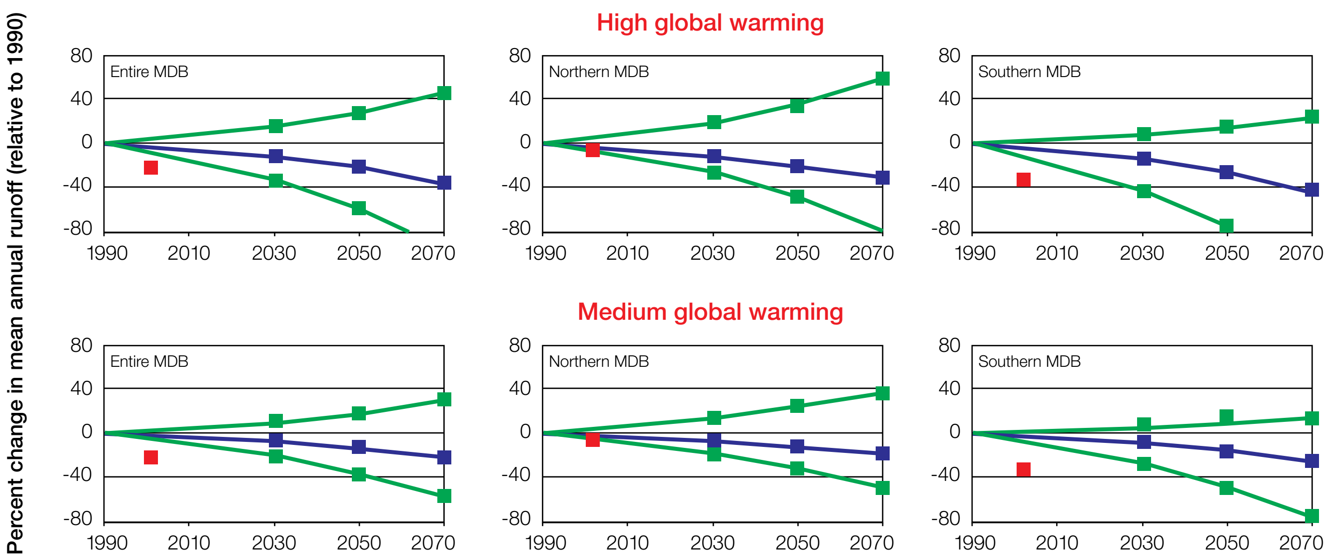
It is important to keep these relative magnitudes in mind as we consider how to manage the bioregion's river red gum forests under the interaction of river regulation, current over-allocation climate variability and climate change. The future of the river red gum forests will depend on whether the current water reform programs are successful in returning water to the over-allocated rivers of the Murray and Murrumbidgee.

7.4.3 Planning for a likely transformation

The forest landscapes within the Riverina region have evolved over long, 'landscape evolution' time periods. Following European settlement, these forests have also been heavily modified as a result of human intervention. They are likely to continue to transform more rapidly due to changes in the climate. As described above, the MDBSY Project suggests we are likely to observe markedly different hydrological regimes over the coming decades (CSIRO, 2008a). It is therefore reasonable, and prudent, to plan for this likely transformation.

The MDBA is in the process of developing a Basin Plan (MDBA, 2009). One of its key elements will be 'sustainable

Figure 7.11: Run-off projections for 2030, 2050 and 2070 relative to 1990 for the entire Murray-Darling Basin (blue lines show trajectory of median runoff change; green lines show breadth of possible range of run-off changes, and red squares indicate the percentage change in run-off associated with the recent (1997–2006) climate) (CSIRO, 2008a)



diversion limits' which will limit the quantity of surface water and groundwater that may be taken from the Basin water resources. Sustainable diversion limits will be set using the best available science and will define the level at which water in the Basin can be taken from a water resource without compromising key environmental assets, ecosystem functions, environmental outcomes or the productive base of the water resource. This will vary in different years and will take into account the effects of climate change and variability.

The revision of sustainable diversion limits within the Basin Plan is the primary tool to achieve fundamental water reform under the National Water Initiative. This work, under the *Water Act 2007*, is designed not only to address over-allocation but also to address the expected reduction in water flows from climate change.

In addition, the Victorian Government's Sustainable Water Strategies are planning for uncertainty in future water availability. For example, the Victorian Government's Draft Northern Region Sustainable Water Strategy, a 50-year water resource plan, states:

The Draft Strategy examines two scenarios in detail – a continuation of recent low inflows … and medium climate change projections… and compares these to the base case. Focusing on (a step change scenario) allows us to plan for the 'worst case' which is less risky than assuming inflows will soon return to average conditions. However, the worst case may not eventuate and therefore it is also important to examine the impacts of medium climate change. Comparing (medium and step change scenarios) against the long-term average ensures that the community is aware of the range of possible water futures. (DSE, 2008)

7.4.4 Framework for considering uncertainty surrounding predictions

The uncertainties inherent in modelling of complex systems need to be acknowledged. The 'best-estimate' predictions from the MDBSY Project involve a median figure from a number of different climate, water use and hydrological models which were calibrated against historical data. At a small temporal or spatial scale the uncertainty of these predictions increases.

The main sources of uncertainty are in the global warming projections and the global climate modelling of local rainfall response to global warming. The uncertainty in the rainfall-runoff modelling of climate change impacts on run-off is small compared with the climate change projections (CSIRO, 2008a). The MDBSY Project takes into account the current uncertainty in climate change projections explicitly by considering results from 15 global climate models and three global warming scenarios based on the IPCC Fourth Assessment Report (IPCC, 2007). The results are then presented as a median estimate of climate change impact on run-off and as the range of the extreme estimates.

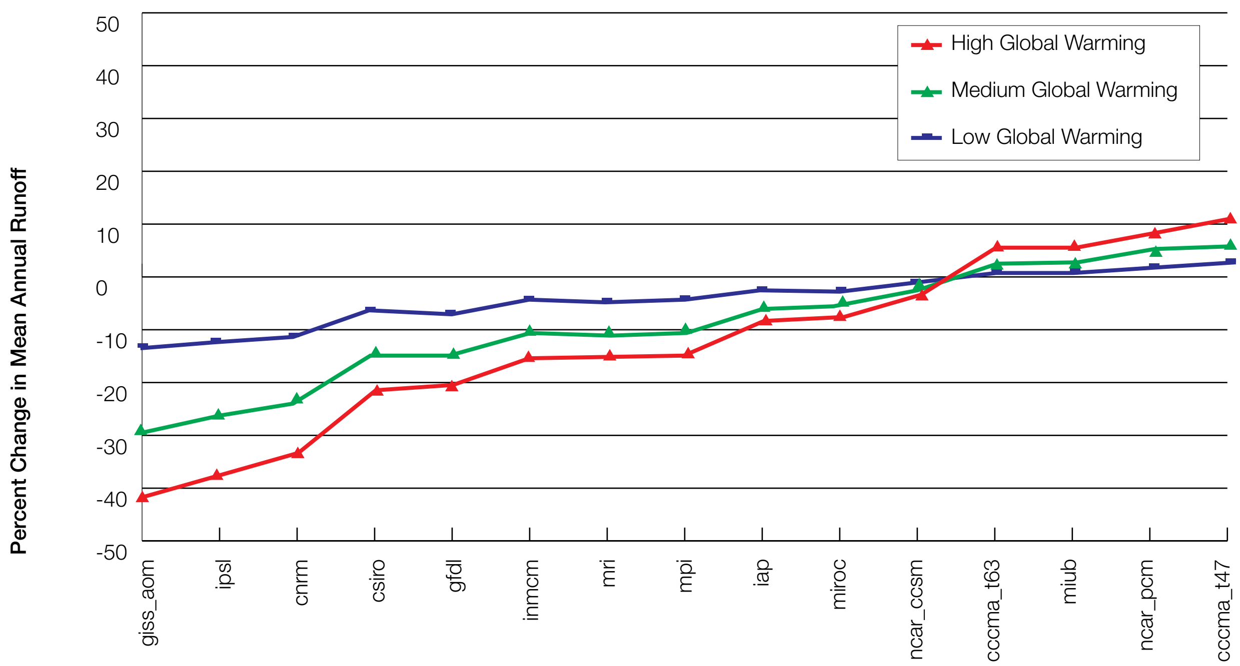
The potential impact of climate change on run-off can be very significant, as shown in **Figure 7.12**. Although there is considerable uncertainty in the estimates, the results indicate that run-off in 2030 in the Murray region is more likely to decrease than increase (CSIRO, 2008a).

Garnaut (2008) describes uncertainty as arising when:

an event is of a kind that has no close precedents, or too few for a probability distribution of outcomes to be defined, or where an event is too far from understood events for related experience to be helpful in foreseeing possible outcomes.

Humans are often required to form judgments about events that are unique, or so unusual that analysis based on secure knowledge and experience is an absent or weak guide. Bayesian decision theory encourages us to treat decisions under uncertainty as if we were taking a risk (Raiffa, 1968; Raiffa and Schlaifer, 1961; cited in Garnaut, 2008). Garnaut (2008) states that we will make the best possible decisions under uncertainty if we force those who are best placed to know to define subjective probabilities that they would place on various outcomes, and work through the implications of those

Figure 7.12: Percentage change in mean annual runoff (2030) in the Murray region under the 45 Scenario C simulations (15 Global Climate Models and three global warming scenarios) relative to Scenario A runoff (CSIRO, 2008a)



assessments as if they were probability distributions based on experience. These subjective probability distributions can then be updated on the basis of experience.

The climate models on which the IPCC assessments are made are diverse and provide numerous observations on possibilities out of their diversity. In addition, each generates numerous results from repeated experiments (Garnaut, 2008). These are the senses in which the IPCC science draws from probability distributions. There are many points at which judgment rather than experience informs the model relationships.

In considering decision-making under conditions of climate change uncertainty, Garnaut (2008) states the following:

Under conditions of such uncertainty, it is sensible to ask whether it would be better to delay decisions while information is gathered and analysed. However, it is as much a decision to do nothing, or to delay action, as it is to decide to take early action. The issue is whether delay would be a good decision. When global warming first became a major international public policy issue nearly two decades ago, it may have been good policy to take modest and low-cost steps on mitigation, while investing heavily in improving the information base for later decisions. In 2008, the costs of delay—in the probabilistic terms that frame a good decision under conditions of uncertainty—are high.

CSIRO proposed a framework for considering the uncertainties of predictions. This framework considered the magnitude and threat of the modelled change and the uncertainty of the analysis (shown in **Figure 7.13**).

The environmental and social implications of the climate modelling suggest a categorisation of 'high threat', therefore calling into question the adequacy of water sharing arrangements regardless of the level of uncertainty. Although the specific trajectory of the future climate at a specific site has a high level of uncertainty, there is a consensus in the predictions about broad-scale trends.

7.5 Climate change scenarios used in this assessment

For the remainder of this assessment, the NRC has based its modelling on the following three climate scenarios drawn from the MDBSY Project (CSIRO, 2008a):

- the historic climate base case (Scenario A)
- the continuation of the recent drought (Scenario B)
- the best-estimate (median) 2030 climate (focusing on the median of the range, and where uncertainty is reported as a wet extreme and a dry extreme in the range) (Scenario C).

Salt scalds at Lake Victoria State Forest

These three climate scenarios (applied in the MDBSY Project) are derived from the latest modelling for the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007).

In the following chapter, the future flooding regimes at selected sites are assessed based on the three climate scenarios outlined above. The MDBSY Project indicates that the wet-extreme 2030 climate would lead to little change in flood frequency for the assessed environmental sites. However, flood events would be somewhat larger, except in the case of the Gunbower-Koondrook-Perricoota Forest, where event size would fall slightly. These hydrological changes would not be expected to have additional impacts on the assessed sites.

The dry-extreme 2030 climate would cause hydrological changes slightly more severe than a long-term continuation of the recent climate. Thus it is considered that the range of possible impacts under climate change for flooding are adequately presented in the selected three scenarios used in this assessment.

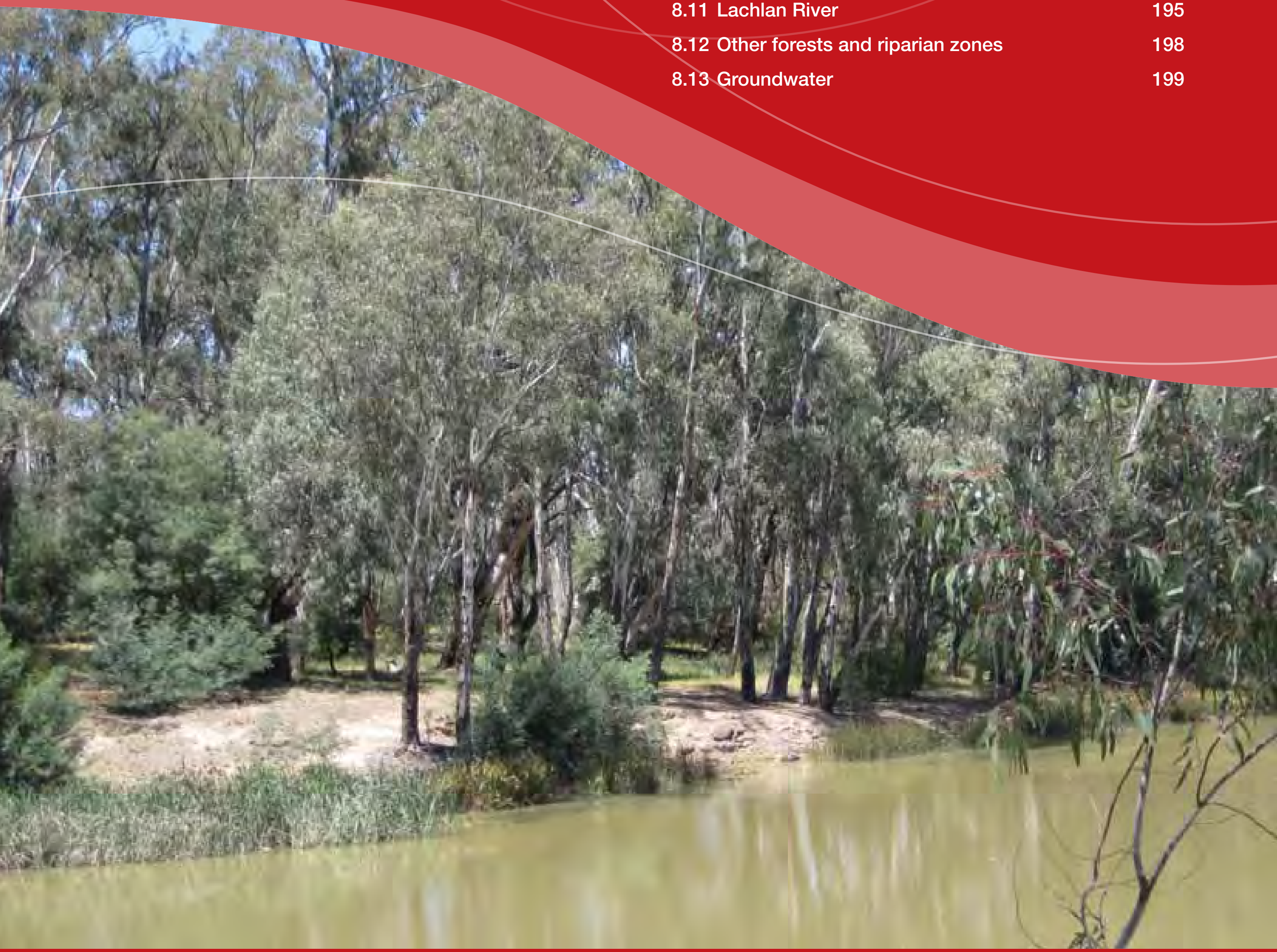
Due to divergence in the range of possible greenhouse gas emission trajectories, projections further into the future (that is, beyond a 2030 climate) become increasingly uncertain. By 2070, the median climate under high global warming is expected to be broadly similar to the dry-extreme 2030 climate. Further, as stated earlier, the rate of global emissions growth since 2000 has been greater than for the most fossil-fuel intensive of the IPCC's emission scenarios. CSIRO (2008d) notes that this highlights the need for flexibility and adaptive capacity in water resources management in the Murray-Darling Basin.

Figure 7.13: Framework for considering uncertainty of modelled predictions (adapted from CSIRO, 2008)

	Low threat	High threat
Low uncertainty	Current water sharing arrangements appear sufficient for ongoing management of water resources.	Current water sharing arrangements are likely to be inadequate for ongoing management of water resources, as they do not adequately consider future threats.
High uncertainty	Current water sharing arrangements appear sufficient for ongoing management of water resources, but careful monitoring and adaptive management is recommended.	Current water sharing arrangements are likely to be inadequate for ongoing management of water resources. Further work to reduce the major sources of uncertainty can help guide changes to water sharing arrangements.

Chapter 8

Implications of changes in climate for water availability and flooding regimes



8.1 Overview

The river red gum forest ecosystems and the floodplains of the Riverina bioregion are already adjusting to the long-term impacts of river regulation and water extraction for irrigation, as well as a shift from winter/spring flooding to predominantly summer flooding. In addition, there has been natural variability in rainfall. The period since the 1950s although generally wetter than the 1900-1949 period saw a substantial reduction in the frequency, duration and magnitude of floods.

The current drought and future climate variability and predicted climate change will further reduce water availability for the majority of river red gum forests across the bioregion. Successful water reform will moderate this reduction if it can reduce water extraction by establishing sustainable diversion limits and return water to these over-stressed rivers.

This chapter supports Step 3 of the analytical framework by:

- outlining the characteristics and water requirements for each water management unit (WMU) and the forests associated with them
- assessing future water availability and flooding regimes under different climate scenarios
- assessing the likely impacts of future water availability for the forests
- discussing the dependence of the forests on groundwater.

The key findings of this chapter are:

- River regulation has fundamentally changed the flow regimes of the major rivers in the bioregion. The future health of the river red gum forests depends fundamentally on the success of COAG water reforms in restoring water to these stressed and over-allocated floodplain river ecosystems.
- A further substantial reduction in the magnitude, frequency and duration of floods can be expected under climate change for the majority of forest stands, particularly the larger forests of Millewa, Koondrook-Perricoota and Werai. Large 'landscape restoration' floods are unlikely to occur. However, the delivery of environmental water to the Millewa forests and intervention works at Koondrook-Perricoota will assist in maintaining some moderate-sized floods.
- A further reduction in flood extent, duration and frequency can also be expected under climate change for forest stands associated with the Murrumbidgee and Lachlan Rivers, and riparian zones along the Edward, Wakool and Murray Rivers downstream of the Koondrook-Perricoota forests.
- The forests along the upper Murray River are more resilient as local rainfall towards the east is comparatively higher and may increase. These forests can also access local shallow groundwater systems recharged by river levels kept high during summer to supply water for irrigation.
- Some river red gum communities are likely to be highly dependent on groundwater. There is evidence that river red gums in the Riverina bioregion use groundwater opportunistically as a water source in prolonged dry periods and times of water scarcity. Flooding is a significant recharge mechanism in some areas of the bioregion.

8.2 River regulation in the Murray-Darling Basin

As discussed in **Chapter 2**, the river red gum forests and associated ecosystems of the Riverina bioregion have developed as a result of the long-term, geomorphic evolution of the landscape and its associated flooding regimes.

River regulation has dramatically changed the flow regimes of the major rivers in the region. It is estimated that the total public storage in the Murray-Darling Basin's larger storages (>10GL) is approximately 24,500 GL (GHD, 2009). This storage volume equates to approximately twice the average annual discharge of the Murray-Darling. The total annual flow at the River Murray mouth has been reduced by 61 per cent and the river now ceases to flow through the mouth 40 per cent of the time, compared with 1 per cent prior to water resource development (CSIRO, 2008a).

Table 8.1 shows the reductions in current flows compared with natural flows across all the major rivers in the basin.

The development of these storages and the water that is being extracted has greatly affected the natural flow and flooding frequency of rivers throughout the MDB. For example,

Table 8.1: Mean and median annual flows during natural and current conditions since 1892 (Water Audit Study, MDBMC, 1995)

	Flows under natural conditions (GL/year)		Current flows under regulated conditions (GL/year)	
	Mean	Median	Mean	Median
Darling	3,042	1,746	2,272	1,053
Murrumbidgee	2,794	2,527	1,184	644
Goulburn, Broken and Campaspe	3,668	3,510	1,774	1,211
Loddon	247	202	100	37
Namoi	872	570	402	177
Murray	13,754	11,883	4,915	2,539

Cuba State Forest on the Murrumbidgee River

an 18,300 ML/day flood at Yarrawonga weir on the Murray occurred every 1.1 years in the pre-development (no regulation) flow history. That level of flood only occurs once every 2.6 years under current development conditions.

These systems are likely to decline further in health under climate change predictions. For example, modelling of the future flow regime for the CSIRO Murray-Darling Basin Sustainable Yields (MDBSY) Project using the best-estimate (median) 2030 climate scenario, indicates that that flooding (18,300 ML/day) at Yarrawonga will be reduced to one event every 3.5 years. For this assessment, the NRC has used the current level of development when modelling the likely impact of climate variability and change, as this is the best information currently available.

The top two panels of **Figure 8.1** from MDBSY show how river regulation and water resource development have dramatically altered the relative proportions of river flow going to extractive water use, the river floodplains and wetland, and the end of system lakes, estuaries and marine environment respectively. The bottom two panels show how the two climate change prediction scenarios (continuation of the recent climate and median 2030 climate) may exacerbate this situation.

The figure demonstrates the greatest impact upon water used for the environment was the commencement of current development (river regulation) rather than climate change scenarios or the recent drought.

It is important to note that the end of system flows of water provide environmental, economic and social values to the coastal estuaries and the communities that rely upon them. As can be seen in **Figure 8.1**, the flow to the estuary and marine environment reduces dramatically upon commencement of river regulation and this situation continues under recent climate and dry extreme climate scenarios.

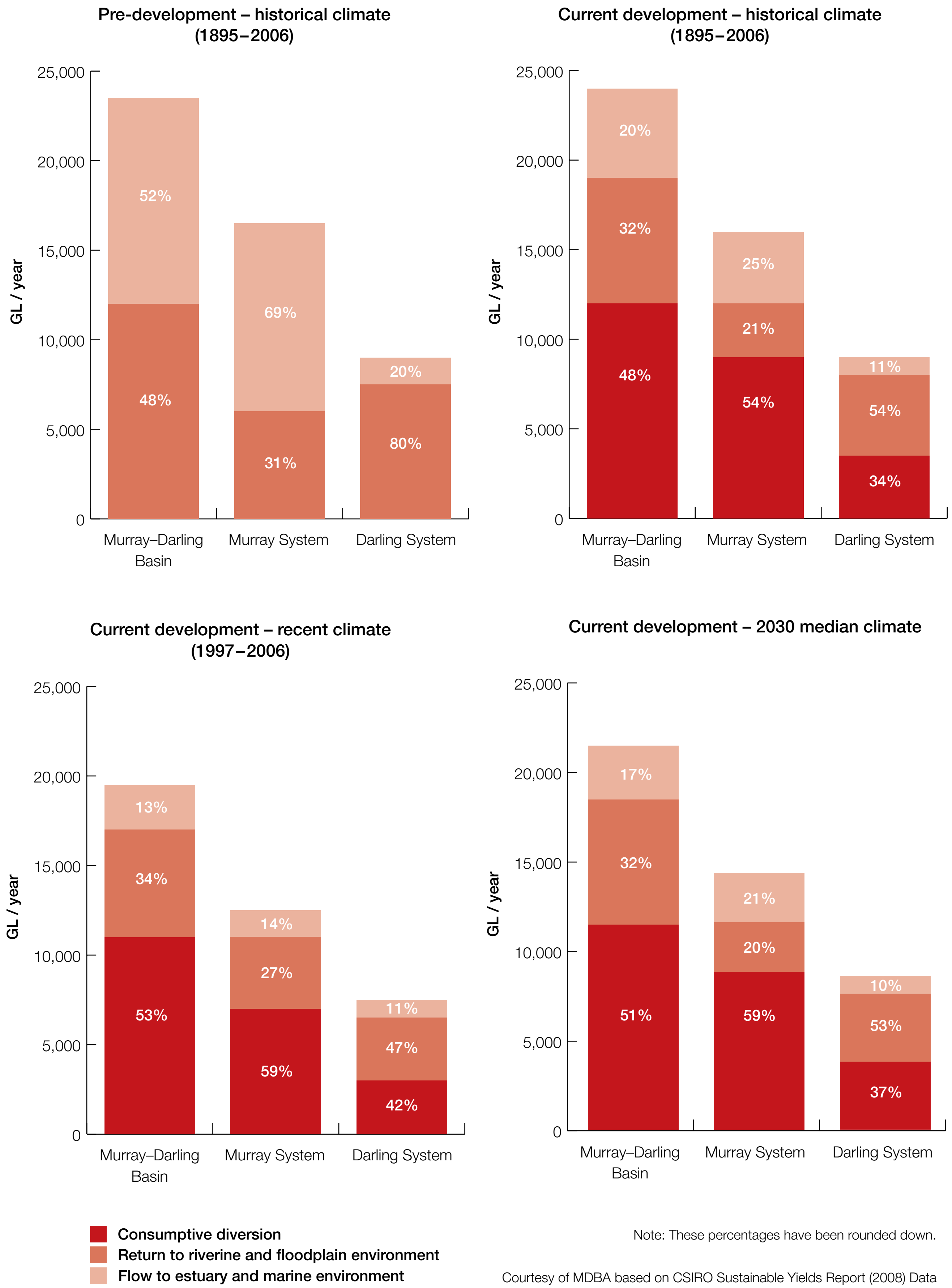
In the Murray system, the riverine and floodplain environment receives proportionally more water under the existing recent climate (1997–2006) than either the current development historical climate (1895–2006) or the 2030 dry extreme climate scenario.

Lower flows in the system are also important. Regulation has effectively eliminated all low-flow events in the major rivers, which has also helped to trigger significant ecological change. At Albury, downstream of Hume Reservoir, not only is the average annual flow 10 per cent higher than natural, the seasonal patterns are now virtually the reverse of natural conditions.

8.3 Ecological functions and the hydrology of red gum forests

Unconfined, meandering, lowland rivers such as the Murray River at Yarrawonga have a high natural frequency of out-of-channel flow. Typically, the geomorphology of such rivers evolves to form a channel capacity capable of carrying a one in two year flood event. Flows greater than this spill onto the floodplain via paleochannels and flood-runners. The subsequent return flows to the main river channel contribute to a whole suite of biological and geochemical functions.

Figure 8.1: Murray Darling Basin annual water availability, consumptive use, flows to floodplains and wetlands, flows to lakes, estuaries and marine environment over four climate and water resource development scenarios (courtesy of MDBA based on MDBSY Project data (CSIRO, 2008a))

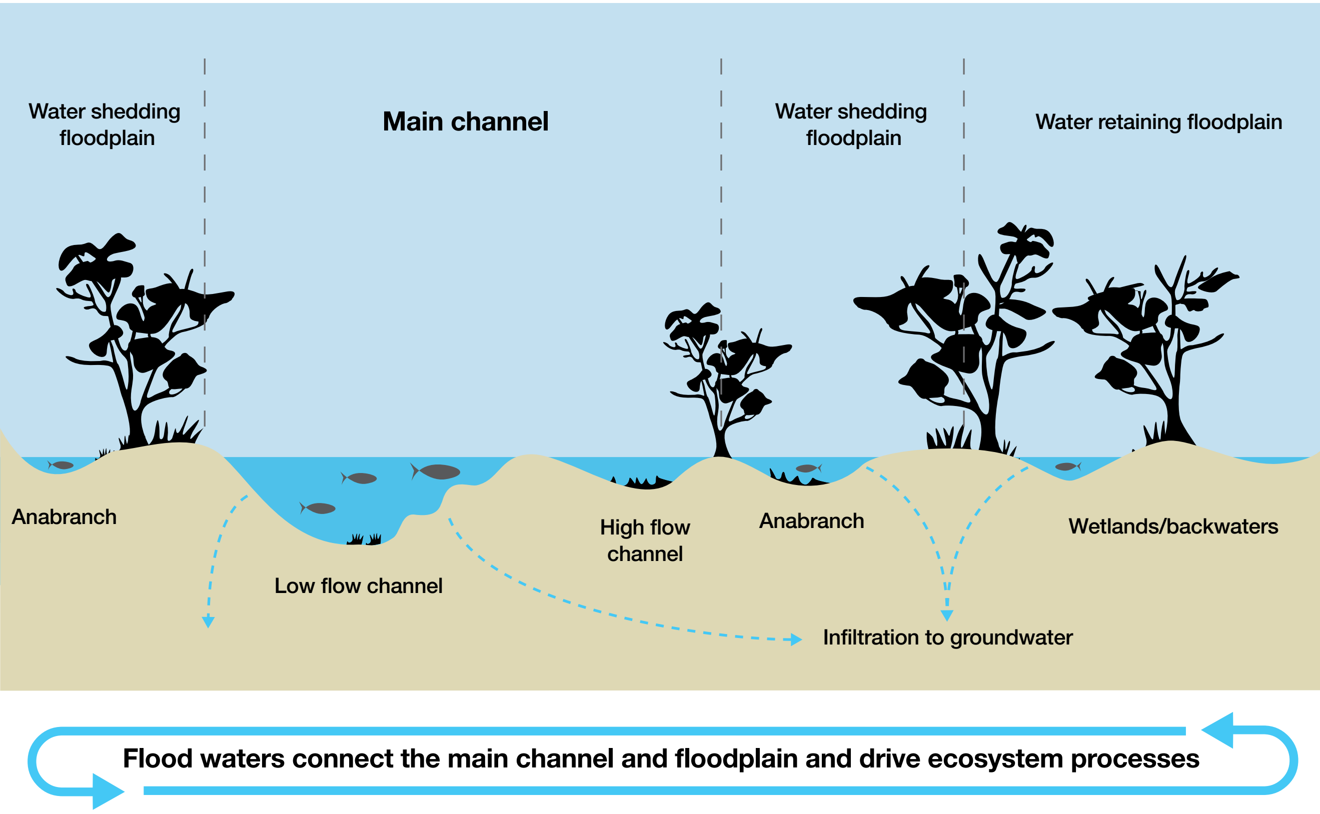


As illustrated in **Figures 8.2 and 8.3**, the ecology of both the river channel and floodplain is reliant upon the connectivity between the two systems created by reasonably frequent flooding. Flooding is essential in maintaining the character, diversity and resilience of the channel, wetlands and forests in these lowland river ecosystems.

The forest floodplains are the source of much of the primary productivity for the river and are the engine room for energy and the drivers of fundamental food webs. River red gum forests are potentially the key primary producers in the river floodplain ecosystems, supporting and driving other ecosystem processes (Hillman, T., pers. comm., 2009). For example, they produce organic carbon and other nutrients in the form of forest litter which is distributed across the floodplain in flooding events. It has been estimated that red gum forests produce 2-6 tonnes of litter per hectare, per year (O'Connell, 2003).

Thus broad ecosystem services are derived from out of channel flows and sufficient volumes are required to connect the river

Figure 8.2: Cross section view of ecological functions and the hydrology of red gum forests



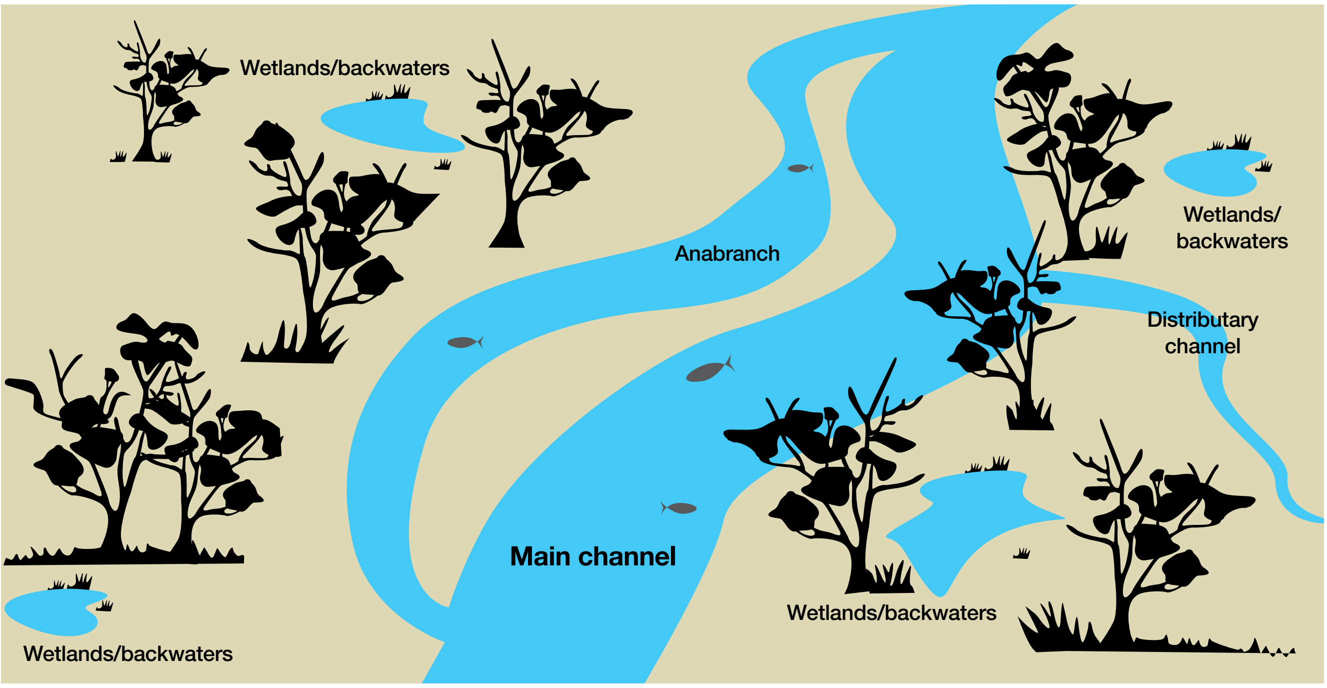


Figure 8.3: Oblique view of ecological functions and the hydrology of red gum forests

to the floodplain river red gum ecosystems as part of restoring health to the Murray, Murrumbidgee and Lachlan Rivers as a whole.

Hillman (unpub, 2009) has discussed both the different components of the river system and the different phases of an inundation event:

- River system components – water-shedding floodplain (in this case eucalypt forest, mainly red-gum), water-retaining floodplain (wetlands, backwaters, lakes), and channel (main stream and free-flowing anabranches).
- Inundation event phases – initial inundation, flooded period, receding inundation, post-inundation.

The different components and phases all play key roles in the ecological processes of river red gum forests, but also in the forests' role in the broader riverine landscape.

Significant volumes of water will be needed to inundate large areas of floodplain ecosystems every two years or so as required to restore the ecological functions. However, this water is not completely "lost" from the river system as a considerable proportion of floodwaters return to the river. Whilst difficult to estimate based on current knowledge, it is expected that between 50 and 80 per cent of floodplain flows return to the river following a flood event. Actual return flows would be site specific and depend on flood duration and antecedent conditions, amongst other factors.

8.4 Water reforms to reconnect the rivers and floodplains

The future health of river red gums along the Murray River will be determined in large measure by the degree of success of the water reform program. These reforms include: The Living Murray Program; the National Water Initiative; the Commonwealth Water Act 2007 and the roles of the Murray Darling Basin Authority and National Water Commission; the Commonwealth Government's 'Water for the Future' program; and the recovery of environmental water by the Commonwealth Environmental Water Holder.

The Living Murray (TLM) was established in 2002 as an intergovernmental agreement to recover water for the benefit of six 'icon' sites selected along the Murray River (refer **Figure 8.4**). The program's first step, to recover 500 GL, commenced in 2004 and finishes in 2009. The MDBA recently confirmed that this 500GL target will be met through a range of measures, including market-based instruments and infrastructure works. It is understood that all existing projects under The Living Murray will be completed, but further environmental water initiatives will be developed in the context of the new Murray-Darling Basin Plan.

The TLM portfolio of recovered water is a mixture of high, medium, low and opportunistic (unregulated and supplementary) securities. Due to the nature of the various entitlements, the volumes available for use at icon sites at any particular time will vary depending on river flows, allocations and water management rules.

An independent review of TLM Initiative First Step, conducted by KPMG in April 2009, reported that the amount of water that may be available for environmental watering in spring 2009 was 3.55 GL (MDBA, 2009b). The review notes that in a wetter year, TLM portfolio could realise a significantly larger quantity of water for environmental watering, including opportunistic entitlements.

The Living Murray progress report (MDBA, Nov 2009) notes that the "current suite of projects will deliver 485 GL or 97 per cent of the 500 GL target over coming months". However, of the 485 GL of licence entitlement, the MDBA Annual Environmental Watering Plan 2009–10 is currently forecasting the actual allocation amounts listed in **Table 8.2** as being available for the coming seasons.

These amounts are orders of magnitude smaller than the actual volumes required to restore the ecological functions of red gum forests' and the riverine environment.

To date, the water reforms envisaged in the National Water Initiative are making slow progress. The National Water Commission's recent review of progress against the National Water Initiative found that "evidence suggests that limited real progress has been made in reducing the number of systems identified as over-allocated and over-used" (NWC, 2009). Water is being purchased and infrastructure is being built to improve flooding regimes and water management at sites such as Millewa and Koondrook-Perricoota. The focus is on recovering sufficient water to maintain a series of key water-dependent environmental assets.

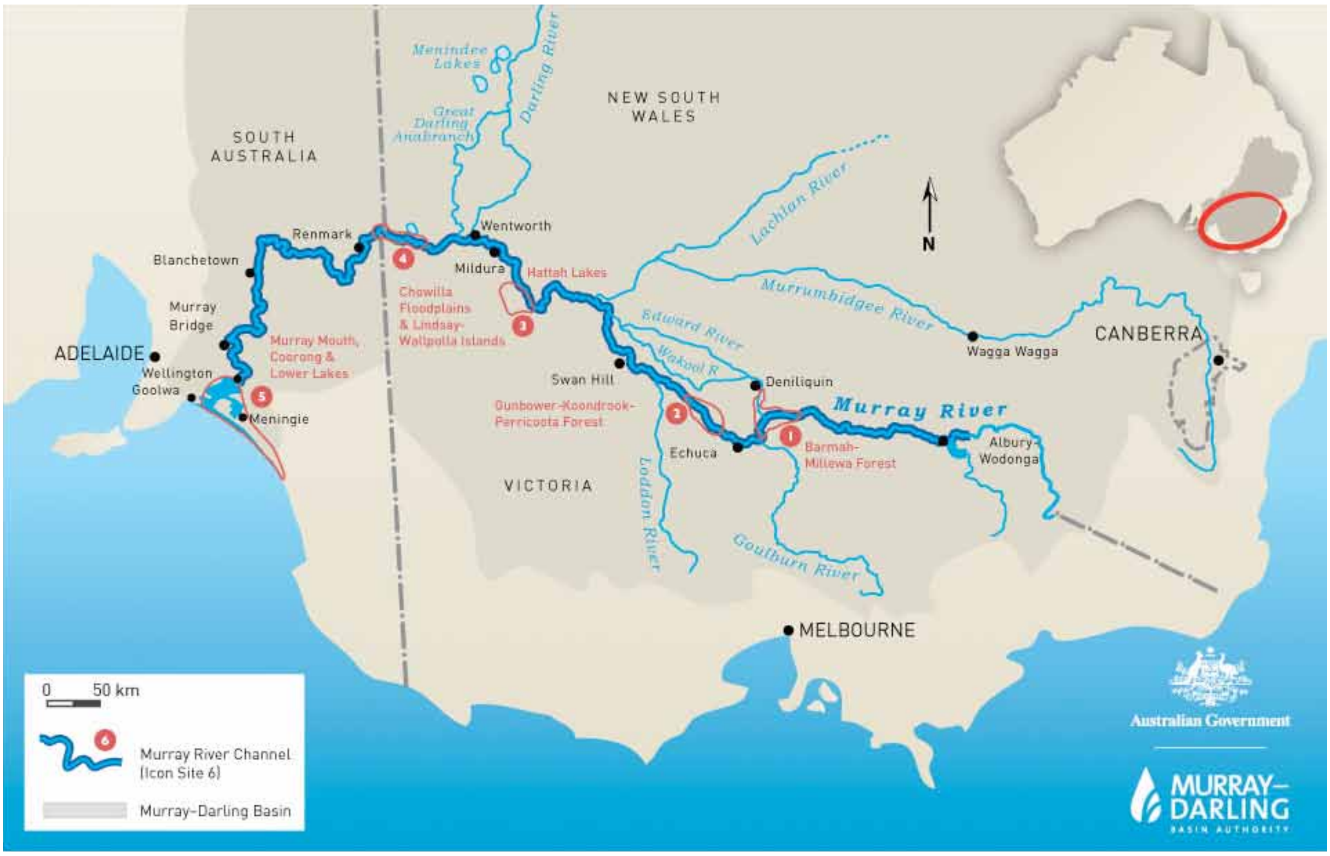
Ultimately, the Australian Government's water holdings will include its share of water savings made through the programs of the national water plan, 'Water for the Future'. The Water for the Future framework was announced in April 2008 and will be delivered through a 10-year, $12.9 billion investment in strategic programs, improved water management arrangements and a commitment to deliver a range of water policy reforms in both rural and urban areas. The Australian Government has committed $3.1 billion over 10 years to purchase water in the Murray-Darling Basin through a program known as 'Restoring the Balance in the Murray-Darling Basin'.

The *Water Act 2007* establishes the Commonwealth Environmental Water Holder (CEWH) who will manage the Commonwealth's environmental water to protect and restore the water-dependent environmental assets of the Murray-Darling Basin, and outside the Basin where the Commonwealth owns water. The water rights acquired by the Commonwealth through these programs will be managed by the CEWH. As at 30 September 2009, the water recovery program had secured

Table 8.2: Forecasted available TLM water 2009–2010

Season	Forecast allocation amounts (GL)	Carryover availabiltiy (GL)	TOTAL (GL)
Spring 2009	2.5–7	3	6–10
Autumn 2010	26–65	5.57	31–73

Figure 8.4: The Living Murray's six icon sites. Note the sixth site is the river channel itself.



the purchase of 612 GL of water entitlements worth nearly $947 million.

In early 2009, the NSW Department of Environment, Climate Change and Water and the DEWHA signed a memorandum of understanding outlining their intended cooperation in the planning and managing of environmental water. Under this memorandum, allocations held by the CEWH are being delivered for agreed environmental priorities in accordance with NSW Annual Environmental Watering Plans prepared for each valley.

It now falls to the Basin Plan and its successful implementation to continue this good work. With the Basin Plan expected to be completed in 2011, and implemented in 2014, the NRC can only speculate at this stage about its effects.

A CSIRO (2008) study indicates that the current surface water-sharing arrangements in the Murray-Darling Basin would generally protect consumptive water users from much of the anticipated impact of climate change, but offer little protection to riverine environments. Future water-sharing arrangements in the Basin will need to comply with the Basin Plan. In its Concept Statement for the Basin Plan the MDBA has stated that "it is likely that the Basin-wide sustainable diversion limit for both groundwater and surface water will be set at a level below the current level of use" (MDBA, 2009c).

8.5 Scale of water reform required to save the forests

In a system as large and complex as the Murray Darling Basin, water policy has many conflicting demands. After more than thirteen years of severe drought and record low flows all elements of this system are experiencing severe stress. It is a social choice how much water we extract from a river such as the Murray and how the remaining water is delivered in a re-constructed flow regime. It is this social choice that will determine the future of the red gum forest ecosystems more than any other factor.

Further complicating this social choice are the predictions of climate change. Given the most recent scientific information (Steffen 2009 & Allison et al 2009), long term management of the Murray and the red gum forests should at least be based on the 'medium' climate change scenario in the CSIRO Sustainable Yields project. Indeed it may well be prudent to adopt the 'step change' (1997 – 2006) scenario as many of the climate change indicators are tracking on a 'worst case' trajectory.

The science that informed the original The Living Murray process in 2002 stated that 1,500 GL would give the Murray a "moderate" chance of being ecologically healthy. This same science stated that in the order of 4,000 GL would be required to provide a high likelihood of a healthy river system to return key indicators of health to two-thirds of their natural level.

In **Tables 8.6** and **8.7** the NRC has documented the flooding requirements of the largest red gum forests in the central Murray Barmah-Millewah icon site. Based on this information, the NRC calculates that to maintain their ecological character these forests require at least:

- smaller floods once every two years of say 20GL/day for between 60 to 150 days (ie total volumes of between 1,200 GL to 3,000 GL every two years), and

- a larger landscape restoration flood once in 11 years of 35GL/day for 90 days, plus a peak of 45GL/day for 15 days (ie about 3,825GL every 11 years).

Much of this water would eventually return to the river, bringing nutrients and carbon flows with it to recharge the river ecology. With re-use of this water, environmental watering of this level could fundamentally restore the natural flood regimes of the Ramsar-listed icon sites at Millewa, Perricoota-Koondrook and Werai forests in NSW, the Victorian forests of Gunbower and Barmah, and smaller river red gum forests along the riparian zone of the NSW /Victorian border and into South Australia.

The NRC calculates that to achieve these flooding regimes would require approximately 25 per cent of the long-term, median annual flow at Yarrawonga, or 2,000GL/year on average. This amount would need to be dedicated to sustaining essential floodplain ecosystem processes along the Murray River system. Achieving this challenging target will require the Murray-Darling Basin Authority to set appropriate Sustainable Diversion Limits and the Commonwealth Environmental Water Holder to recover and deliver to the Murray system appropriate amounts of environmental water.

Together, these two reform mechanisms need to ensure that an additional 1,200GL of water is made available to enhance current environmental water entitlements on the Murray system. Current environmental water entitlements include 500GL for the Murray River system as a whole under The Living Murray,100GL for the Barmah-Millewa forests, and entitlements recently recovered by the Commonwealth Environmental Water Holder..

Without the allocation and delivery of these large volumes of water mimicking unregulated flood patterns, the iconic red gum forests of the Riverina region will continue their well progressed transformation to a less water dependent ecology. Detailed knowledge of the 'ecosystem services' provided by the riverine landscape is poor. The United Nations 2004 Millenium Ecosystem Assessment grouped ecosystem services into four broad categories:

- *provisioning*, such as the production of food and water

- *regulating*, such as the control of climate and disease

- *supporting*, such as nutrient cycles and crop pollination, and

- *cultural*, such as spiritual and recreational benefits.

Risk can be defined as the product of likelihood and consequence. As discussed above, climate science is showing an increased likelihood of a water scarce future and the best available knowledge is directing us toward managing on the basis of a 'step change' scenario and consequences this has for water availability. Consequence of the loss of ecosystem services if significant. Therefore we are facing a high, if not extreme risk, yet our management response in terms of water reform does not seem to align with this scale of risk both in terms of the scale and pace of reform required.

Without the allocation and delivery of large volumes of water we are likely to lose many critical ecosystem services. The scale of impact of these losses can be expected to be significant and permanent for a range of environmental, economic and social values.

8.6 Analysis of impacts to high flow events under climate change

Flooding is essential to maintaining the character, diversity and resilience, of lowland floodplain ecosystems including their channels, wetlands and forests. As explained in **Chapters 2 and 4**, ecosystem services are derived from flood flows.

The NRC completed a simple statistical analysis for a range of flood flows using the River Analysis Package (eWater CRC, 2007) and the MDBSY Project data for Murray River flows at Yarrawonga (CSIRO, 2008a). The River Analysis Package assists river and water resource managers to undertake condition assessments, environmental flow planning and river restoration design.

Four flow scenarios were used in the analysis:

- Scenario P: Historic (pre 1997) climate without current water resource development extractions

- Scenario A: Historic (pre 1997) climate with current water resource development extractions

- Scenario B: Recent climate (1997 to 2006) "step change" with current water resource development extractions

- Scenario Cmid: Median 2030 climate change with current water resource development extractions.

These flow scenarios are equivalent to the CSIRO MDBSY climate scenarios as outlined in **Chapter 7**, including an additional Scenario P based on the historic climate without current water resource development.

A range of flood flows at Yarrawonga from 18,300 ML/day to 100,000 ML/day was assessed. In addition, the duration of flood events was tested from long (60 day events) to brief (1 day) flood pulses. The results of the analysis are presented in **Table 8.3**.

Some important observations from this analysis are:

- The smaller, long duration floods (20,000 ML/day, 60 days) occurred in "without development" conditions about every one to two years. Under 2030 climate change these events are predicted to occur once every 5 years and only once every 10 years under a step-change future (that is, if there were to be a long-term continuation of the recent climate).

- The very large 'landscape restoration' floods (100,000 ML/day, 10 days) occurred in "without development" conditions about once every 11 years. Under 2030 climate change and step change these events do not appear in the flow forecast modelling, that is, they are unlikely to occur.

The following sections present further analysis using these scenarios for each WMU.

Table 8.3: Analysis of flood flows at Yarrawonga for four climate and water resource development scenarios (Data courtesy of CSIRO)

			Scenario P (historic climate, pre-development)			Scenario A (historic climate, current development			Scenario B (step-change climate, current development)			Scenario Cmid (2030 climate change, current development)		
Flood magnitude	Season	Duration	Frequency	Average period between floods	Maximum period between floods	Frequency	Average period between floods	Maximum period between floods	Frequency	Average period between floods	Maximum period between floods	Frequency	Average period between floods	Maximum period between floods
ML/d			No. occurrences	Years	Years	No. occurrences	Years	Years	No. occurrences	Years	Years	No. occurrences	Years	Years
18,300	Aug–Dec	60+ days	74	1.1	3.8	36	2.6	10.9	11	8.2	34	26	3.5	13.6
25,300	Aug–Dec	60+ days	45	1.9	5.7	25	3.2	12.7	6	14.2	37.7	16	5.4	17.6
35,000	Aug–Dec	60+ days	21	4.4	10.6	9	9.1	24.0	2	38.6	38.6	5	14.2	37.8
35,000	Aug–Dec	30+ days	54	1.7	6.0	25	3.7	12.8	4	19.1	24.8	10	8.6	17.7
45,000	Aug–Dec	30+ days	30	3.0	12.7	11	7.4	24.0	1	N/A	N/A	6	12.6	37.9
45,000	Aug–Dec	60+ days	7	12.2	37.8	3	28.1	38.5	1	N/A	N/A	2	17.9	17.9
60,000	Aug–Dec	1+ days	141	0.8	9.8	77	1.2	13.3	19	4.5	38.7	43	2.1	17.0
60,000	Aug–Dec	10+ days	68	1.3	6.8	23	3.5	24.1	2	0.0	0.0	11	5.8	37.8
60,000	Aug–Dec	30+ days	11	7.8	24.1	4	18.8	37.8	0	N/A	N/A	1	N/A	N/A
80,000	Aug–Dec	1+ days	72	1.3	6.8	39	2.4	17.9	9	9.5	38.7	20	4.3	37.8
80,000	Aug–Dec	10+ days	24	3.4	15.9	8	8.2	37.8	0	N/A	N/A	1	N/A	N/A
80,000	Aug–Dec	30+ days	2	63.8	63.8	1	N/A	N/A	0	N/A	N/A	0	N/A	N/A
100,000	Aug–Dec	1+ days	53	1.8	13.6	23	3.7	20.8	3	29.0	56.6	7	12.7	37.9
100,000	Aug–Dec	10+ days	8	11.2	25.0	2	38.7	38.7	0	N/A	N/A	0	N/A	N/A
100,000	Aug–Dec	30+ days	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A

8.7 Millewa forests

The assessment for Millewa forests includes:

- site characteristics and water requirements
- future water availability and flooding regimes
- the likely impacts of future water availability for the associated forests.

8.7.1 Site characteristics

The Barmah-Millewa forests and associated wetlands are maintained by the large volumes of water (regular flooding) when the Murray River exceeds channel capacity at the Barmah Choke. The Barmah Choke is a section of the Murray River with limited capacity to carry flows (MDBC, 2006a). The channel capacity of the Barmah Choke is approximately 10,400 ML/day at Yarrawonga Weir.

The surface hydrology of the forests involves an intricate arrangement of inflow sources and drainage routes. The regularity, extent, duration and season of flooding is governed by flow in the Murray River. Relatively small changes in topography influence the distribution and depth of flooding. Water passes over the floor of the forests as sheet flow in large floods, and through the forests predominantly as creek flow during small flood events.

Over 50 water management structures are currently present through the Barmah-Millewa forests. Primary structures are regulators with a discharge capacity generally greater than 100 ML/day and occur in anabranch streams near their exit point from the Murray River, Edward River and Gulpa Creek. The purposes of these structures are to maintain regulated flows within the stream, and to permit floods to pass into the forest (MDBC, 2006a). Secondary and tertiary regulating structures (with discharge capacity of <100 ML/day – for example, pipes, culverts, earthen banks and small regulators) are mostly situated in drainage features within the interior portions of the forest.

Bank undercutting at Millewa State Forest

The main purpose of these structures is to manipulate water distribution and depth within localised areas, and to provide vehicle access (MDBC, 2006a). Once flows at Yarrawonga Weir exceed 10,400 ML/day (Barmah Choke capacity), the regulators are progressively opened to allow water to enter the forest. The majority of flood flow entering the Millewa forests leaves the Murray River and flows past Deniliquin in the Edward River. Flood flow then enters the Edward-Wakool system, passing through the Werai Forests system, before finally returning to the Murray River some 200 kilometres to the west at Wakool junction (GHD, 2009).

Since regulation of the Murray River, the natural hydrologic regime has been considerably altered. For example, under natural conditions, 70 per cent of the forest would be flooded for an average of 2.9 months in 78 per cent of years. Since regulation, this level of flooding is only experienced for an average of 1.3 months in 37 per cent of years. Overall, the frequency of flooding and the duration of inundation in the major vegetation communities have been significantly reduced.

Small localised flooding, covering less than 10 per cent of the forest, occurs approximately eight times more frequently since regulation began, and tends to occur between December and April (MDBC, 2006a). This unseasonal flooding generally occurs because of the rejection of pre-ordered irrigation supplies after rain. This typically causes the Murray River flows to increase from near-forest-channel capacity of about 10,400 ML/day to a flow of 12,000 to 15,000 ML/day or more for a period of up to about five to seven days. Unseasonal flooding may also arise in part from increased tributary flows. Agreement between Forests NSW and the Victorian Department of Sustainability and the Environment has allowed an arrangement to annually alternate the acceptance of any excess river flows during the unseasonal flooding period (December–April). This co-operative arrangement allows the wetlands in each state a better chance of drying every second year akin with a more natural regime (MDBC, 2006a).

The Living Murray interim ecological objective for Barmah-Millewa Icon Site is to enhance forest, fish and wildlife values, by ensuring:

- successful breeding of thousands of colonial waterbirds in at least three years in 10
- healthy vegetation in at least 55 per cent of the area of the forest (including virtually all of the giant rush, moira grass, river red gum forest and some river red gum woodland) (MDBC, 2006a).

Water requirements of the Millewa forests can generally be described as the flooding regime that occurred under natural (pre-regulation) conditions (MDBC, 2006a). For river red gum forests, inundation for up to five months in winter–spring, in approximately 40–92 per cent of years, would be ideal **(Table 8.4)**.

Critical limits of acceptable change for river red gum forest and woodland across the NSW Central Murray State Forests were provided in the Draft Ecological Character Description (ECD) (GHD, 2009)[1] and are shown in **Table 8.5**.

These are initial values proposed for future refinement, and indicate that a minimum flood frequency of 50 per cent of years (for the appropriate duration and season) is required to maintain river red gum forest. This 50 per cent minimum flood frequency correlates well with the 40 per cent lower threshold stipulated in the Icon Site Management Plan (MDBC, 2006a).

The approximate flow levels required to inundate varying extents of forest in the combined Barmah-Millewa forests are provided in **Table 8.6**.

Based on these estimates, a summer–spring flood of 18,300 ML/day is needed to achieve the interim environmental objectives (55 per cent inundation), according to the Icon Site Management Plan (MDBC, 2006a). However, the most recent assessments by the MDBA and hydrological modelling indicate that environmental flows required to achieve the Barmah-Millewa objectivesare likely to be much higher than the 18,300 ML/day (Water Technology 2009; Burns, I., MDBA, 2009, pers comm).

Table 8.4: Flood frequencies of the major Barmah-Millewa forest vegetation communities before river regulation (MDBC, 2006a)

Vegetation community	Flood frequency (% of years with inundation)	Duration	Season
Giant Rush	75–100%	7–10 months	Winter to mid–summer
Moira Grass	65–100%	5–9 months (no more than 10 months; min. depth 0.5 m)	Winter to mid–summer; 2–3 months dry in late summer to early autumn
River Red Gum forest	40–92%	5 months	Winter–spring
River Red Gum woodland	33–46%	1–2 months	Spring
River Red Gum/Black Box woodland	14–33%	1–4 months	Winter–spring

Table 8.5: Critical limits of acceptable change for red gum in NSW Central Murray State Forests (extracted from GHD, 2009)

Sub-component /process	Adaptive management action	Optimum frequency (% of years)	Minimum frequency (% of years)	Optimum operating conditions	Environmental outcomes
River Red Gum Forest	Exceed channel capacity, flood lower parts of floodplain	70–90%	50%	Flood pulse in Aug–Dec Inundation less than 24 months	Watering of river red gums and other native plant species Magnitude (i.e. extent of flood) will determine extent of forest inundated
River Red Gum Woodland	Exceed channel capacity, achieve broad scale flooding	30–70%	20%	Flood pulse in Sep–Nov-Inundation less than 24 months	Watering of river red gums and other native plant species

Table 8.6: Desired flow magnitude and flooding extent for Barmah-Millewa forests (MDBC, 2006a)*

Flow at Yarrawonga Weir	Inundation extent
<10,600 ML/day	In-channel flows
10,600–18,300 ML/day	Inundates up to 55% of Barmah-Millewa Forest (this includes virtually all Giant Rush, Moira Grass, River Red Gum forest and some River Red Gum woodland)
18,300–25,300 ML/day	Inundates 55–66% of Barmah-Millewa Forest
>25,300 ML/day	Inundates >66% of Barmah-Millewa Forest

* Hydrological modelling for the Barmah-Millewa Forest has indicated that flows in the order of 35,000 ML/day are required to achieve the desired inundation extents to meet the objective of 55 per cent inundation (Water Technology, 2009).

[1] The ECD has not been formally endorsed by the Australian Administrative Authority for the Ramsar Convention (DEWHA).

These assessments set out in **Table 8.7** are part of the preliminary unpublished data analysis which has been undertaken for the development of the Murray-Darling Basin Plan. The analysis was based on the recent hydrological modelling by Water Technology (2009) conducted for the Barmah-Millewa forests.

Based on hydrological modelling (Water Technology, 2009) and MDBA analysis (MDBA, pers. comm.), flows of around 35,000 ML/day or greater will be needed to achieve the interim ecological objective for the combined Barmah-Millewa (see **Table 8.7**), which is effectively double the original estimate of 18,300 ML/day proposed in the Icon Site Management Plan.

Within the Millewa forests WMU, sub-units called water management areas (WMAs) delineate areas of the forest where points of inflow and outflow best segregate one section of the forest from another (Leslie and Harris, 1996). The concept of WMAs allows different management requirements and opportunities within each area to be recognised on a localised basis, and then integrated within the overall sphere of forest management (Leslie and Harris, 1996). Eight WMAs have been identified within the Millewa forests WMU, and overlying these are four more general WMAs identified by Forests NSW **(Figure 8.5)**. For flows over 17,000 ML/day, the Millewa forests are typically treated as one unit; however lower flows can be managed in a more detailed way across the four inundation areas (Rodda, G., Forests NSW, 2009, pers comm).

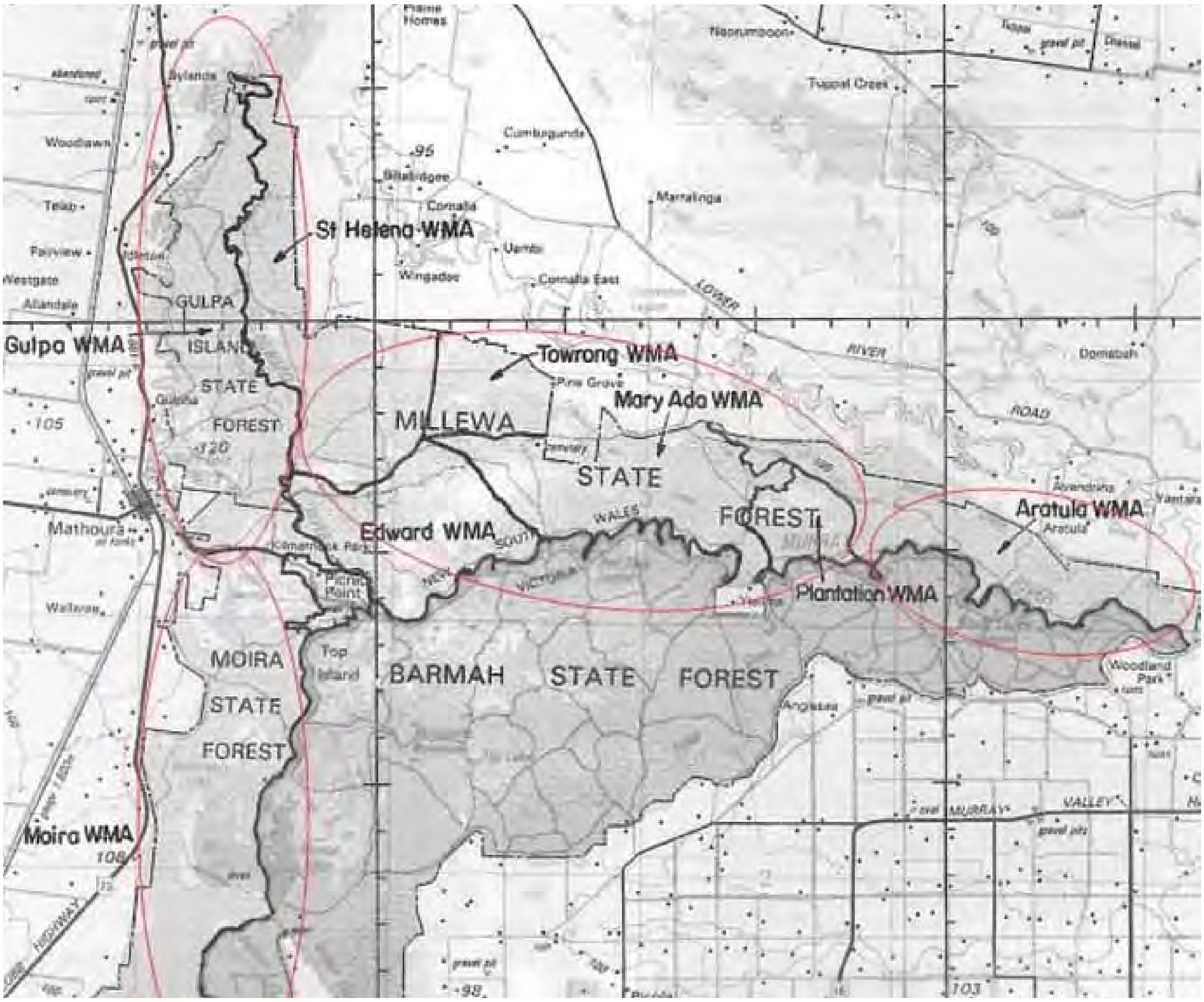
8.7.2 Future water availability

The CSIRO MDBSY Project studied the flooding implications in Barmah-Millewa forests under a range of climate scenarios. Scenarios A, B and C (outlined in **Chapter 7**) are used in this assessment:

- Scenario A – historical climate with current development
- Scenario B – recent climate (1997–2006, 'step-change') with current development
- Scenario Cmid – future climate to 2030 with current development.

Implications on flooding for Barmah-Millewa forests were assessed for the beneficial spring–summer flood, defined as 18,300 ML/day (for a period of 60 days in August–December) at Yarrawonga Weir (**Table 8.8**). This is the volume that was initially understood to correspond with achieving the 55 per cent inundation of the forest required to achieve the interim ecological objective, based on the Icon Site Management Plan.

Figure 8.5: Millewa forests' eight WMAs (Leslie and Harris, 1996) plus four general water management areas (red outlines)



Results on the flood frequency under each of the scenarios are shown in **Table 8.9.**

Under scenarios B and Cmid (step-climate change and 2030 climate change), floods exceeding 18,300 ML/day are likely to occur less frequently, with a greater period between floods, and with a lower average flood volume per year and per event. The reduction in flood frequency is considerably more extreme under step-climate change (B) than modelled 2030 climate change (C), as would be expected, as step-climate change assumes a continuation of conditions from the last ten years.

Modelled scenarios include environmental water allocations for Barmah-Millewa forests. This included a 100 GL/year environmental water entitlement, plus a lower-security allocation of 50 GL to be provided in years where the irrigation water allocation in Victoria exceeds 130 per cent. The 100 GL/year of high-security water, and additional 50 GL (when triggered), is to be drawn equally from NSW and Victoria, and

Table 8.7: Requirements to meet Barmah-Millewa ecological objectives in relation to red gum forests based on preliminary MDBA analysis

Objective	Area of inundation	Flow to achieve inundation	Duration	Frequency	Timing	Max time between events
Healthy vegetation in at least 55% of the area of the forest	36,300 ha	Flow peaking at 45,000 ML/day with extended periods above 35,000 ML/day achieves approximately 64% total forest flooded.				
... including virtually all vegetation of the River Red Gum forest	Approx. 42,700 ha (with other types total 62,000 ha)	Flows 25,000–35,000 ML/day with peak of 45,000 ML/day. Achieves 71% inundation River Red Gum forest (64% total forest)	3 months total	1 in 3 years	Winter, spring	3 years
... including some vegetation of River Red Gum woodland	Approx. 13,700 ha (with other types total 62,000 ha)	Flow above 35,000 ML/day peaking above 45,000 ML/day. Achieves 50% inundation of River Red Gum woodland (64% total forest)	1 month	1 in 3 years	spring	4 years

Table 8.8: Barmah-Millewa beneficial flow event definition (CSIRO, 2008a)

Flow event description	Flow event definition	Indicators reported
Beneficial spring–summer flood	Flows exceeding 18,300 ML/day for 60 days Aug–Dec at Yarrawonga Weir.	Average period between floods Maximum period between floods Average flood volume per year Average flood volume per event

Table 8.9: Barmah-Millewa forests results for floods exceeding 18,300 ML/day under Scenarios A, B and C, plus per centage change (from Scenario A) in indicator values for scenario Cmid (adapted from CSIRO 2008a)

Barmah-Millewa Forest	A	B	Cmid	B	Cmid
Floods exceeding 18,300 ML/day	**Years**			**% change from Scenario A**	
Average period between floods	3.5	4.55	3.96	30	13
Maximum period between floods	10.9	33.90	21.26	211	95
	GL			**% change from Scenario A**	
Average flood volume per year	291	55	148	-81	-49
Average flood volume per event	905	226	516	-75	-43

can be accrued in storage as an environmental water allocation kitty up to a maximum of 700 GL (MDBC, 2006a).

Additional environmental water not included in the modelling is the 500 GL/year to be recovered and applied to the six Icon Sites under the First Step decision of the Living Murray initiative. The Living Murray program has recently undertaken modelling which examined the degree to which environmental water requirements of the Icon Sites can be met with the 500 GL under historical climate conditions, and the potential impact of climate change (2030) (TLM, 2008). This modelling considered the feasibility and benefits of structural works proposals for the relevant Icon Sites.

As Barmah-Millewa does not have a defined structural proposal, no call on TLM water was modelled. Rather the focus was on other Icon Sites, with Barmah-Millewa being treated in a relatively passive context (including current operating rules and entitlements). However, overall it was felt that the Barmah-Millewa forests would benefit from the additional water recovery year and the operation of other structures (TLM, 2008).

Modelled future water availability of Commonwealth Environmental Water Holdings that will arise from its Water for the Future Program is not included in this analysis.

8.7.3 Future flooding regime

A floodplain inundation model for Barmah-Millewa forests has recently been completed (Water Technology, 2009). The calibrated modelling achieved a good reproduction of flooding extents compared to satellite-derived flood extent observations. The model outputs include flooding extents for a range of inundation levels based on flow volume at Yarrawonga Weir. The modelled inundation extents were overlaid on the vegetation group mapping (included in **Chapter 4**) to provide an indication of the extent of river red gum vegetation communities in Millewa Forest inundated by various flows in the Murray River channel.

The results are shown in **Table 8.10.** A comparison of these design flows with the predicted inundation extents for the combined Barmah-Millewa forests can also be made and is shown in the table.

The results of the Water Technology modelled inundation extents for the Millewa forests as shown in **Table 8.10** indicate the following:

- At 15,000 ML/day (closest design flow to 18,300 ML/day), 46 per cent of river red gum very tall forest is inundated, plus 14 per cent of river red gum tall open forest (combined river red gum very tall forest and river red gum tall open forest inundated 16 per cent).
- At 25,000 ML/day, approximately 86 per cent of river red gum very tall forest is inundated, plus 32 per cent of river red gum tall open forest (combined 36 per cent), and 5 per cent of river red gum–box woodland.
- With flows up to 35,000 ML/day, approximately 90 per cent of river red gum very tall forest is inundated, plus 44 per cent of river red gum tall open forest (combined 47 per cent), and 7 per cent of river red gum–box woodland.
- Larger flows of 45,000 ML/day will inundate up to 96 per cent of river red gum very tall forest, plus 73 per cent of river red gum tall open forest (combined 59 per cent), and 21 per cent of river red gum–box woodland.

Table 8.10: Modelled inundation extent of river red gums in Millewa forests at various design flows (based on flow at Yarrawonga) that have been mapped (Water Technology, 2009)**. A comparison of approximate inundation extent for the combined Barmah-Millewa forests** (MDBC, 2006a) **is also shown.**

Modelled inundation extent for Millewa Forest (adapted from Water Technology 2009)							Inundation extent for combined Barmah-Millewa forests
Design flows at Yarrawonga Weir	River Red Gum Very Tall Forest		River Red Gum Tall Open Forest		River Red Gum-box Woodland		Based on MDBA preliminary analysis (except 60,000 ML/day – CSIRO analysis)
ML/day	area (ha)	%	area (ha)	%	area (ha)	%	
10,400							
13,000							
15,000	997	46	4,212	14	86	3	18,300 ML/day was the initial estimate to achieve 55% inundation extent of combined forest based on the Icon Site Management Plan.
25,000	1,842	86	9,639	32	141	5	Achieves 71% inundation of River Red Gum forest (corresponding with the 'virtually all Red Gum Forest' objective in the Icon Site Management Plan.
35,000	1,919	90	13,144	44	192	7	Achieves 50% inundation of River Red Gum woodland
45,000	2,022	94	16,889	57	329	12	Flows peaking at 45,000 ML/day with extended periods above 35,000 ML/day achieves approx. 64% of total forest flooded.
60,000	2,061	96	21,753	73	570	21	Flow required for 55% inundation extent based on CSIRO RiM-FIM modelling (Overton et al., 2006a)

Table 8.11: Flood frequency assessment under climate change scenarios

Flood magnitude ML/day	Season	Duration	A	B	Cmid
18,300	Aug–Dec	60 days+			
Average period between floods (years) Maximum period between floods (years)			2.6 10.9	8.2 34.0	3.5 13.6
25,300	Aug–Dec	60 days+			
Average period between floods (years) Maximum period between floods (years)			3.2 12.7	14.2 37.7	5.4 17.6
45,000	Aug–Dec	60 days+			
Average period between floods (years) Maximum period between floods (years)			28.3 38.7	N/A* N/A	17.9 17.9*
60,000	Aug–Dec	60 days+			
Average period between floods (years) Maximum period between floods (years)			19.3 37.8	N/A N/A	N/A N/A

*Same as average because only two events were recorded.

The Water Technology modelling has not been the subject of widespread review and there is some uncertainty as to its accuracy. Additional floodplain inundation modelling by the CSIRO (Murray River Floodplain Inundation Model) indicates that perhaps even greater flood magnitudes will be required to achieve the equivalent inundation of the combined Barmah-Millewa forests than is predicted by the Water Technology modelling (Overton et al., 2006a). Thus, it is demonstrated that there is uncertainty in the modelled results, however the predictions all indicate that higher flows are required to inundate significant extents of the Barmah-Millewa forests.

To examine the future flood frequency of larger floods (>18,300 ML/day) under climate change (step-change and 2030 climate change), daily modelled streamflow data (1895–2006 at Yarrawonga Weir) were obtained for the CSIRO climate scenarios (A, B, Cmid) based on current development.

The differences in flood frequency for larger floods, in addition to the 18,300 ML/day, were compared across the different scenarios, to examine the likely impacts on inundation. This analysis was conducted using the River Analysis Package to determine the number of events in the flow series data. A two-day flood independence criterion was used in the River Analysis Package, and events were defined as noted in **Table 8.11**.

Floods are expected to become significantly less frequent under climate-change Scenarios B and Cmid. Slight differences in data reported for the 18,300 ML/day between this analysis and the CSIRO analysis **(Table 8.9)** are likely to be the result of subtleties in the data analysis process (e.g. flood independence). Larger floods are expected to occur much less frequently, with no floods of 60,000 ML/day (for 30 days) occurring under 2030 climate change (or step-climate change) **(Table 8.11)**. There is a significant reduction in the frequency of naturally occurring floods between 25,000–45,000 ML/day under climate change scenarios B and Cmid. The approximate (modelled) extents of flood magnitudes in **Table 8.11** are shown in **Figures 8.6–8.10.**

Additional flood magnitudes for which inundation extents are not available were assessed in **Section 8.3**. This analysis showed that the very large "landscape restoration" floods (100,000 ML/day for duration of ten days) are unlikely to occur under 2030 median climate change (scenario Cmid) or a climate under continuation of the recent drought (Scenario B).

Easement constraints upstream of Millewa forests also limit the potential for future large delivered floods. Current easement constraints of 25,000 ML/day between Hume Dam and Lake

Mulwala limit the ability to manipulate the delivery of floods larger than 25,000 ML/day along this reach (Burns, I, MDBA, pers. comm., 2009). The delivery of floods larger than 25,000 ML/day to Millewa forests depends on contributing natural flood flows from the unregulated Ovens River being passed downstream of Lake Mulwala/Yarrawonga Weir. Under current river operation, 'seasonal' flood flows (floods occurring between May and December) from the Ovens catchment are passed, whilst between December and April the Murray River downstream of Yarrawonga Weir is operated at 10,600 ML/day to limit unseasonal flooding of the forests (Jones, M, MDBA, pers. comm., 2009).

It is understood that an expansion of easements up to a capacity of 40,000 ML/day is currently being investigated (Broekman, L, Forests NSW, pers. comm., 2009; Burns, I, MDBA, pers. comm., 2009). If easements are increased to allow increased flooding at 40,000 ML/day, a greater extent of vegetation could be inundated, in the order of the modelled extent for the 45,000 ML/day design flow **(Table 8.10).**

Estimating return flows to the Murray River for a flood event in the Millewa forests is not straightforward. Based on an analysis of gauged flows at downstream Yarrawonga, Barmah and Deniliquin, during a 25,000 ML/day flood measured at the downstream Yarrawonga gauge approximately 80 per cent of flows (20,000 ML/day) remain in the Murray/Edward river systems (passing either the Barmah or Deniliquin gauges) (MDBA, pers. comm., 2009). Not all 5,000 ML/day of 'losses' can be attributed to the Barmah-Millewa forests as losses would also occur due to other uses upstream of the forests. Actual return flows would be dependent on flood duration and antecedent conditions, amongst other factors. It should be noted that this figure cannot be extrapolated to higher flows as other processes appear to influence the contribution of flows to the Edward River above about 40,000 ML/day measured at the downstream Yarrawonga gauge.

While acknowledging that inundation of large areas of floodplain ecosystems on a biennial basis will require significant volumes of water, it should be recognised that diversions for environmental watering are not completely "lost" from the river system. A considerable proportion of floodwaters return to the river. Whilst difficult to estimate based on current knowledge, it is expected that between 50-80 per cent of floodplain flows return to the river following a flood event. Actual return flows would be site specific and depend on flood duration and antecedent conditions, amongst other factors.

8.7.4 Flooding conclusions

To achieve the interim ecological vegetation objectives for the Barmah-Millewa forests, flows in the order of 35,000 ML/day are likely to be required[2]. These are significantly higher flows (effectively double) than the original 18,300 ML/day desirable flow event defined in the Icon Site Management Plan.

Floods are expected to become significantly less frequent under climate-change Scenarios B and Cmid (see **Table 8.11**). Analysis conducted for this assessment has indicated that under 2030 climate change (Scenario Cmid), the average frequency of floods >25,000 ML/day may reduce from occurring every 3.2 years (under historic climate, scenario A) to every 5.4 years, with the maximum period between floods increasing from 12.7 to 17.6 years. Therefore inundation extents beyond 25,000 ML/day are unlikely to be achievable at the frequency required for sustaining river red gum vegetation.

Flood inundation – Moorna State Forest

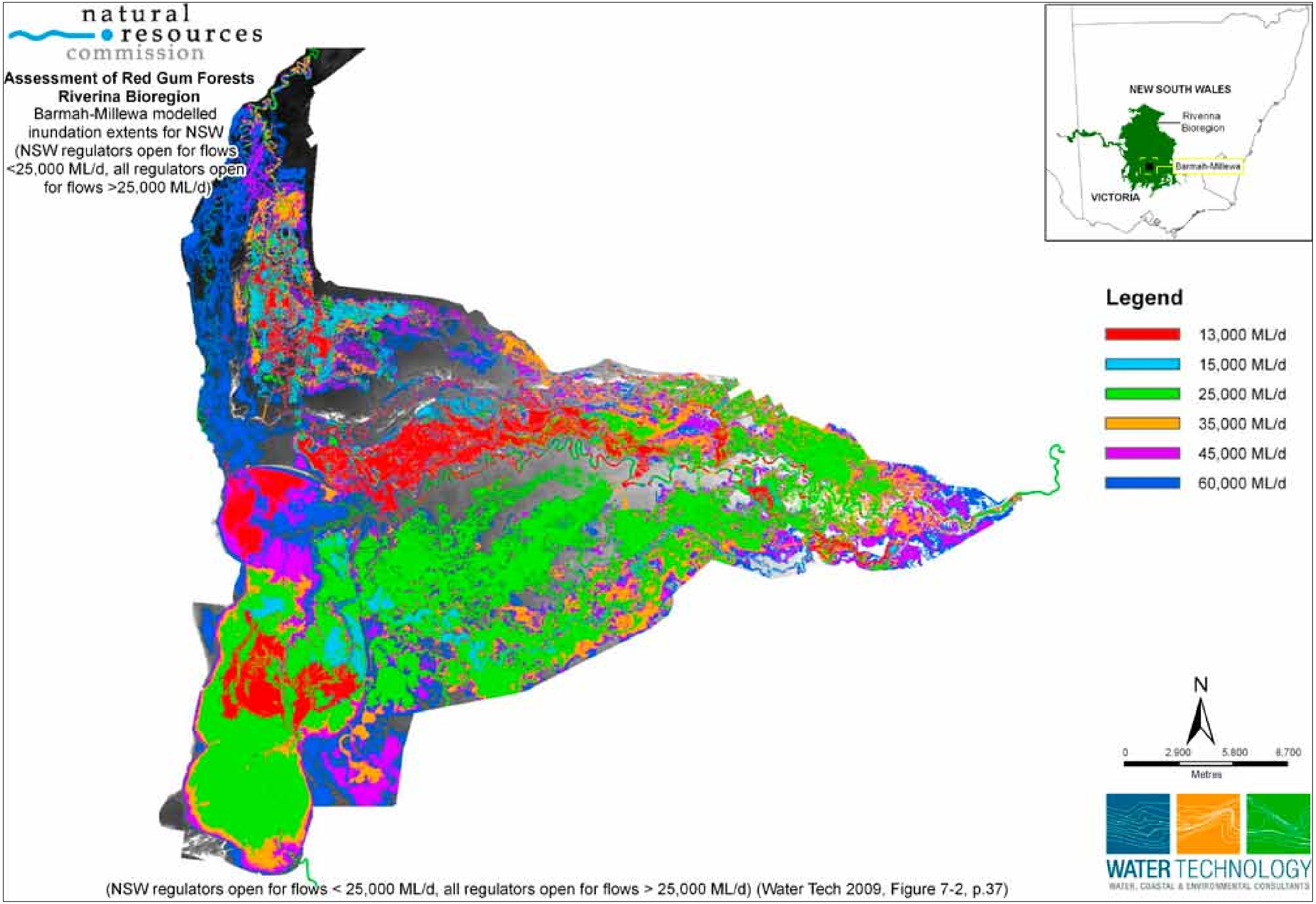
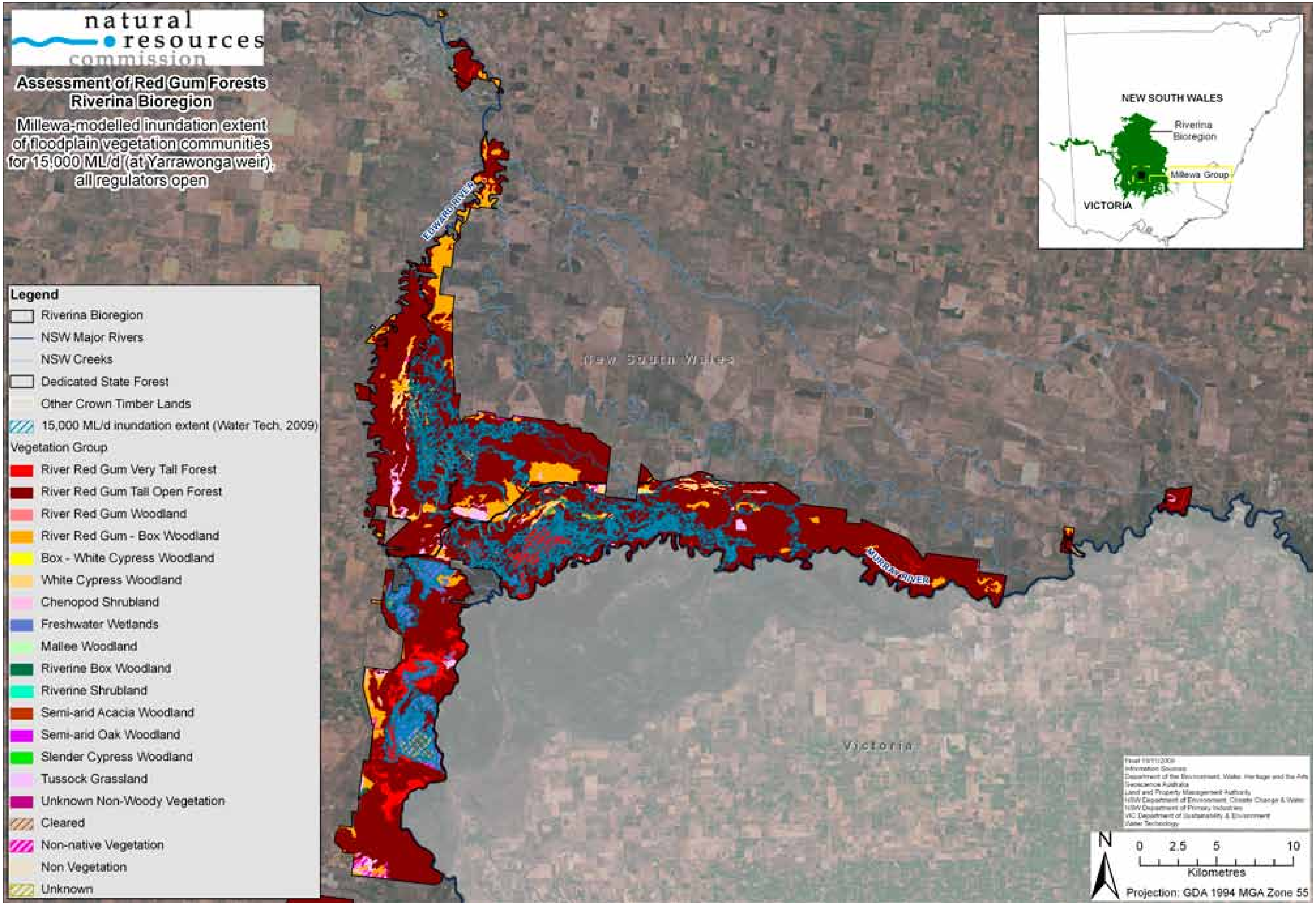


Figure 8.6: Barmah–Millewa modelled inundation extents for NSW (NSW regulators open for flows <25,000 ML/day; all regulators open for flows >25,000 ML/day) (Water Technology, 2009)

Figure 8.7: Millewa-modelled inundation extent of floodplain vegetation communities for 15,000 ML/day (at Yarrawonga Weir), all NSW regulators open (adapted from Water Technology, 2009)



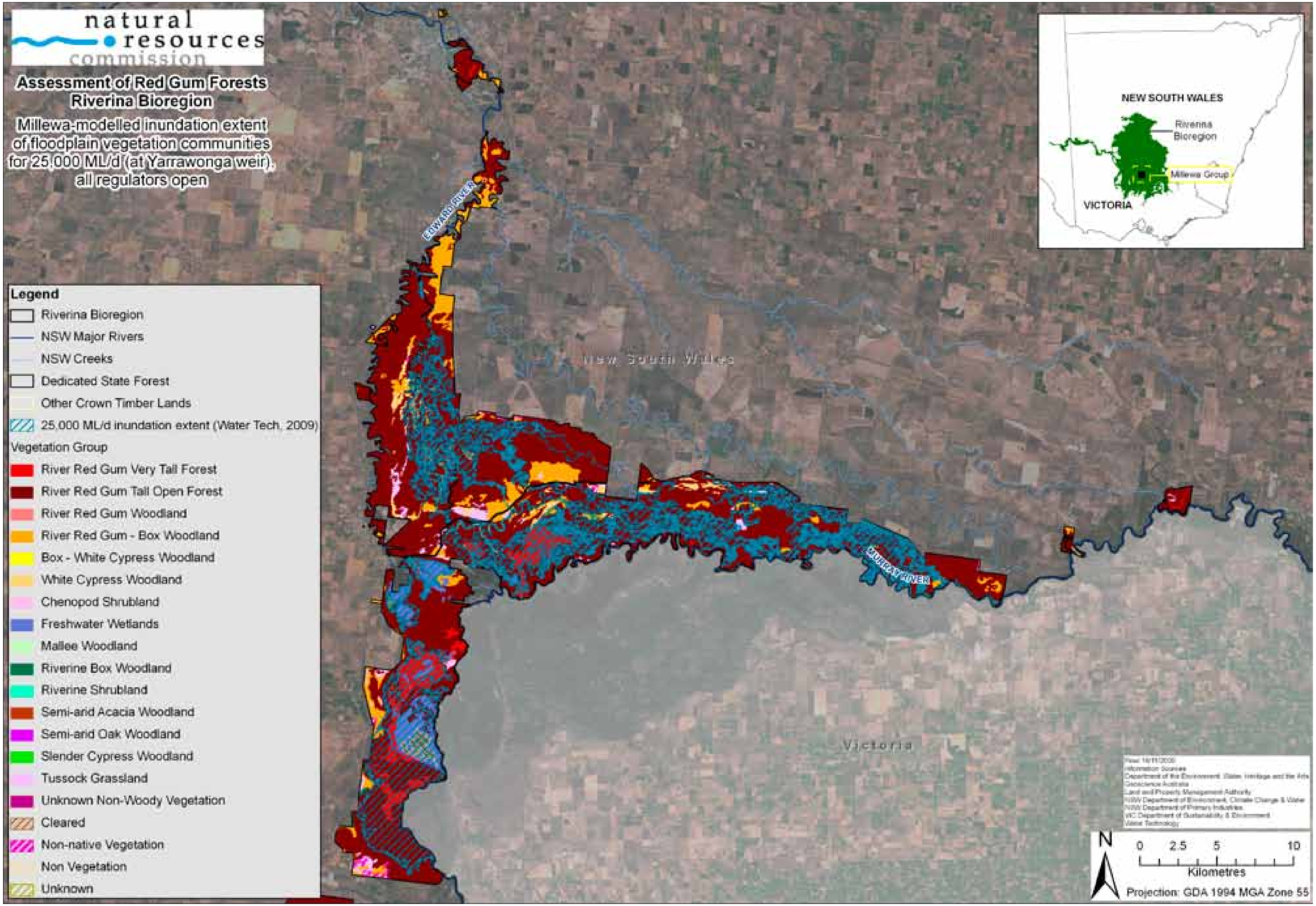
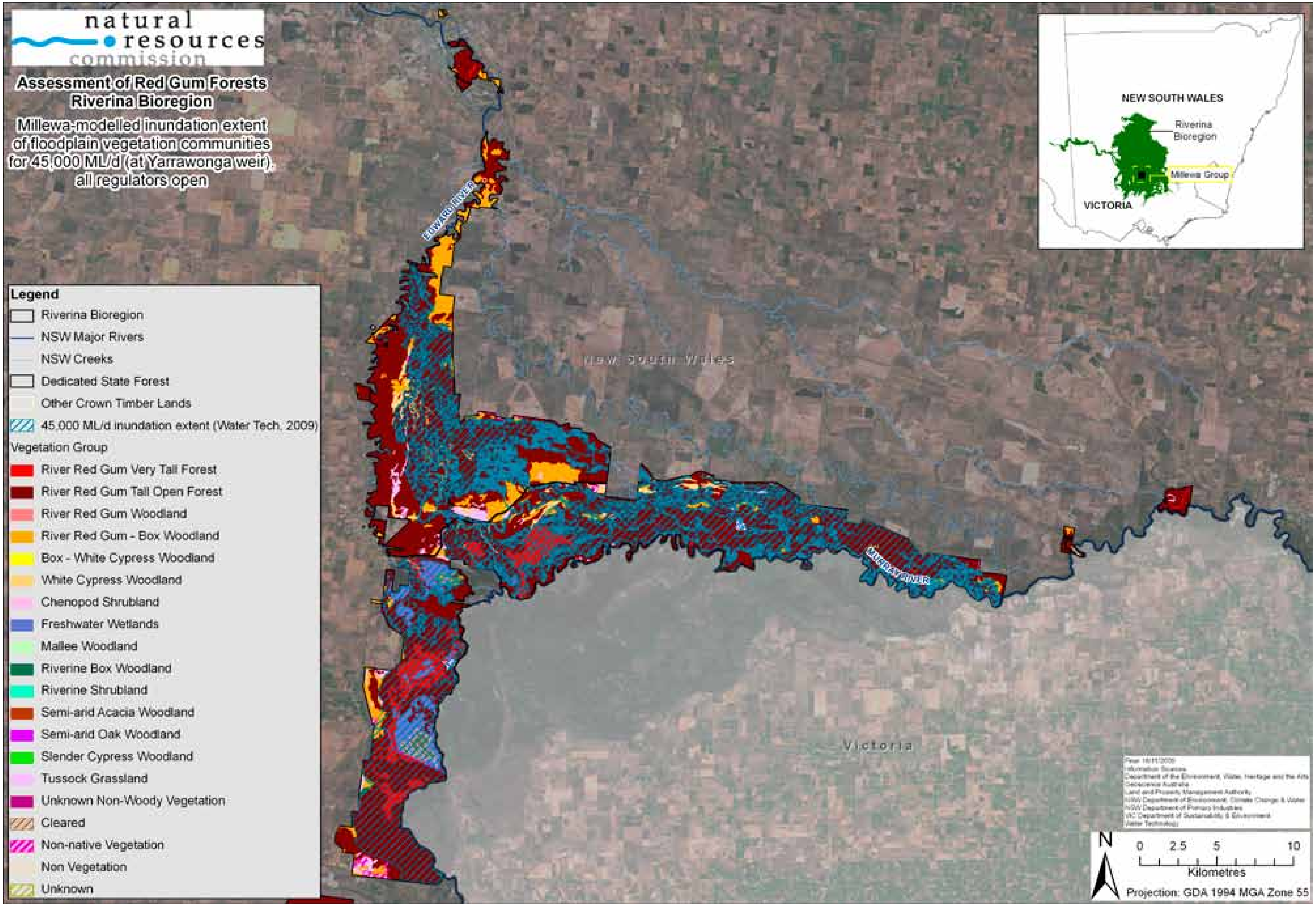


Figure 8.8: Millewa-modelled inundation extent of floodplain vegetation communities for 25,000 ML/day (at Yarrawonga Weir), all regulators open (adapted from Water Technology, 2009)

Figure 8.9: Millewa-modelled inundation extent of floodplain vegetation communities for 45,000 ML/day (at Yarrawonga Weir), all regulators open (adapted from Water Technology, 2009)



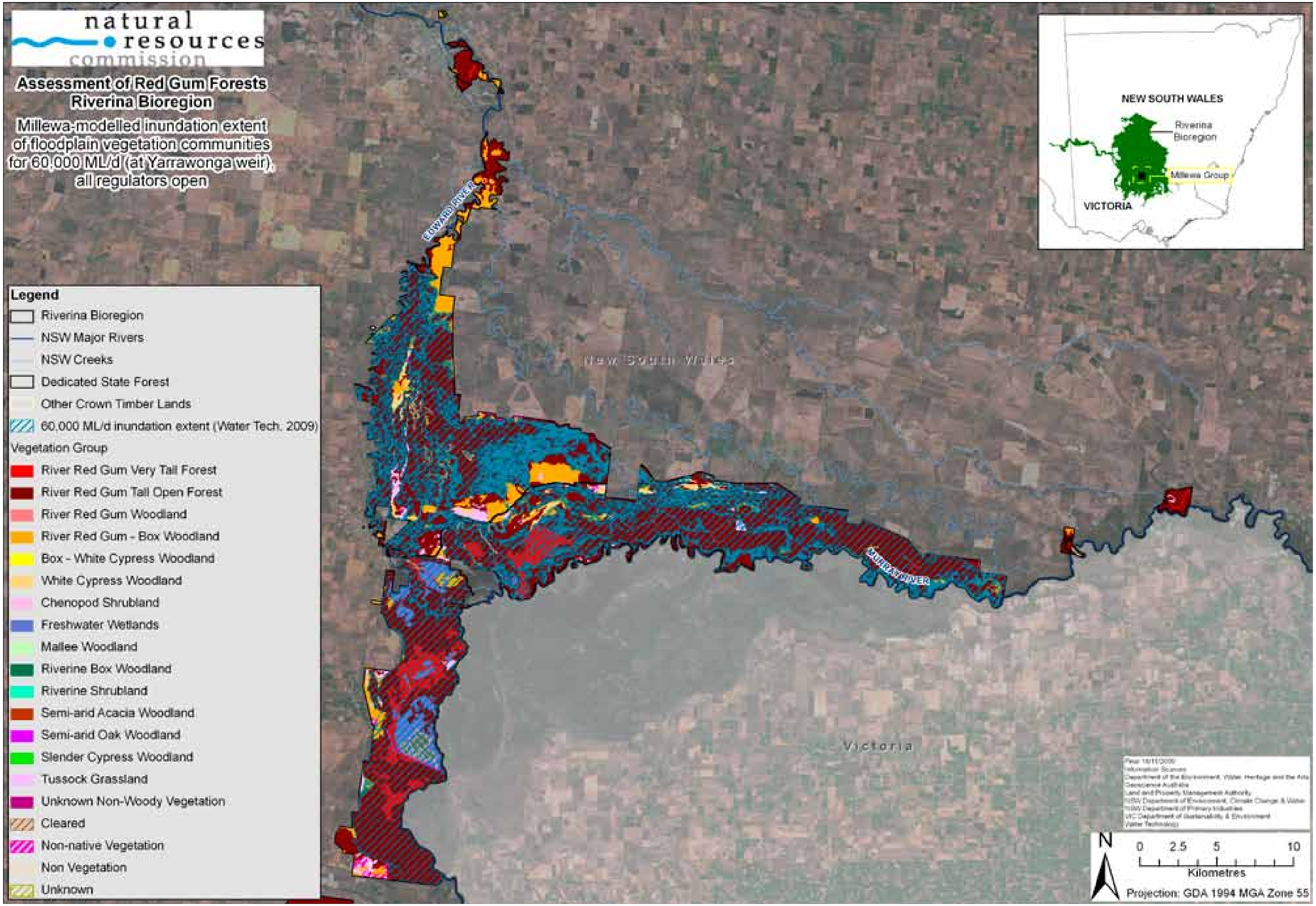


Figure 8.10: Millewa-modelled inundation extent of floodplain vegetation communities for 60,000 ML/day (at Yarrawonga Weir), all regulators open (adapted from Water Technology, 2009)

Given the current easement constraints of 25,000 ML/day between Hume Dam and Lake Mulwala, there is also limited potential to artificially deliver larger floods to the forest unless easements are increased. The delivery of floods larger than 25,000 ML/day to Millewa forests depends on contributing natural flood flows from the unregulated Ovens River being passed downstream of Lake Mulwala/Yarrawonga Weir.

While there is confidence that 18,300 ML/day can be delivered to the Barmah-Millewa forests into the future, based on the information gathered from this assessment, this type of flow is unlikely to achieve the vegetation element of the Living Murray Program ecological objectives for the combined forest. Regulator structures within Millewa forests may allow the distribution and depth of flood waters in localised areas to be manipulated.

At 25,000 ML/day, hydrodynamic modelling indicates that the extent of inundation in Millewa Forest includes 86 per cent of river red gum very tall forest, plus 32 per cent of river red gum tall open forest, and 5 per cent of river red gum-box woodland.

8.8 Koondrook-Perricoota and Campbells Island forests

The assessment for Koondrook-Perricoota and Campbells Island includes:

- site characteristics and water requirements
- future water availability and flooding regimes
- the likely impacts of future water availability for the associated forests.

8.8.1 Site characteristics

The Gunbower-Koondrook-Perricoota Icon Site, composed of the Gunbower Forest in Victoria and the Koondrook-Perricoota

Table 8.12: Inundation of Koondrook-Perricoots forests (MDBC, 2008, cited in GHD, 2009)

River flow (ML/day)	Inflow to forest (ML/day)	Inundated area in hectares/% of total					
		River Red Gum forest		River Red Gum woodland		Total River Red Gum forest	
15,000	0	-	-	-	-	-	-
20,000a	300	500	2%	-	-	500	2%
25,000	1,500	1,030	54%	2,060	12%	3,520	11%
30,000b	3,800	1,330	70%	7,400	43%	10,300	33%
35,000	6,500	1,885	99%	16,245	95%	25,000	80%

a – inflows to forest via Burrumbarry Creek start at 16,000 ML/day
b – channel capacity of Murray River is 30,000 ML/day, beyond which overtopping and broad area flows commence

Table 8.13: Natural (pre-regulation) flood frequencies of the Koondrook-Perricoota Forest vegetation communities (MDBC, 2006b)

Water regime class	Frequency	Duration	Timing
River Red Gum with flood dependent understorey	7–9 years in 10	4 months	Winter/spring

Table 8.14: Target water requirements for meeting ecological objectives (Forests NSW, 2008b)

Indicator	Measure	Target	
		Minimum	Preferred
Extent	Proportion of River Red Gum forest (with water-dependent understorey) inundated	30%	>70%
Timing and duration	Between August and December for at least three consecutive months	Sep, Oct and Nov	Aug–Sep, Oct, Nov–Dec
Frequency	Number of inundations	50% of natural	Natural precedent
	Maximum period between inundations	4 years	Natural precedent

[2] The objective is 55 per cent healthy vegetation, including virtually all river red gum forest and some woodland. This flow estimate is based on the recent hydrological modelling for the Barmah-Millewa Forest (Water Technology, 2009), and preliminary assessments conducted by the MDBA (Burns, I, MDBA, pers. comm., 2009).

forests in NSW covers approximately 50,000 hectares of Murray floodplain (MDBC, 2006b).

The Koondrook-Perricoota forests are State Forest, covering approximately 32,000 hectares. This area is managed by Forests NSW and is included in the NSW Central Murray State Forests Ramsar site. To the north-west of the Koondrook-Perricoota forests is the Campbells Island forest. These forests together incorporate the second largest area of river red gum forest after the Millewa forests.

The Koondrook-Perricoota forests are located downstream of the Hume and Dartmouth Dams and the Barmah Choke and has been significantly altered by river regulation (MDBC, 2006b). High banks on the river channel inhibit flooding by low flows from entering the forest. The decline in forest health was noted as early as 1948 in some areas (MDBC, 2006b).

Torrumbarry Weir is located near the south-eastern end of the Koondrook-Perricoota forests. The weir is used to raise the level of the Murray River by approximately 6 metres (Forests NSW, 2008b). The flow at Torrumbarry Weir depends largely on flows in the Murray River at Barmah and the flow from the Goulburn River that joins the Murray River near Echuca. The magnitude of flooding in the Koondrook-Perricoota forests is strongly dependent on whether flows in the Murray River and Goulburn River coincide (MDBC, 2005).

The flow of floodwater through the Koondrook-Perricoota forests is dominated by the Burrumbury-Barber Creek system. Torrumbarry Weir, being at the upstream end of Koondrook-Perricoota forests, creates a head of water to provide flow into the Burrumbury Creek system which enters through two inflow effluents at Swan Lagoon when the Murray River flow exceeds 16,000 ML/day (Forests NSW, 2008b; GHD 2009). This flow does not inundate a significant portion of the forest, with broad area flows observed when the flows exceed channel capacity in the Murray (>30,000 ML/day) (GHD, 2009). **Table 8.12** shows the inundation of the forest at different flow rates of the Murray River.

Water requirements of Koondrook-Perricoota are targeted to achieving a closer representation of conditions that occurred under natural (pre-regulation) conditions (MDBC, 2006b). This comprises a cycle of regular periodic surface flooding in winter and spring, combined with annual summer/autumn drying **(Table 8.13)**. Regulation and consumptive demands of the river have resulted in a decrease of the frequency of flooding to once every 10–12 years (DECC, 2008).

The Living Murray Program specifies that environmental water will be used for Koondrook-Perricoota forests to maintain and restore a mosaic of healthy floodplain communities:

- 80 per cent of permanent and semi-permanent wetlands in healthy condition
- 30 per cent of river red gum forest in healthy condition
- successful breeding of thousands of colonial waterbirds in at least three years in ten
- healthy populations of resident native fish in wetlands (MDBC, 2006b).

The water requirements to achieve these objectives are listed in **Table 8.14.**

The closer the flood frequency to the natural precedent, the greater the ability of the floodplain to maintain the functional, structural and compositional attributes of its natural state. However, Forests NSW considers the minimum target for reduced flood frequency to be half the natural frequency (Forests NSW, 2008b).

Optimum flooding for the Koondrook-Perricoota forest requires high flows in the Goulburn, medium to high flows in the Murray River and a high flow in the Wakool (Forestry Commission, 1992 cited Forests NSW, 2008b). It is technically difficult to supply the volume of water required to simulate a natural flood through deliberate releases (Forests NSW, 2008b).

There is no specific environmental water allocation for the Koondrook-Perricoota forests, and to date there has been no substantial recovered water under The Living Murray program, delivered to the site, despite the poor state of the health of the forest (MDBC, 2007a). There has been a minor 1 GL use of adaptive environment water to water Pollack Swamp in the north-west via private infrastructure on two occasions (MDBC, 2007a).

Forests NSW are currently undertaking a project to install new water management infrastructure to divert water into the Koondrook-Perricoota forest from the Torrumbarry Weir pool. This is referred to as the Koondrook–Perricoota Flood Enhancement Works.

The Koondrook-Perricoota Forest Flood Enhancement Works aims to:

- maximise the effectiveness of more frequent lower flood peaks
- deliver water to 30–52 per cent of the forest
- connect the river with thousands of hectares of potential fish breeding habitat
- maintain waterbird breeding colonies
- maintain the essential process that sustains the forest
- restore and maintain foraging and breeding habitat across the forest for a range of species (Forests NSW, 2009b).

The completion of these works is critical to maintaining the ecological character of these forests.

The structural works will allow up to 6,000 ML/day flow to be passed through the constructued delivery channel. Forests NSW has outlined the main structural components of the proposal as:

- an excavated channel to connect Bullock Head Creek and the Burrumburry Creek System to the Torrumbarry Weir pool to enable the flow of water into the forest
- upstream structures to allow diversion of water into the forest from Torrumbarry Weir and escape regulators at Swan Lagoon, to prevent flows re-entering the Murray River
- downstream structures to prevent water leaving the forest and to maximise return flows back to the Murray River. This will include a return channel and a floodway to increase water returns to the Murray River
- downstream stoplog regulators will be implemented to control the flow of the water out of the forest

Weir on the Murrumbidgee River – Yanga National Park

- a levee around the downstream perimeter of the forest is required to protect adjoining properties from flooding (Forests NSW, 2009b).

Forests NSW completed the preliminary environmental assessment for this project in April 2009 and plan to complete construction by mid-2011.

8.8.2 Future water availability

The CSIRO MDBSY Project

The CSIRO MDBSY Project studied the flooding implications in Gunbower-Koondrook-Perricoota forests under a range of climate scenarios. These three scenarios are defined earlier in this chapter.

Implications on flooding for Gunbower-Koondrook-Perricoota forests were assessed for the beneficial spring-summer flood, defined as the 30,000 ML/day (for a period of 30 days in August–January). **Table 8.15** shows the likely implications of each of the scenarios on the beneficial flood frequency. Under scenarios B and Cmid (step-climate change and 2030 climate change) floods exceeding 30,000 ML/day are likely to occur less frequently, and with a lower average flood volume per year and per event.

Future water availability for Gunbower-Koondrook-Perricoota forests under the CSIRO MDBSY assessment does not include:

- additional environmental water from the 500 GL/year to be recovered and applied to the six Icon Sites under The First Step decision of the Living Murray initiative
- future water availability of Commonwealth environmental water holdings that will arise from the Water for the Future Program, or
- operation of the Koondrook-Perricoota Forest Flood Enhancement Works.

The Living Murray Environmental Works and Measures Program

The Living Murray program has recently undertaken modelling that:

- examined the degree to which environmental water requirements of the Icon Sites can be met with the 500 GL under historical climate conditions, and the potential impact of climate change (to 2030), and
- indicates the feasibility and benefits of structural works proposals for the relevant Icon Sites, to inform investment decision-making under the Environmental Works and Measures Program (EWMP) (TLM, 2008).

Icon Site-specific infrastructure has been investigated under the EWMP to identify how the Icon Sites can be efficiently

Table 8.15: Environmental indicator values under Scenarios A, B and Cmid, plus per cent change (from Scenario A) in indicator values for Scenario Cmid (CSIRO, 2008a)

Gunbower-Koondrook-Perricoota forests	A	B	Cmid	B	Cmid
	Years			% change from Scenario A	
Average period between floods	3.8	5	4	30	15
Maximum period between floods	11.8	38	21	219	77
	GL			% change from Scenario A	
Average flood volume per years	118	12	57	-90	-52
Average flood volume per event	401	52	221	-87	-45

Note: this data does not include proposed flood enhancement works discussed watered, given that floods from the river are no longer frequent enough to sustain the health of the system. The operation of the Koondrook-Perricoota Forests Flood Enhancement Works was modelled in this investigation.

Two levels of operation – a preferred operation and a minimum operation – have been modelled for each of the works and water proposals, so that a broad-sensitivity analysis could be undertaken for the investment decision. The preferred operating strategies reflect the operation of the water and work proposals and are used to test the feasibility of the proposals under the current climate. The minimum operating strategies represent the minimum water use/requirement needed to deliver the environmental outcomes that would support investment, and have been modelled using the 2030 median climate change scenario (Scenario Cmid) to conduct a sensitivity analysis to test the viability of structures in low water years.

The two operating strategies tested for the Koondrook-Perricoota Forest Flood Enhancement Works are listed in **Table 8.16.**

The objective of the study was to prove the feasibility of the works, and it was considered that if the tested flood events could be delivered, then the works were worth building. The modelling does not represent how the works would operate in reality and is not conclusive about the limits of what could be delivered.

The modelling found that the water requirements of Koondrook-Perricoota Forest (as per the operating strategies in **Table 8.16**) could be fully met by the 500 GL recovered by the First Step decision plus 70 GL of Murray River increased flows – component of the water recovered under the Snowy Water Inquiry Outcomes Implementation Deed if the proposed flood enhancement works are undertaken. The sites' overall demand is lower than the volume of water recovered both under the preferred operation with the current climate scenario (Scenario A) and also for the minimum operating regime under a 2030 climate change scenario (Scenario Cmid).

The operation of the Koondrook-Perricoota Forests Flood Enhancement Works is detailed in the Preliminary Works Operation Plan (NSW Department of Commerce, 2009). As stated in the plan, the Flood Enhancement Works has been designed to provide the flexibility to operate within a range of flows to sustain a range of ecological processes, for example:

Koondrook State Forest on the Murray River

- frequent, low flows to maintain the wetland habitats occurring in lagoons, depressions and flood runners
- less frequent floods of medium magnitude to maintain the extent of the river red gum communities, with larger floods maintaining the extremities, and smaller floods supporting the core areas with flood-dependent understorey communities
- floods of long duration to cue and facilitate bird breeding.

The proposed scheme is capable of inundating up to 52 per cent of the forest (with the 6,000 ML/day event), but cannot maintain this extent. Maximum maintainable extent is 41 per cent, with this reducing quickly during the flood recession. The decision to water will be based on the water requirement of the ecological system and the availability of water, and it will be guided by the series of Watering Principles, and tempered by risk management strategies (NSW Department of Commerce, 2009). Unregulated water will be used when beneficial, and overbank flows will be favoured as a cue for initiating watering.

Table 8.16: Koondrook-Perricoota operating strategies assessed in TLM modelling (TLM, 2008)

Operating strategy	Preferred	Minimum
Flood frequency	1 in 3 years	1 in 3 years
Intervention watering duration	105 days	100 days
Diversion rate	6,000 ML/day for 50 days, then 3,400 for 55 days	2,000 ML/day
Threshold/criteria to start operation	>6,000 ML/day available flow at Torumbarry	>2,000 ML/day available flow at Torumbarry
Threshold/criteria to stop operation	>34,000 ML/day at Torumbarry for 3 months	>26,000 ML/day at Torumbarry for 3 months
Maximum time between events	4 years	7 years

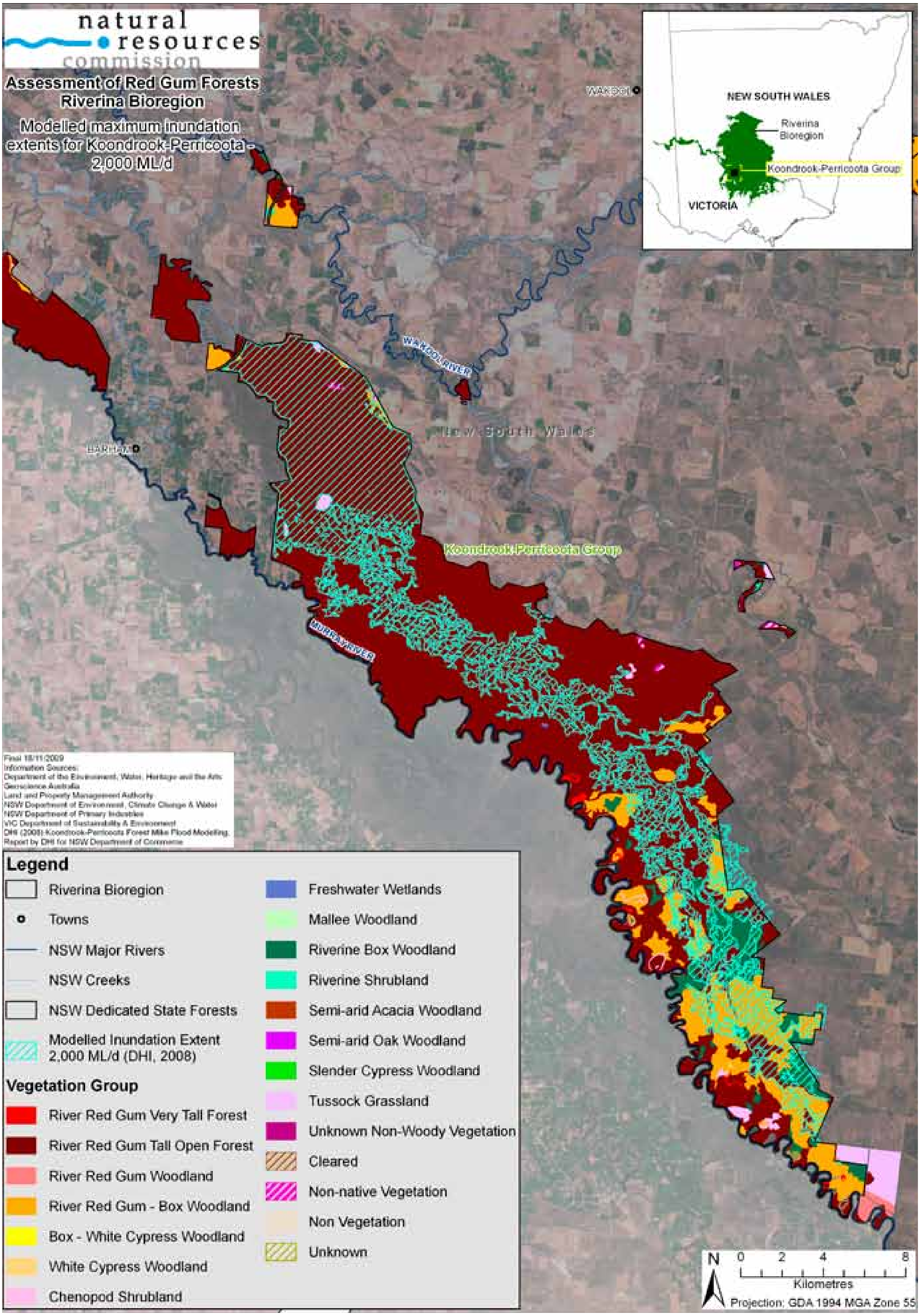


Figure 8.11: Modelled maximum inundation extents for Koondrook-Perricoota – 2,000 ML/day (DHI Water and Environment, 2008)

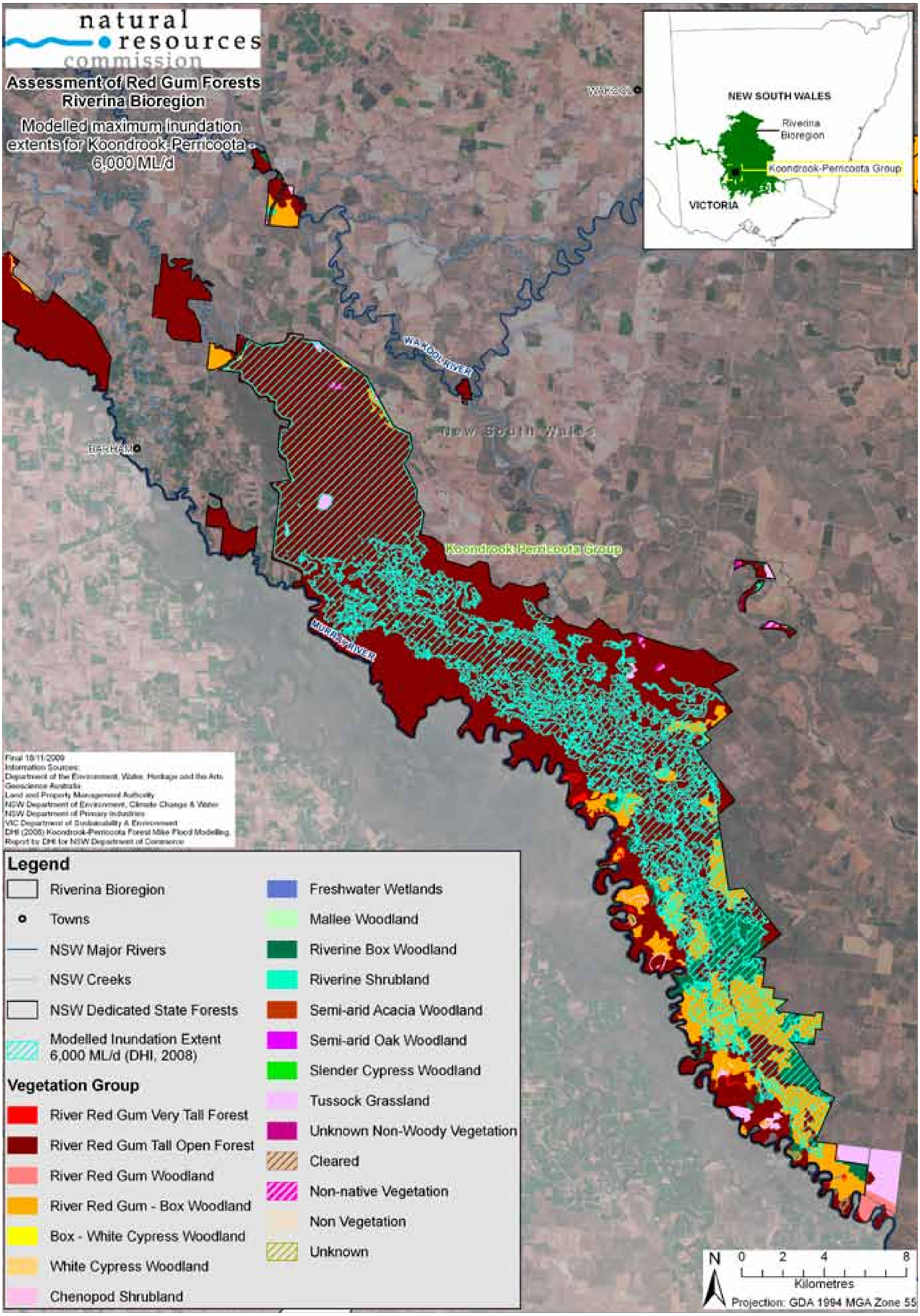


Figure 8.12: Modelled maximum inundation extents for Koondrook-Perricoota – 6,000 ML/day (DHI Water and Environment, 2008)

The plan comments that the exact ecological outcomes of the proposed structures will be unknown until they have been operated in real time under a range of conditions. The exact nature of both unregulated and regulated river flows, and the quantum of environmental water available, is unknown. Consequently, operation of the structures will be altered in line with adaptive management principles in order to react to the ecological response observed.

8.8.3 Future flooding regime

A floodplain inundation model for Koondrook-Perricoota forests with the proposed Flood Enhancement Works was developed in 2008 for the NSW Department of Commerce (DHI Water and Environment, 2008). The model outputs include flooding extents for four flow options. **Table 8.17** summarises the results of this model run.

The spatial data for maximum flood extents at 2,000 and 6,000 ML/day was overlaid on vegetation types mapped for this project to determine the extent of vegetation types inundated. **Table 8.18** summarises the results of this assessment. **Figures 8.11** and **8.12** map the inundation extent by vegetation type for these two flow rates.

Based on flood extent modelling, the peak flood event for the flood enhancement works (6,000 ML/day) would inundate 52 per cent of the Koondrook-Perricoota forests. This comprises inundation of 55 per cent river red gum tall open forest and 56 per cent of river red gum–box woodland. The minimum flood event (2,000 ML/day) would inundate 34 per cent of the Koondrook-Perricoota forests. This comprises inundation of 38 per cent river red gum tall open forest and 33 per cent of river red gum–box woodland.

Dying trees in Bama State Forest

Table 8.17: Flow component for steady state runs (DHI Water and Environment, 2008)

Water regime class	Frequency	Duration	Timing
6,000 ML/day	78.5	45	52
4,000 ML/day	78.45	75	47
3,000 ML/day	78.3	80	42
2,000 ML/day	78.1	80	34

Table 8.18: Vegetation groups inundated under 2,000 ML/day and 6,000 ML/day

Vegetation Group	Koondrook and Perricoota State Forests (Ha)	6,000 ML/day (Ha)	%	2,000 ML/day (Ha)	%
River Red Gum Very Tall Forest	82	0		0	
River Red Gum Tall Open Forest	25,979	14,263	55	9,754	38
River Red Gum Woodland	0	0		0	
River Red Gum Box Woodland	4,010	2,258	56	1,319	33

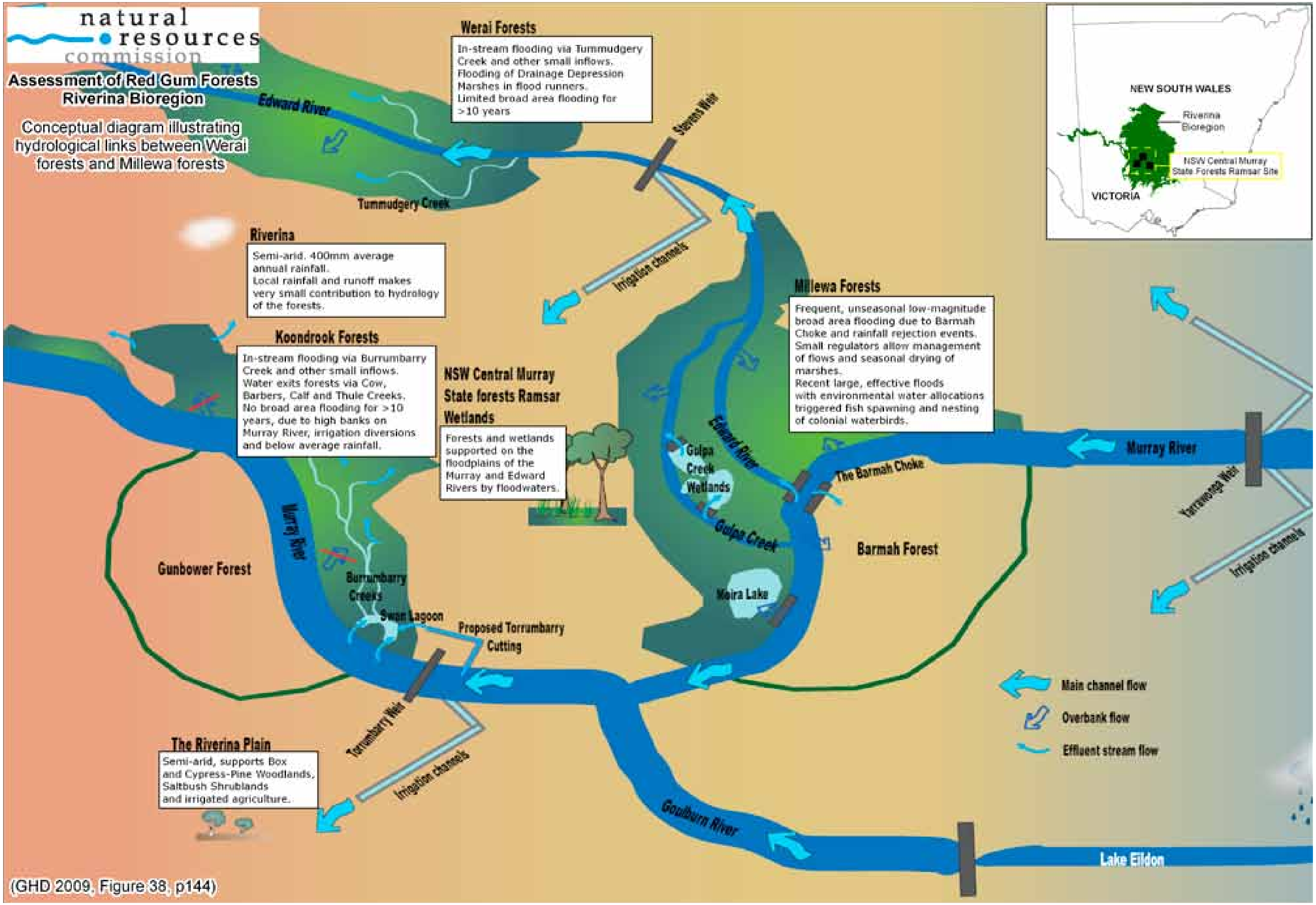


Figure 8.13: Conceptual diagram illustrating hydrological links between Werai forests and Millewa forests (GHD, 2009)

Based on the proposed 6,000 ML/day flow event (reduced to 3,400 ML/day after 50 days) hydraulic modeling of the Flood Enhancement Works indicates that of the 466 GL diverted into the forest, an estimated 222 GL (that is, 48 per cent) will be returned directly to the Murray River (Forests NSW, 2008b).

8.8.4 Flooding conclusions

The majority of the river red gum sites (87 per cent) in Koondrook-Perricoota forests are unhealthy or stressed (Turner and Kathuria, 2008). Without the proposed flood enhancement works, floods of the necessary frequency, volume or duration to provide for the water requirements of significant areas of the forest will not occur. The Flood Enhancement Works will need to be undertaken for any significant improvement to the health of the Koondrook-Perricoota forests to be achieved.

The Living Murray modelling indicates that watering requirements of Koondrook-Perricoota forests necessary to support the feasibility of the Flood Enhancement Works can be fully met by the 500 GL recovered by the First Step decision, plus the 70 GL of the Murray River Increased Flows – component. The frequency of flood events to be delivered and met in the modelling was approximately 1 in 3 years.

Based on flood extent modelling undertaken by DHI Water and Environment, the peak flood event for the flood enhancement works (6,000 ML/day) would inundate 52 per cent of the Koondrook-Perricoota forests. This comprises inundation of 55 per cent river red gum tall open forest and 56 per cent of river red gum–box woodland. The minimum flood event (2,000 ML/day) would inundate 34 per cent of the Koondrook-Perricoota forests. This comprises inundation of 38 per cent river red gum tall open forest and 33 per cent of river red gum–box woodland.

The Flood Enhancement Works will provide the flexibility to operate within a range of flows to sustain a range of ecological processes. A positive effect is expected once water is delivered. However the exact ecological outcomes arising from operation of the proposed structures will be unknown until they have been operated in real time, under a range of conditions, and the operation of the structures will be altered in line with adaptive management principles to react to the observed ecological responses.

Significant improvements in forest health will not be achieved quickly. The Flood Enhancement Works are currently in the planning phase. Construction (estimated to be complete by mid 2011), testing, monitoring and adapting operation will follow and so there is a lengthy time period between now and effective operation of the works for significant improvement to the health of the Koondrook-Perricoota forests to be achieved.

8.9 Werai forests

The assessment for the Werai forests includes site characteristics and water requirements. Little is known of the future water availability and flooding regimes, so these areas have not been addressed.

8.9.1 Site characteristics

The Werai forests occupy an area of 11,403 hectares, including the Werai State Forest and Barratta Creek State Forest (GHD, 2009). The forests are situated approximately 46 kilometres northwest of Deniliquin, on the floodplain of the Edward and Niemur Rivers between Yadabal Lagoon and Morago (GHD, 2009). This site is not an Icon Site, however it has Ramsar-listed wetlands of international significance which include river red gum forest.

The Werai forests unit is hydrologically linked to the Millewa forests via the Edward River **(Figure 8.13)**. When flow exceeds the Barmah Choke capacity (>10,400 ML/day at Yarrawonga Weir), substantial volumes of water are diverted down the Edward River and ultimately to the Werai Forests (GHD, 2009). The Bullatale Creek also brings water from central Millewa to the Edward River near Deniliquin during periods of high flow (GHD, 2009).

The Werai forests can be considered as having two commence-to-flow points. This means that low-flow and high-flow flooding can be managed differently.

Floodwater enters the forest via three effluents (Tumudgery Creek, Niemur River and Reed Beds Creek), all of which have regulator structures, as well as overbank flow. Generally, overbank flooding in the lower portions of the forest starts at about 2,900 ML/day at downstream Stevens Weir (downstream of Deniliquin) (GHD, 2009). Flows up to 13,000 ML/day constitute broad-area flooding (floodplain forests) (GHD, 2009). On average, the Werai forests are flooded 3 to 4 days after the Millewa forests are flooded.

Regulation has changed the flood regime of the Werai forests. Wetlands in the Werai forests that would have been inundated yearly are now only flooded infrequently (NSW MWWG, 2001). Flow events in the Edward River are not as variable as they have been, with flows at or near channel capacity for most of the year (VEAC, 2006).

There is no Environmental Water Allocation or water management plan in place for Werai forests.

8.6.2 Future water availability and flooding regime

As the Werai is hydrologically linked to the Millewa forests, future water availability in the Werai will be affected by water availability in the Murray River and Millewa forests. The reduction in the frequency of larger floods in Millewa Forest, particularly those >25,000 ML/day, will result in a subsequent reduction in flooding of the Werai. A more specific relationship between flooding in Millewa and flooding in the Werai is unknown at this time.

Hydrological modelling has not been undertaken for the Werai at the time of this investigation, therefore an assessment of specific flooding regimes and extents has not been possible.

8.10 Murrumbidgee River

The assessment for the Murrumbidgee River includes:

- site characteristics and water requirements
- environmental watering arrangements
- future water availability and flooding regimes
- the likely impacts of future water availability for the associated forests.

The Murrumbidgee River has two WMUs of interest:

- downstream of Narrandera
- the Lowbidgee/Yanga region.

Due to the availability of information on the Mid-Murrumbidgee Wetlands, this information is used to assess water availability and flooding regimes for the 'downstream of Narrandera' WMU.

8.10.1 Site characteristics

The Murrumbidgee River is located within southern NSW and its valley covers 87,348 square kilometres, or 8.2 per cent of the Murray-Darling Basin. The region is bounded to the east by the Great Dividing Range, to the north by the Lachlan region, and to the south and west by the Murray region.

The Murrumbidgee River rises in the Snowy Mountains to the east, and flows 1,600 kilometres westward across widening alluvial flats and onto broad plains towards its junction with the Lachlan and Murray rivers. The Lachlan confluence is in the Great Cumbung Swamp 50 kilometres north-east of Balranald. The Murray junction is about 85 kilometres further west, and this area constitutes the Lowbidgee. **Figure 8.14** illustrates the river's path.

Most of the nationally or internationally significant wetland areas are in the lower Murrumbidgee floodplain near Hay (Murray, 2008). The region includes the Fivebough and Tuckerbil Swamps Ramsar site, which is a non-riparian site near Leeton, the nationally significant Mid-Murrumbidgee Wetlands and Lowbidgee Floodplain along the Murrumbidgee River, and numerous smaller important wetlands.

The Murrumbidgee River is greatly affected by the dams of the Snowy Mountains Hydro-electric Scheme, plus diversions for irrigation and water supply, with a total of 14 dams and eight large weirs (Murrumbidgee CMA, 2008). The current level of surface water extraction in the Murrumbidgee River is relatively high, with 53 per cent of average available water being diverted for use (CSIRO, 2008b).

A study by Thornton et al. (1994, as cited in Murray, 2008) looked at hydrological changes and their effect on wetland bird breeding habitat in 96 river red gum wetlands between Wagga Wagga and Hay. The study showed that the present water regime was compromising river red gum health because it was keeping trees either too wet or too dry.

River red gum forests on the Murrumbidgee River

Improved knowledge of which wetlands fill at different river heights would assist in better targeting of environmental water (Murray, 2008). Murray (2008) mapped and categorised individual wetlands along the Murrumbidgee according to their hydrological category (how they receive water) and flow conditions. Maps provide information on wetland inundation for three different river flow scenarios at Wagga Wagga (up to 35,000 ML/day; up to 47,000 ML/day; and over 47,000 ML/day). The flow scenarios were based on targets set for environmental flows by the Murrumbidgee River Management Committee – Regulated (50,000 ML/day at Wagga Wagga) and physical constraints of the systems (32,000 ML/day at Gundagai). Relationships of the likely flow at Narrandera given a certain flow at Wagga are also provided.

Mid-Murrumbidgee Wetlands (downstream of Narrandera)

The Mid-Murrumbidgee Wetlands are an assemblage of lagoons and billabongs along the Murrumbidgee River, from Narrandera to Carrathool, with an estimated total area of 2,500 hectares. Wetlands are on the floodplain and receive flows from the river mostly during winter and spring floods. River red gum forest and woodlands dominate the vegetation of the area, with black box woodland being more marginal on the floodplain (CSIRO, 2008b; Environment Victoria, 2001). Land tenure is a mixture of State Forest, Crown reserves and freehold.

Commence-to-flow thresholds for billabongs and lagoons at several locations on the middle section of the Murrumbidgee River region are between 12 and 29 GL/day, and the Narrandera State Forest (a substantial wetland area) floods at 26.8 GL/day at the Narrandera gauge (CSIRO, 2008b; Hardwick et al., 2001).

The hydrology of the mid and lower Murrumbidgee floodplain wetlands has been altered by river regulation and development of irrigation areas (NSW DLWC, 1996b and AgriBusiness Task Force, 2000, as cited in Murray, 2008). This has included the occurrence of high flows in summer rather than late winter or early spring, and reductions in the flood peak heights of low and medium flood events (Murray, 2008). Since development and flow regulation commenced in the Murrumbidgee region, the average period between big floods that inundate the Mid-Murrumbidgee Wetlands has nearly doubled, and the maximum period between events has more than tripled (CSIRO, 2008b).

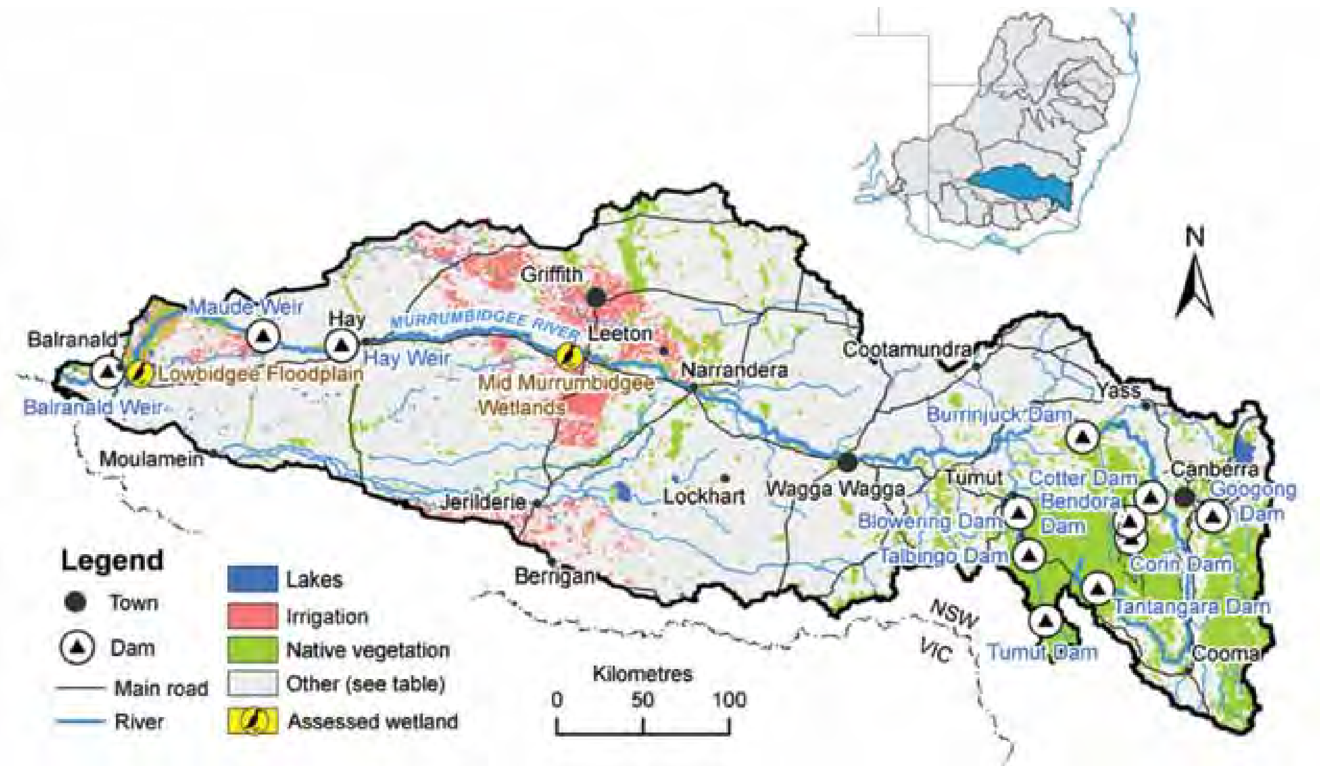
Lowbidgee/Yanga region

The Lowbidgee Floodplain is around the lower Murrumbidgee River, downstream of Maude, and covers some 200,000 hectares. The broader Lowbidgee is subdivided into the Nimmie-Pollen-Caira system near Maude Weir, and the Redbank-Yanga system further downstream. The floodplain receives floods overbank or via controlled diversions from Maude and Redbank weirs, which occurs most often during winter and spring (CSIRO, 2008b; Kingsford and Thomas, 2001).

Vegetation of the Nimmie-Pollen-Caira system is predominantly extensive areas of Lignum, however the Redbank-Yanga system is covered by river red gum forest and woodlands, with black box on the floodplain margins (CSIRO, 2008b; Environment Victoria, 2001). Land tenure is mostly freehold, although recently the NSW Government purchased much of the Redbank-Yanga portion (over 31,000 hectares) and dedicated a national park in 2005 (CSIRO, 2008b; DECC, 2007).

The Murrumbidgee River decreases in channel capacity in a downstream direction from a channel capacity of 35 GL/day at Hay to 20 GL/day at Maude Weir and 11 GL/day at Redbank Weir (CSIRO, 2008b; Kingsford and Thomas, 2001). Overbank flows onto the Lowbidgee Floodplain occurs at 20 GL/day (at Maude), although controlled diversions from both Maude and Redbank weirs can occur at much lower flow levels (CSIRO, 2008b).

Figure 8.14: Landuse and key environmental assets in the Murrumbidgee River region (CSIRO, 2008b)



For the Lowbidgee Floodplain, the average period between high-flow events has more than tripled since flow regulation commenced and the maximum period between events has more than doubled (CSIRO, 2008b).

8.10.2 Environmental watering arrangements

Almost all of the wetlands along the mid-Murrumbidgee, downstream of Narrandera, don't flood from regulated flows (Maguire, J, DECCW, pers. comm., 2009). Since the year 2000 there hasn't been sufficient base flow in the Murrumbidgee River to enable effective flooding of the Mid-Murrumbidgee Wetlands. Further, there is little infrastructure along the mid-Murrumbidgee to assist managed flood events of the wetlands.

By contrast, large areas of floodplain in the Lowbidgee/Yanga and Nimmie-Pollen-Caira systems can be flooded via controlled diversions from Maude and Redbank weirs, with return flows to the river. Water releases in recent years have been directed to the Lowbidgee wetlands.

A summary of recent environmental water releases is provided in **Table 8.19** below. With continued water shortages in the Murrumbidgee valley and the relative ease in directing water to large areas of the Lowbidgee, it is considered likely that mid-Murrumbidgee wetlands will continue to lose out on environmental water releases directed predominantly to the Lowbidgee.

Environmental water can be provided for the Murrumbidgee wetlands and forests through:

- environmental water allowances under the Water Sharing Plan (WSP)
- State Water through the NSW RiverBank program
- the CEWH under programs of the *Water for the Future* program
- the RiverReach project.

Water Sharing Plan (WSP)

WSPs provide water to support the ecological processes and environmental needs of rivers, and direct how extractive water is to be shared. The NSW *Water Management Act 2000* requires that the sharing of water must protect the water source and its dependent ecosystems and that WSPs should establish specific environmental water rules.

The WSP for the Murrumbidgee Regulated River Water Source, commenced on 1 July 2004, and applies for 10 years. This WSP provides for environmental water allowances (EWAs) which are a volume of water in the dams that can be released when needed for environmental purposes. These purposes include assisting water bird breeding, flooding of wetlands, assisting fish passage or breeding, restoring water quality or maintaining flows in the lower reaches of the river which better reflect natural flows (NSW DWE, 2009).

The WSP was suspended in November 2006 due to extremely dry conditions (NSW DWE, 2009). One environmental water release was made in December 2005, prior to suspension of the WSP, totalling 14GL and inundating approximately 10,000 hectares of wetlands.

No water has been accredited to the EWA accounts in the last three years. At the time the WSP was suspended, the balance of water in the accounts was 110,000 ML (NSW DWE, 2009). Some of this water has been used to underpin water availability for critical needs in the Murrumbidgee valley during suspension of the WSP. The WSP will be reinstated when the EWA accounts are fully repaid and all high security needs are fully accounted for (DECC, 2008).

NSW RiverBank program

The NSW RiverBank program has been set up within DECCW to work within the established water access rights framework to buy water licences and manage them for environmental benefit.

The indicative investment target for RiverBank in the Murrumbidgee in 2009/10 is $8 million (DECCW, 2009). Target environmental assets in the Murrumbidgee for RiverBank 2009/10 are Yanga National Park and the Nimmie-Caira system, including areas of southern bell frog habitat; bird, fish and amphibian breeding locations; and river red gum forests and woodlands. These sites are the same as those for previous years.

The assets selected for watering under the RiverBank program reflect the relatively small amount of water that will be available to the program over this period (DECCW, 2009).

Table 8.19: Summary of environmental water releases for Murrumbidgee environmental assets since suspension of the WSP in November 2006 (NSW DWE, 2009; Senator the Hon. Penny Wong, 28 October 2009; Maguire, J, DECCW, pers. comm., 2009)

Date	Volume (ML)	Water	Location/objective
Nov 2007–Apr 2008	8,800	NSW Critical water planning process, debited under EWA2 account	Support southern bell frog populations in Yanga National Park in the Lowbidgee
May–July 2009	25,000	WSP EWA	Yanga National Park and private land
Oct 2009	2,600	CEWH: 1,900 ML WSP EWA: 1,700 ML	Yanga National Park/Lowbidgee floodplain to support southern bell frog populations, maintain and recover wetland habitat including river red gum
Nov 2009 (10 days)	600	WSP EWA	Nimmie-Caira system 'Piggy backed' on top of 6,000 ML stock and domestic release

Commonwealth environmental water holdings

In October 2009, a total of 1.9 ML was provided to two sites in Yanga National Park on the Lowbidgee Floodplain from the Commonwealth's environmental water holdings, purchased through the Australian Government's Murray-Darling Basin water buyback program (Australian Government media release, 28 October 2009).

The two sites that received water contain river red gum and are important breeding areas for the southern bell frog, listed as an endangered species in NSW and as vulnerable under the EPBC Act. The sites were selected by the CEWH based on input by the NSW Government and advice from the Environmental Water Scientific Advisory Committee. The Commonwealth's allocation of environmental water was in addition to 2GL provided by the NSW Department of Climate Change, Environment and Water.

Murrumbidgee RiverReach project

RiverReach is a joint project between the Murrumbidgee CMA and Murrumbidgee Irrigation funded by the Australian Government through the Australian Water Fund Water Smart Australia Program (DEWHA, 2009).

Table 8.20: Definition of environmental indicators (wetland commence to flood flows) assessed by CSIRO (CSIRO, 2008b)

Name	Description
Mid-Murrumbidgee Wetlands	
Average period between high-flow events	Average period (years) between flows exceeding 26.8 GL/day at Narrandera gauge
Maximum period between high-flow events	Maximum period (years) between flows exceeding 26.8 GL/day at Narrandera gauge
Average flooding volume per year	Average annual volume above 26.8 GL/day at Narrandera gauge
Average flooding volume per event	Average event volume above 26.8 GL/day at Narrandera gauge
Lowbidgee Floodplain	
Average period between high-flow events	Average period (years) between flows exceeding 20 GL/day at Maude Weir
Maximum period between high-flow events	Maximum period (years) between flows exceeding 20 GL/day at Maude Weir
Average flooding volume per year	Average annual volume above 20 GL/day at Maude Weir
Average flooding volume per event	Average event volume above 20 GL/d at Maude Weir

Table 8.21: Environmental indicator values under climate-change Scenarios A, B and Cmid, and percentage change (from Scenario A) in indicator values under Scenarios B and Cmid (CSIRO, 2008b)

	A	B	Cmid	B	Cmid
Mid-Murrumbidgee Wetlands		**Years**		**% change from Scenario A**	
Average period between high-flow events	0.8	2.0	1.0	150	29
Maximum period between high-flow events	9.7	10.9	9.7	12	0
		GL		**% change from Scenario A**	
Average flooding volume per year	652	202.1	443.4	-69	-32
Average flooding volume per event	525	383.3	451.5	-27	-14
Lowbidgee Floodplain		**Years**		**% change from Scenario A**	
Average period between high-flow events	1.5	3.5	1.7	133	16
Maximum period between high-flow events	10.5	16.2	10.5	54	0
		GL		**% change from Scenario A**	
Average flooding volume per year	509	132.3	341.0	-74	-33
Average flooding volume per event	785	486.7	604.5	-38	-23

The aim of the RiverReach project is to examine flexible and efficient approaches to offering water for environmental objectives and irrigators needs through innovative water products, giving preference to those that maintain existing irrigator rights. Water market products may supply an additional 40 GL of water during wet years to supplement environmental flows in the Murrumbidgee Valley. There is potential for the RiverReach products to augment the environmental water under the WSP or environmental water plans developed by DECCW regarding the environmental water they manage.

8.10.3 Future water availability

The CSIRO MDBSY Project studied the flooding implications for the Murrumbidgee River under a range of climate scenarios defined earlier in this chapter, in Scenarios A, B and Cmid.

Implications for flooding along the Murrumbidgee River was assessed based on flood frequencies exceeding 26.8 GL/d at Narrandera gauge and 20 GL/day at Maude Weir. These flood frequencies represent the commence-to-flow volumes for inundation of the wetlands. **Table 8.20** presents the definition of environmental indicators used in this assessment.

Table 8.21 presents the likely flooding outcomes under each climate Scenario, A, B and Cmid. High-flow flooding sufficient to commence wetland inundation is likely to occur less frequently and be of lesser volumes (per year and per event) under climate change (Scenarios B and Cmid). This analysis does not include modelled future water availability of Commonwealth Environmental Water Holdings that will arise from its Water for the Future program. For the Mid-Murrumbidgee Wetlands, under scenario B (step-climate change) the average period between high flows would more than double to nearly two years, and the maximum period between events would increase slightly to nearly 11 years (CSIRO, 2008b). Average flooding volumes per event and per year would also be substantially reduced. Under scenario Cmid (2030 climate change) the average period between high flows would increase but the maximum period between events would not be affected (CSIRO, 2008b). The average flooding volume per year and per event would also be reduced, and so further degradation of these wetlands is likely.

For the Lowbidgee Floodplain, under Scenario B (step-climate change) the average period between high flows would more than double to 3.5 years, and the maximum period between these events would increase by over 50 per cent to more than 16 years (CSIRO, 2008b). Average flooding volumes per event and per year would also be substantially reduced. Under Scenario Cmid the average period between high flows would increase, but the maximum period between events would not be affected (CSIRO, 2008b). The average flooding volume per year and per events would also be reduced, and so further degradation to these wetlands is also likely.

8.10.4 Future flooding regime

The reduction in frequency and magnitude of future floods under climate change is likely to result in a reduction of the extent to which river red gum stands along the Murrumbidgee River will be inundated. A floodplain inundation model is not currently available for the Murrumbidgee River region, therefore detailed information on the extent of river red gums inundated at various flow levels is not feasible at this time.

Based on a recent internal DECCW study (DECCW, 2009), the refurbishment of existing water management infrastructure and water-flow gauging systems could provide more water to State Forests in the Murrumbidgee River (downstream of Narrandera) WMU. Cuba and MIA State Forests can be delivered environmental watering allocations via irrigation supply channels that occur on neighbouring properties. Areas of Wooloondol State Forest are permanently inundated from Hay Weir pool and methods to allow periodic drying could also be investigated.

8.11 Lachlan River

The assessment for the Lachlan River includes:

- site characteristics and water requirements
- future water availability and flooding regimes
- the likely impacts of future water availability for the associated forests.

The Lachlan River has two WMUs of interest:

- Booligal Wetlands
- Great Cumbung Swamp.

8.11.1 Site characteristics

The Lachlan River region is located within central western NSW and covers 85,532 square kilometres, or 8 per cent of the Murray-Darling Basin. The region's topography varies from tablelands in the east, through the central slopes and onto the western plains where the Lachlan River terminates in the extensive wetlands of the Great Cumbung Swamp (**Figure 8.15**).

Moon Moon and McFarlands State Forests receive over-bank flows from the river and are important ecological sites. State Forests further downstream are of poorer health (refer to **Chapter 4**).

The Lachlan region contains several large wetlands of national importance; however there are no wetlands classified as Ramsar sites of international significance (CSIRO, 2008c). The Booligal Wetlands and the Great Cumbung Swamp are amongst the most notable sites.

The Lachlan River is regulated with large storages, and flows are also affected by major water extractions (CSIRO, 2008c). The NSW Government recently decided to reduce flows from Wyangala Dam from 500 ML/day to approximately 250 ML/day (NSW Office of Water, 2009). This will result in no flows into Wallamundry Creek, Nerathong Creek and Wallaroi Creek; and a reduction in flows passing Condobolin.

Booligal Wetlands

The Booligal Wetlands cover approximately 5,000 hectares on the lower Lachlan River, situated on the low-gradient braided channels of the Muggabah-Merrimajeel Creek, a distributary creek system which leaves the Lachlan River. The wetlands include the Booligal Swamp and Little Gum Swamp. The latter has a dominant over-storey of river red gum (CSIRO, 2008c; Magrath, 1992). Flood flows into the system are infrequent and the area drains rapidly once floods in the river recede (CSIRO, 2008c; Environment Australia, 2001).

Large-scale water bird breeding is understood to occur in the Booligal Wetlands when flows exceed 2,500 ML/day for a period of two months at the Booligal gauge (CSIRO, 2008c; Driver et al., 2005).

As a result of water resource development, the average period between winter-spring floods entering the Booligal wetlands has increased from 6.2 years to 8.3 years (34 per cent), and the maximum period between these events has increased from 18.7 to 22.2 years (9 per cent) (CSIRO 2008c).

These changes are consistent with observed substantial reductions in the frequency and size of waterbird breeding events in the Booligal wetlands.

Great Cumbung Swamp

The Great Cumbung Swamp is around 16,000 hectares at the terminus of the Lachlan River and is adjacent to the Murrumbidgee River and the Lowbidgee Wetlands. The swamp is dependent on flood flows in the Lachlan River (CSIRO, 2008c; Environment Australia, 2001). River red gum and black box cover large areas of the swamp (CSIRO, 2008c). Broad-scale flooding of the swamp is understood to occur when flows exceed 3,000 ML/day at the Booligal gauge (CSIRO, 2008c; Brady et al., 1998), but an optimal duration has not been specified for these events.

The Great Cumbung Swamp has suffered from water regulation. There has been a substantial increase in the average period between winter-spring flood events from 1.2 years to 2.5 years (102 per cent) (CSIRO, 2008c). The maximum period between these events has also increased from 6.6 years to 16 years (143 per cent).

These changes are consistent with observed deterioration in the condition of vegetation in the Great Cumbung Swamp (CSIRO, 2008c).

8.11.2 Future water availability

The CSIRO MDBSY Project completed an assessment of sustainable water yields in the Murray-Darling Basin. Climate and hydrological modelling was conducted for a range of scenarios including:

- Scenario A – historical climate, with current development
- Scenario Cmid – future climate to 2030, with current development.

Scenario B – step climate change was not modelled for the Lachlan.

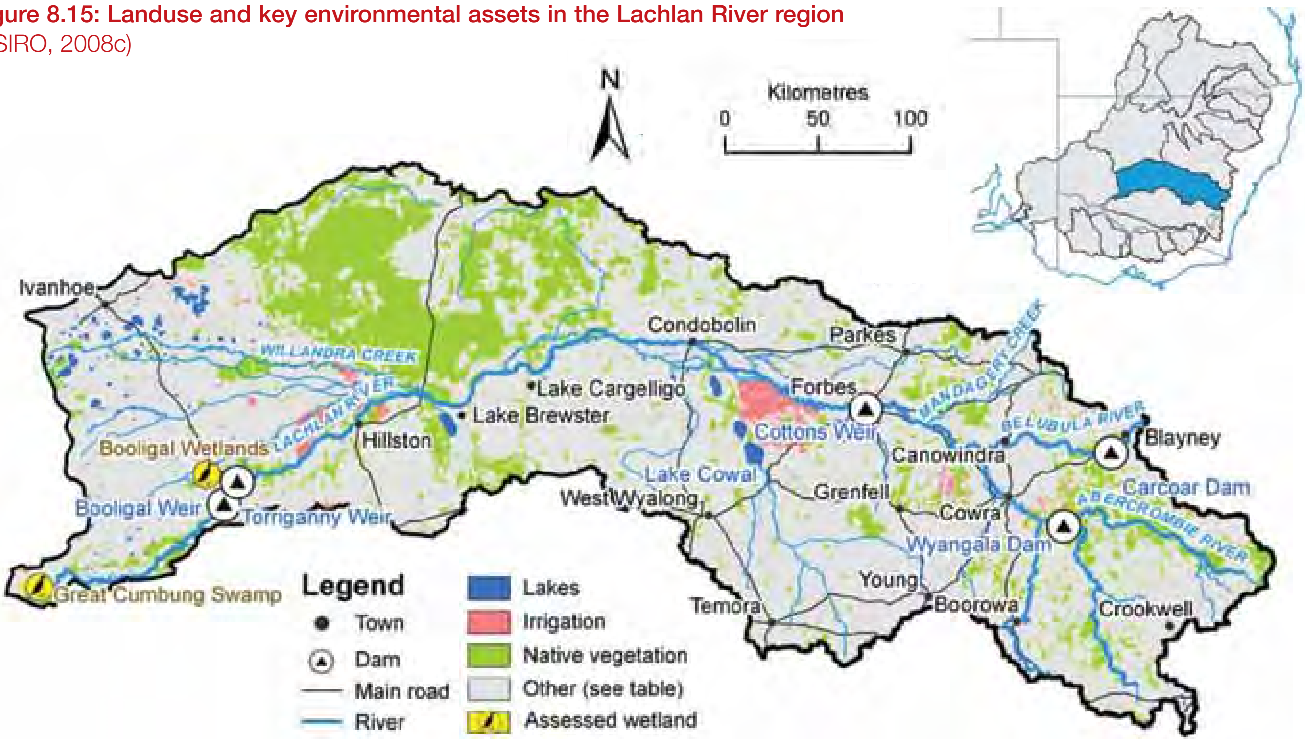
Table 8.22 lists the environmental indicators used in this study. The Booligal wetlands flow used represents the trigger for water bird breeding in the wetlands. The Great Cumbung Swamp indicator corresponds to significant flooding in the swamp (CSIRO, 2008c).

Table 8.23 provides the modelled results for each indicator under climatic Scenarios A and Cmid. High-flow flooding sufficient to achieve water bird breeding and wetland inundation is, in general, likely to occur less frequently and be of lesser volumes per year (but not per event), under 2030 climate change (Scenario Cmid).

For the Booligal Wetlands, under 2030 climate change (Scenario Cmid) the average period between winter-spring inflows into the wetlands would increase by a further 24 per cent (CSIRO, 2008c), which would likely reduce the frequency of waterbird breeding events in these wetlands (CSIRO, 2008c). However, the maximum period between events would not be affected.

For the Great Cumbung Swamp, under 2030 climate change (Scenario Cmid) the average period between winter-spring flood events would increase by a further 24 per cent, and the maximum period between these events would increase by a further 16 per cent (CSIRO, 2008c). These increases are likely to have an

Figure 8.15: Landuse and key environmental assets in the Lachlan River region (CSIRO, 2008c)



adverse affect on the vegetation of the swamp, of which a large portion is river red gum, and its use by waterbirds (CSIRO, 2008c).

8.11.3 Future flooding regime

Future flooding is expected to decrease in frequency and magnitude (extent) under climate change. This is on top of already significant decreases which have occurred due to river regulation. This will likely reduce the extent to which river red gum stands along the Lachlan River are inundated. A floodplain inundation model is not currently available for the Lachlan region, therefore detailed information on the extent of river red gums inundated at various flow levels is not feasible at this time.

Table 8.22: Definition of environmental indicators assessed by CSIRO (CSIRO, 2008c)

Name	Description
Booligal Wetlands indicators	
Average period between high-flow events	Average period (years between flows in excess of 2,500 ML/day at Booligal gauge for 2 months between 15 May to 15 November
Maximum period between high-flow events	Maximum period (years between flows in excess of 2,500 ML/day at Booligal gauge for 2 months between 15 May to 15 November
Average flooding volume per year	Average flow volume above 2,500 ML/day at Booligal gauge for two months between 15 May to 15 November per year
Average flooding volume per event	Average flow volume above 2,500 ML/day at Booligal gauge for two months between 15 May to 15 November per event
Great Cumbung Swamp indicators	
Average period between high-flow events	Average period (years between flows in excess of 3,000 ML/day at Booligal gauge for two months between 15 May to 15 November
Maximum period between high-flow events	Maximum period (years between flows in excess of 3,000 ML/day at Booligal gauge for two months between 15 May to 15 November
Average flooding volume per year	Average flow volume above 3,000 ML/day at Booligal gauge for two months between 15 May to 15 November per year
Average flooding volume per event	Average flow volume above 3,000 ML/day at Booligal gauge for two months between 15 May to 15 November per event

Table 8.23: Environmental indicator values under Scenarios A and Cmid, and per centage change (from Scenario A) in indicator values under Scenario Cmid (CSIRO, 2008c)

	A	Cmid	Cmid
Booligal Wetlands indicators	**Years**		**% change from A**
Average period between high-flow events	8.3	10.3	24
Maximum period between high-flow events	22.2	22.2	0
	GL		
Average flooding volume per year	40.7	32.2	-21
Average flooding volume per event	376	394.8	5
Great Cumbung Swamp indicators	**Years**		**% change from A**
Average period between high-flow events	2.5	3.1	24
Maximum period between high-flow events	16	18.6	16
	GL		
Average flooding volume per year	47	36.2	-23
Average flooding volume per event	124	119.0	-4

According to an internal study by DECCW (2009), only large-scale infrastructure to divert river flows will assist the resilience of the Lachlan River forests and the study suggested that it is not practical to consider such options.

This analysis does not include modelled future water availability of Commonwealth environmental water holdings that will arise from its Water for the Future program.

8.12 Other forests and riparian zones

Smaller river red gum forest stands are supported within the Upper and Lower Murray River riparian zone WMUs, and the Edward and Wakool River riparian zone WMU.

The assessment for these WMUs includes:

- site characteristics and the impact of regulation on water availability
- comments on implications for flooding where possible.

8.12.1 Upper Murray River riparian zone

The Upper Murray River riparian zone is located between Albury and Tocumwal. The flow regime of this zone is significantly modified by the storages of Hume Dam, Yarrawonga Weir and the Snowy Mountains Scheme. The National Land and Water Resources Audit 2000, in its hydrological disturbance index, rated the zone as moderately modified (NWC, 2007).

The effect of regulation varies throughout the zone. At Albury, the river flows have increased compared to natural flows as a result of extra water diverted from the Snowy Mountain Scheme. Downstream of Yarrawonga, annual flow is 25 per cent less than natural conditions, but summer flow is 19 per cent greater than natural (Gippel and Blackham, 2002). Flow variability has been decreased and water level is held at relatively constant near capacity discharge for much of the year. Seasonality has been altered, and the frequency and duration of winter-spring flooding has been reduced (Gippel and Blackham, 2002). The summer and autumn flows are higher than natural whilst winter and spring flows are lower. Overall, the average annual flow is approximately 6 per cent higher than natural conditions (MDBC, 2006c).

Regulation has increased the proportion of total flow passing down the river channel from about 88 per cent to 94 per cent. During high flows the remaining 6 per cent overtops the bank and inundates the floodplain (MDBC, 2006c).

As annual rainfall tends to increase and evaporation to decrease, from west to east and from north to south across the bioregion, the reliance of river red gum forests on surface flooding is reduced in the Upper Murray River riparian zone.

The analysis of forest condition in the bioregion undertaken by DECCW using SLATS (Pennay, 2009) and discussed in **Chapter 4** indicates that the forests in the Upper Murray riparian zone are more resilient to climate change. The SLATS data available from 1988 to 2009 were used to observe changes

Bama State Forest on the Murray River

in projected foliage cover, indicative of condition and moisture stress in the river red gum forests of the bioregion. The Upper Murray forests exhibited a general slight increase in projected foliage cover over the period from 1988 to 2008 with slope values of 0.14 and 0.2. A stable or increased projected foliage cover over the past two decades, including the last decade of extreme drought and low flows, acts as a coarse indicator of forests that are more resistant to a water-constrained future environment (Pennay, 2009). The forests along the Upper Murray River riparian zone are included in this category.

The Barooga group of forests is known to be in good condition, and are comprised almost entirely of river red gum. Elsewhere, river red gums have been cleared over much of the floodplain and riparian zone. There are, however, isolated sections of riparian zone and floodplain that have reasonable indigenous vegetation associations, particularly toward the upstream and downstream ends (ID&A, 2001). Regeneration is notable in several areas within the zone. Woody weeds, predominantly willows, are scattered throughout this zone with several sections dominated by exotic vegetation (ID&A, 2001).

To meet its commitments downstream for town water supply, irrigation and environmental flows, the MDBC can legally release flows of up to 25,000 ML/day along the reach between Hume Dam and Lake Mulwala (Brown, P., GHD, pers. comm., 2009). This is known as the regulated channel capacity. One of the positive impacts of this release is the potential for survival of river red gum stands. This volume is historically regarded as bank full along this reach. Due to the passage of time and an aggrading channel bed, the definition of bank full has changed and a number of the Murray River channels have changed shape and dominance. Some of these channels are now located on private land. As a result, the 25,000 ML/day now impacts on private land. The MDBA has set up a framework and model for determining relief packages for landholders facing inundation and access issues due to the regulated river flow regimes (Brown, P., GHD, pers. comm., 2009). This 25,000 ML/day is the same easement constraint referenced earlier under the Barmah-Millewa discussion, and may be increased in the future.

The forests along this reach would receive flooding (by flows exceeding 25,000 ML/day) during spills from Hume Dam. However, the potential to provide environmental water during regulated periods is currently limited due to the current regulated channel capacity.

The local shallow groundwater systems would be augmented by high river levels over summer during irrigation releases, and this may also contribute to sustaining river red gum forests along this reach between Hume Dam and Lake Mulwala.

8.12.2 Wakool and Edward rivers riparian zone

Downstream of Deniliquin the Edward River emerges onto a broad, flat floodplain. Enclosed between the Edward and Murray Rivers and fed from the Edward River, the Wakool River is part of an extensive network of high-level anabranches. During major flood conditions, approximately 50 per cent of the total flow passing Deniliquin leaves the Edward River via the Wakool River and Yallakool Creek (MCMA, 2006).

Parts of the Wakool River system adjoin the Koondrook-Perricoota forests, one of The Living Murray six icon sites, and comprises hundreds of kilometres of rivers and creeks. The river system and adjoining forest are recognised as having high ecological value (MDBC, 2007).

As a consequence of prolonged and extreme drought conditions and a high level of regulation upstream, the water in the system is diminishing to a series of disconnected waterholes (MDBC, 2007). In 2008, the continuous environmental flows for the system ceased. Now only occasional pulse flows are provided to the system (WSC, 2009). Options for infrastructure to effectively deliver environmental water allocations to this WMU are limited (DECCW, 2009).

8.12.3 Lower Murray River riparian zone

The forests contained within the Lower Murray River riparian zone are possibly the least frequently flooded and most stressed forests in the Riverina bioregion. The hydrological regime of this section has been significantly changed. Less than half the natural median annual discharge now reaches the border with South Australia (Gippel et al., 2002). Periods of prolonged low flow are more frequent. The frequency, duration and magnitude of all but the largest floods have been reduced (Gippel et al., 2002). This results in a reduction in the inundation extent and frequency of the adjacent floodplain and associated vegetation.

Gol Gol, Euston, Moorna and Lake Victoria State Forests are situated alongside weir pools so there are possible minor infrastructure options available to artificially flood these forests (DECCW, 2009). State Forests such as Ki, Mallee Cliffs and Manie can only receive water during very high Murray River flows. There are limited options for artificial flooding of the forests in the Lower Murray River riparian zone (DECCW, 2009).

8.13 Groundwater

There is evidence that river red gums use groundwater opportunistically as a water source in forests of the Riverina bioregion. As an environment dries, river red gums will make a transition from using water from the shallow unsaturated zone to using groundwater, provided that the quality is sufficiently fresh and watertable accessible. Hence, some communities can be highly dependent on groundwater in prolonged dry periods and times of water scarcity.

Flooding is a significant recharge mechanism in the shallow floodplain groundwater systems of the Riverina bioregion. Flood recharge is likely to be more significant than rainfall recharge and regional groundwater flow in some areas but this varies from site to site and is not yet well understood.

Groundwater levels in both deep and shallow aquifers in the Riverina bioregion are falling due to groundwater extraction and recent climatic conditions. The current and future impact on the floodplain ecosystems is not well understood, but it is likely that groundwater has and will become less accessible as a source of water for vegetation. This will have negative impacts on vegetation health if specific populations are dependent on this groundwater, to any degree, in times of water scarcity.

The following section outlines:

- the degree to which river red gum and other woodland forests of the Riverina bioregion are groundwater dependent ecosystems (GDEs)
- the geomorphological, hydrogeological, surface water flooding and groundwater processes and factors which affect this dependence
- case studies giving evidence of river red gum communities using groundwater as a water source are presented.

Figure 8.16: Geomorphic regions of the Murray Basin (Brown and Stephenson, 1991)

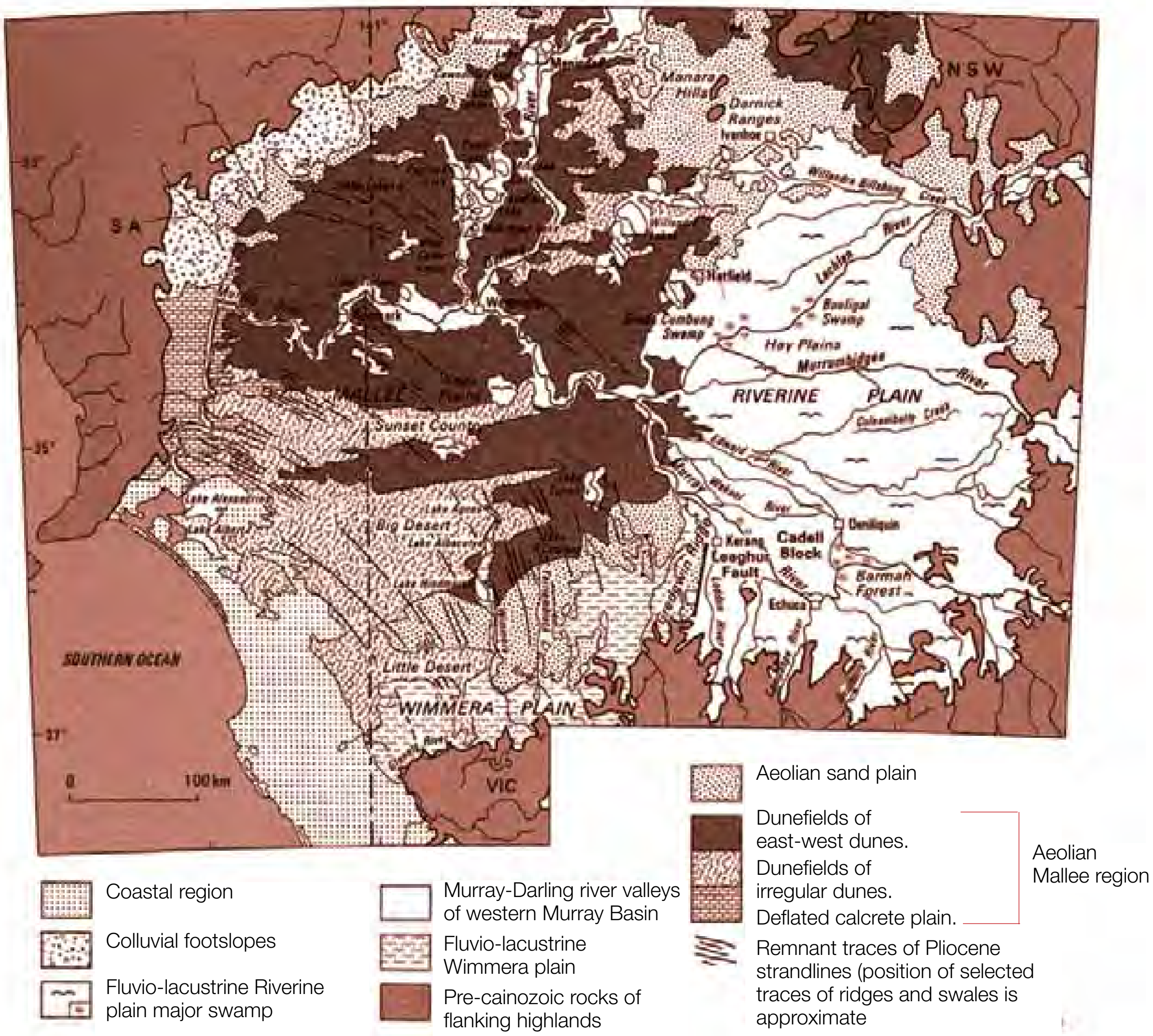
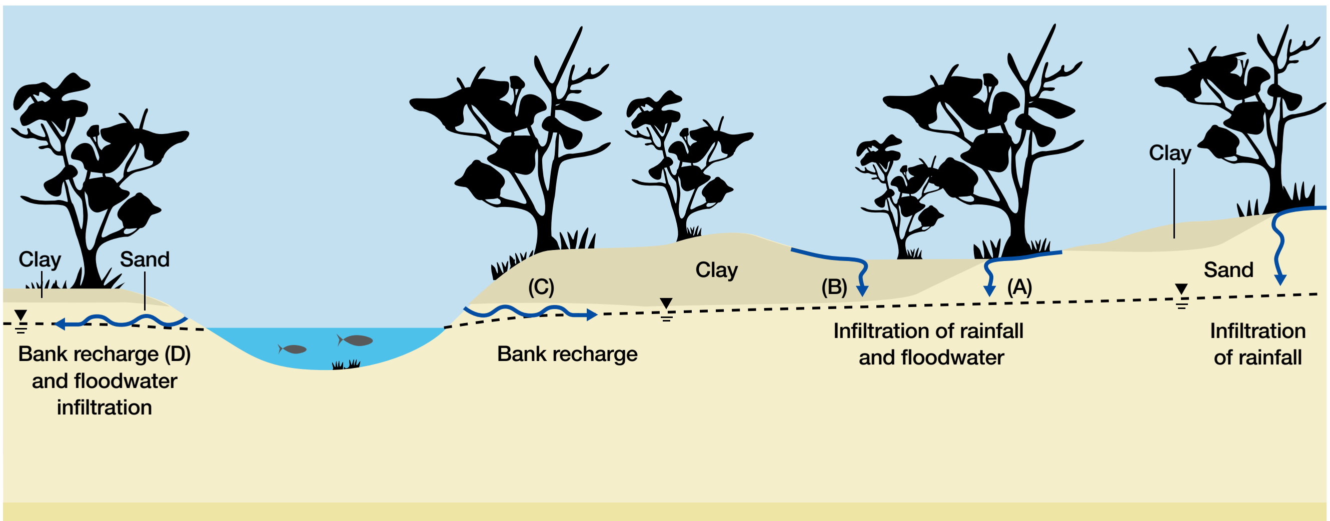


Figure 8.17: Conceptual model of shallow groundwater recharge (after Holland et al., 2006)



8.13.1 Geology and hydrogeology

The geomorphology and geology of the Murray Riverine plain (eastern Riverina bioregion) has been described by Pels (1964, 1966) while the Mallee and Murray Trench areas (western Riverina bioregion) have been described by Bowler and Magee (1978) and more recently Brown and Stephenson (1991) as shown in **Figure 8.16**. Although the regional geology of the two regions is quite different, the above mentioned studies and others since, have shown there to be similar variation in the presence and extent (horizontally and vertically) of clay and sand units within the current river floodplains. This has a significant impact on the hydrogeology of the area at a local scale and the mechanisms by which plant communities can access groundwater. Clay layers, for example, can restrict groundwater recharge but have deeper capillary fringes than sands, giving young plants access to deeper groundwater.

8.13.2 Groundwater recharge

There are three important large-scale recharge mechanisms which maintain the shallow floodplain groundwater of the Riverina bioregion. These are discharge from regional groundwater systems, diffuse recharge from rainfall and flood recharge. It is thought that regional discharge could be important if regional flows slow and levels fall (i.e. due to climate change, low rainfall periods, groundwater extraction) while the latter two mechanisms are thought to be the most significant on a local scale for the floodplain. Flood recharge is likely to dominate over rainfall recharge during floods. However, there are many areas of the floodplain which do not flood as frequently and historically are more likely to depend on rainfall recharge.

Any change in flood frequency or magnitude due to anthropogenic and climatic factors is likely to cause changes to the quality and levels of shallow groundwater. It is useful to describe the various sub-mechanisms of flood recharge since they influence the effectiveness of any given flood in recharging the shallow groundwater.

Local flood recharge to the lower Murray floodplain occurs through four main processes as shown in **Figure 8.17**. (after Holland et al., 2006). It is thought that these processes occur in a similar fashion across the floodplain systems upstream but clearly the complexity of local geomorphology, surface water and groundwater regimes will add variation to this simplified conceptual model. On the right-hand side of the figure (A), vertical recharge is shown to occur through both clays and sands during floods or periods of prolonged rainfall. Recharge through sands is generally more effective than through clays and significant diffuse recharge can occur in meander belt areas of previous river paths, breaks of slope and dune systems. Vertical recharge through clays (B) is initially dominated by flow through preferential pathways such as surface cracks which extend vertically and macropores which can then close as clays swell. Near the river, bank recharge (C) occurs through bank sediments can reach tens of meters horizontally into the aquifer during high flow or flooding events and potentially further when frequent or prolonged high flow and flooding occurs (depending on flood heights and the hydraulic properties of the bank sediments). On the left side of the figure, recharge is a combination (D) of vertical recharge through clays (likely dominated by initial rapid recharge through cracks and macropores, followed by slower diffuse recharge) and bank recharge through bank sediments.

It is understood that the recharge to floodplain areas (observed as groundwater rise) is primarily dependent on the flood height and duration. This has been explored on the Lindsay-Mulcra-Wallpolla floodplains by Richardson et al. (2007) and other previous studies. The change in groundwater elevation was plotted against flow and a linear relationship was found for each monitoring bore. The increase in groundwater level with increase in flood height, is likely to be a combination of a pressure response in the aquifer and physical recharge to the aquifer from inundation. The increase in groundwater response with larger flows could be due to the inundation of specific areas of higher permeability soils where local recharge can occur more effectively.

Vertical recharge through these soils is thought to be the most effective recharge mechanism for floodplains and it may be possible to identify these areas and predict the flows required for them to become inundated. Studies of this nature have not been done to date. Richardson et al. (2007) found that the significance of the range of groundwater level changes for vegetation health would depend on factors including; depth to groundwater, groundwater salinity and soil type.

The water balance of the Koondrook-Perricoota forests are dominated by recharge from overbank river flows (Salient Solutions, 2007) and it is commonly assumed that flood recharge is an important mechanism for many of the floodplain areas in the Riverina bioregion.

8.13.3 Groundwater discharge

In reaches where the groundwater levels (both shallow local systems and regional systems) are above the levels of surface water features (such as creeks, oxbow lakes or rivers), groundwater discharge will occur. In the Mallee/Murray trench area of the Bioregion, regional groundwater generally flows towards the Murray River both horizontally and vertically upwards although the actual connection and dynamics of the flow towards or away from the river is variable. Discharge towards the Murray changes the salinity balance of shallow groundwater systems, dependent on flooding events and the effectiveness of local recharge. Hence, it is common for areas that do not receive regular recharge from river floods and are regional discharge zones such as the Lindsay River area, to be relatively barren landscapes due to higher salinities of shallow groundwater (Dudding, 1992).

In the eastern parts of the Riverina bioregion (that is the Riverine Plain) regional groundwater flow is generally parallel to the surface streams and at great depth. In these environments, the rivers and streams are connected to shallow groundwater systems that are closely controlled by surface water flows and are typically losing or maximum losing in the lower reaches (CSIRO, 2008d).

Evapotranspiration by deep rooted vegetation (i.e. river red gums and black box) is also a significant groundwater discharge mechanism (Hatton and Evans (1998); Holland et al. (2006); Mensforth et al. (1994); Thornburn et al. (1993); and others). As referenced in Salient Solutions (2007) data from the CSIRO has indicated that red gums may be able to transpire at rates up to 2mm/day from shallow water tables and riparian forests may have root systems that can access groundwater to depths of at least 13 metres. Similarly, Doody et al. (2006) have measured transpiration from river red gums of up to near 1.5 mm/day which is thought to be sourced from groundwater when shallow soil water is not available. Estimates of the groundwater use by plant communities on a larger scale have not been done and upscaling from measurements made on individual trees or forests can be problematic.

8.13.4 Current status and trend of groundwater in the bioregion

Over the last century, there has been a number of changes in surface water flow regimes and regional groundwater trends which have different impacts for shallow groundwater systems and the ecosystems of the Riverina bioregion.

Regional and local trends in groundwater levels

The regional groundwater trend across the NSW Riverina bioregion is generally falling in both deep and shallow aquifers (URS, 2008). Rates of decline vary widely and there are many exceptions but deeper aquifers have fallen by tens of metres with smaller declines in shallow aquifers as a result of

Figure 8.18: Location of Southern Riverine Plains groundwater model (Goode and Barnett, 2008)

Lake Mulwala

groundwater extraction and additionally from recent climate conditions. There has been a reversal of vertical gradients (from upwards to downwards) between shallow and deep aquifers in the Murray region of Victoria and NSW (Dudding (2004); Salient Solutions (2007)). This trend is most likely due to the high rates of groundwater extraction in the deeper aquifers for irrigation and a lag in the response of the shallow aquifers. This has the potential to decrease the occurrence of salinity issues in shallow aquifers in irrigation areas and conversely is likely to lead to increasing salinities in the deeper aquifers (as initiated by mixing with the now downward flowing saline groundwater).

The relevance or scale of these potential impacts on the Riverine Plain and Mallee has not been specifically assessed. Salient Solutions noted that the hydraulic gradient under the Koondrook-Perricoota forests has changed direction, and there is now a discharge of the shallow groundwater system to deeper layers, thus reducing the overall volume of shallow groundwater available for use by trees (Salient Solutions, 2007).

An assessment of the impact of groundwater pumping on the Southern Riverine Plain (amongst other components) was done by Goode and Barnett (2008) using MODFLOW (see **Figure 8.18**). The model showed that 42 per cent of current groundwater extraction (2004/2005 values), was sourced from river depletion and the bulk of the remainder from captured groundwater evapotranspiration. This finding is highly significant for ongoing survival of plant communities which are dependent on accessing this groundwater as either a primary or occasional water source.

There is some local variation in shallow floodplain aquifers (primarily along the Murray River) which have been heightened in some areas where discharge from irrigation groundwater mounds is occurring and where the installation of locks has permanently elevated river levels (URS, 2008). Many of the irrigation mounds have begun to or have dissipated between the two most recent Murray-Darling Basin Groundwater Status reports (Ife and Skelt, 2004; and URS, 2008).

The contrasting trends at the local scale cannot be broadly resolved since the dominance of one trend over another will depend on local hydrogeological and other conditions. More detailed and specific description and assessment of the spatial and temporal variation of these groundwater level trends are found in Ife and Skelt (2004) and more recently URS (2008).

Local salinity impacts

Along river reaches where, due to river regulation, river levels are moderated or adjacent to locks which result in a permanent heightening of the river level, the influence of bank recharge may have increased and widened the extent of near-river fresh shallow groundwater. Locally, these groundwater systems have been forced to re-equilibrate to higher river levels despite regional falling trends. It is possible that this has impacted the ability of shallow floodplain aquifers to discharge groundwater (which is often saline).

River regulation has also resulted in a decrease in the frequency and magnitude of flooding which results in less effective recharge events to the shallow floodplain groundwater systems (also in terms of frequency and magnitude). This reduces the availability of shallow (unsaturated zone) fresh water for use by trees and has had impacts to vegetation health in many areas. The higher groundwater levels across some of the floodplains have also brought the watertable to within capillary fringe distance of the ground surface.

When the watertable is close to the surface, evaporation and evapotranspiration concentrate the salts in the unsaturated zone of shallow soils. If this salt is not flushed via recharge events or flooding, then the salinity can have adverse impacts on vegetation communities. The groundwater salinity tolerances of black box and red gums are quite high as reported by Munday et al., (2008) being up to 55 dS/m and 30 dS/m respectively (as measured in the lower Murray part of the bioregion). However, it is doubtful that these species could survive and recruit new generations with water sources of this salinity (Lebbink and Lewin, 2008).

The dynamics of salt accumulating and flushing due to flooding has been studied in much detail in specific floodplain areas using a number of techniques such as WINDS modelling, airborne geophysics, mass balance and flux calculations (recently by Overton et al. (2006a); Munday et al. (2008); Salient Solutions (2007); Pritchard et al. (2009); Richardson et al. (2007); and others). Most of this work has been done in the Murray Trench where the salt load dynamics are influenced by groundwater mounding in irrigation areas (which have recently been found to be dissipating (URS, 2008) in addition to regional saline groundwater discharge.

The flooding frequency has been found to impact the salt loads associated with this discharge as described by Pritchard et al. (2009) for the Wallpolla, Mulcra and Lindsay floodplains. It was found that salt loads to surface water features were related primarily to the groundwater gradients which are dependent on flood frequencies (i.e. higher salt loads in early – mid 1990's due to higher flood frequency and higher groundwater gradients compared to recent salt loads). The flooding events have the capacity to flush salts from the shallow soil and unsaturated zone, down to the shallow groundwater before the groundwater discharges to surface water features. A study by Passfield et al. (2008), modelled the effectiveness of flood frequency in leaching salts from the shallow soils. They found that the period of flooding was more important than the salinity of the flood water and suggest that the use of irrigation drainage water could be considered if it meant more frequent floods could occur.

8.13.5 Groundwater dependence of river red gum forests and woodlands

The long-term viability of any vegetation community is dependent on the availability of fresh water, whether from shallow or deeper unsaturated zone of soils, from the unsaturated capillary fringe above the watertable or the groundwater directly. Vegetation generally will access and use water sources which are of the lowest salinity with expenditure of the least amount of energy (that is, fresh and shallow before more saline and deep sources). Therefore, as an environment dries, shallow unsaturated soil water is commonly used by plants first. If this source is exhausted, then plants may transition to the use of groundwater as their primary water source (provided the groundwater is within reach of the root zone and sufficiently fresh). If shallow or deep unsaturated zone sources of water are regularly unavailable (i.e. periods of low rainfall and low flood frequency) then plant communities will be forced to make a transition to groundwater as a water source. At the same time, shallow groundwater levels are likely to be falling (due to lack of recharge). Hence, the plants may not be able to chase the watertable quickly enough to survive (as has been evident in the Banksia woodlands of Western Australia, see Eamus et al. (2006) and Froend and Bertuch (2007).

The following paragraphs give examples of where groundwater has been shown to be a major source of water to river red gums in the Riverina bioregion.

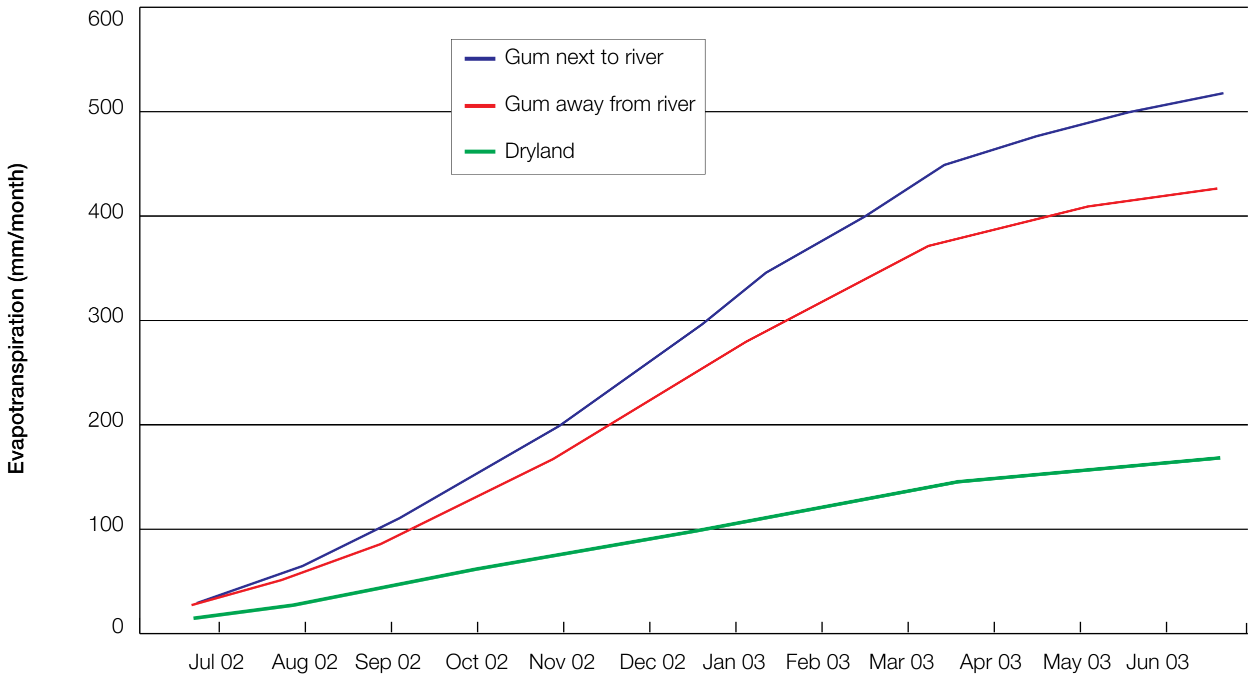
Mensforth et al. (1994) showed that river red gums in the Chowilla floodplain more than 15 metres from the stream margin largely used groundwater (in summer and a combination of groundwater and rainfall-derived soil water in winter). Trees closer to the river used direct river water or flood-derived soil moisture. This work was indirectly supported by the work of Pritchard et al. (2009) via the analysis of bore hydrographs on the Lindsay–Wallpolla Floodplain.

It is thought that some stands of river red gums in the bioregion are maintained in good health by interactions with groundwater rather than through direct flooding. Wen et al (2009) found that the condition of some river red gum stands (close to the channel or permanent water bodies) was not significantly related to flooding history and might suggest that the predominant factor was groundwater. In the Ecological Character description of the lower Lachlan wetlands, Capon et al. (2009) suggested that areas of red gums in the Great Cumbung Swamp are likely to be groundwater dependent. This however requires further investigation as the long-term nature of this relationship has not been directly studied.

A conceptual understanding of groundwater behaviour in the Koondrook-Perricoota forests was developed by Salient Solutions (2007, 2008). These studies found that river red gum populations were likely to be accessing groundwater as a water source at depths of at least 13 metres below ground when shallower water sources were unavailable. The forests were found to be undergoing dynamic changes as a result of the surrounding irrigation development, the changes in flood frequency in the streams and rivers, and most significantly, the impacts from groundwater extraction to the east and south. The responses of vegetation communities to these changes (i.e., transition to groundwater use and impacts on vegetation health) are currently only reasonably understood. It is expected that this situation would be similar at the Millewa Forest and other sites in the region.

There is limited detailed understanding of the complex interactions between surface water and groundwater in the Riverina bioregion in regard to the impact on river red gum health with the exception of a limited number of sites which have been well studied (including Koondrook and Perricoota forests in NSW and others in Victoria (Wallpolla, Mulcra, Lindsay) and South Australia (Chowilla)). These are important processes in determining vegetation responses to a range of watering regimes, however methods for predicting responses on a large scale are limited. This is currently being investigated and assessed as part of the development of the Basin Plan by the MDBA and additionally, the NWC has initiated a project to identify the location and nature of groundwater dependent ecosystems on a national scale.

Figure 8.19: Preliminary results of evapotranspiration from two red gum communities and comparison with dryland using SEBAL



8.13.6 Quantifying river red gum groundwater use

From a water resource management perspective it is important to understand the water balance and water demand of each component of the hydrological system. This allows informed decisions to be made in regard to water requirements for agriculture, industry and environment for the current and future conditions. Additionally, if species such as river red gums are reliant on groundwater to maintain their health in times of water shortage, knowledge of these water requirements become extremely important if the populations are to survive. Historically, it has been difficult to close this water balance since groundwater evapotranspiration has been largely unknown, not considered or roughly estimated (Evans, pers. comm., 2009).

Measurements of evapotranspiration from plant communities has been done using field measurements of sap flow and pan evaporation measurements on a site by site basis or by comparison of historical aerial or satellite images on a larger scale. Although this has been useful for adding to the understanding of specific communities, it has not allowed an assessment of water use by vegetation on large spatial and temporal scales since up scaling can be problematic and detailed temporal data, unavailable.

An emerging methodology for calculating evapotranspiration has been developed by Waterwatch and recently implemented in Australia using Modus (or Landsat) imagery. The method is called Surface Energy Balance Algorithm for Land and has compared extremely well with other field based and modelling methods (see Evans et al., 2009). The method allows daily analysis at the resolution of the satellite image over broad spatial scales and it has the potential to be applied in a wide variety of applications in Australia (i.e. closing the water balance).

An example of this application is shown in **Figure 8.19**. from the preliminary results of the Water Balance Study for Murrumbidgee River (Sinclair Knight Merz, 2009). Thirty sites were randomly selected in the area near the Murrumbidgee River, with average rates for 10 sites from each category shown in the figure. It can be interpreted that the difference between the dryland evapotranspiration and the red gum evapotranspiration is roughly equivalent to groundwater evapotranspiration, assuming that these communities are using groundwater as their primary water source. More work is needed to confirm this assumption (i.e. compare with groundwater levels, antecedent conditions and hydrogeological and plant water use understanding) but the potential applications of this method are vast. A similar comparison was roughly applied in the Barmah Forest with a difference of 170 mm/year seen between a cleared area and red gum forests approximately 100 metres from the Murray River (Evans, pers. comm., 2009).

Future studies are required to quantify groundwater evapotranspiration to close the water balance and gain a large-scale, quantified understanding of current and likely future environmental water requirements under current and future climate conditions.

8.13.7 Potential impact of climate change on groundwater and groundwater-dependent ecosystems

The demand on water resources will undoubtedly increase as a result of climate change and put further pressure on both current water use practices and the environment. Groundwater extractions, reduced rainfall and reduced frequency and magnitude of flooding will all impact on groundwater levels and are likely to adversely impact the shallow groundwater systems and groundwater-dependent ecosystems of the Riverina bioregion.

In a study by the CSIRO which modelled groundwater recharge in the Murray-Darling Basin, it was determined that recharge to the groundwater system will decrease by a factor of 2–3 times the decrease in rainfall (Crosbie et al., 2008). Into the future, this likely decrease in recharge would lower regional groundwater levels and cause the nature of the surface water – groundwater interaction to change. For example, river reaches which are neutral or losing to the groundwater system may become losing and maximum losing, resulting in further reductions in river flows.

The further reductions in frequency and magnitude of surface flooding under climate change will also impact on recharge of groundwater in floodplain areas. Soil salinity issues are also likely to be heightened with greater water scarcity and the decreased frequency and magnitude of flood events.

The MDBSY Project for the Murray region found that "of the future developments considered, the increases in groundwater extraction would have noticeable impacts on the hydrology of some of the Icon Sites" (CSIRO, 2008d). One example of the likely outworking of this finding is that the groundwater levels under Barmah-Millewa and Gunbower-Koondrook-Perricoota forests would be expected to fall by up to one metre in addition to the reduction in groundwater level under current levels of groundwater extraction.

Groundwater modelling was undertaken as part of the MDBSY study to assess the relative impacts of various climate scenarios and groundwater pumping on the state of the groundwater resources in the Southern Riverine Plains (Goode and Barnett, 2008). The modelling demonstrated that 42 per cent of current groundwater pumping (2004/2005 values as current) was sourced from surface water sources (river depletion) and that under future scenario modelling this increased to 58 per cent. The majority of the remainder of the groundwater volume extracted was sourced from captured or reduced groundwater evapotranspiration. The study also suggested that groundwater evapotranspiration was the groundwater discharge process that is most sensitive to climate change, and that this is likely to be mostly realized by losses in water availability to groundwater-dependent ecosystems. The report concludes that "current groundwater use has already and will continue to cause significant drawdown in groundwater levels across the Riverine Plains. As a result continued groundwater extraction at current rates will draw heavily on surface water resources and is possibly already impacting GDEs." River red gum forests including Koondrook-Perricoota are identified in this study as possible GDEs.

McFarlands State Forest

Chapter 9

Implications of water scarcity for environmental values

9.1 Overview

The best available science and knowledge indicates that the Riverina bioregion is likely to receive less rainfall and surface run-off and increased temperatures under climate change scenarios. This, along with river regulation, will continue to affect flooding regimes and ecological processes across the Riverina floodplain ecosystems. These changes will influence the structure and composition of forests, including river red gum forests and the environmental values they support.

The change in floodplain structure will be predicted. For example, wetlands in the outer floodplains are projected to diminish, including their stands of red gum woodlands. Depending on the co-species present at the time, these landscapes could transform into a range of other ecosystem types including box woodlands and shrublands.

As we move towards an uncertain future, clear management goals will be critical. For example it will be important to focus management on conserving components of the landscape that can be maintained and on managing for change in areas that are undergoing clear ecological transition.

This chapter supports **Step 4** of the analytical framework by assessing the implications of climate variability, climate change and consequent changes in water availability for:

- the ecological attributes of the red gum forests
- the threatened species that are supported by the forests
- each water management unit (WMU) and the associated forests.

The key findings of this chapter include:

- Reduced flooding is a major threat to the environmental values of river red gum forests of the bioregion. Twenty-three listed species are considered to be at moderate to high risk of regional population decline as a result of the predicted impacts of climate change and river regulation on flooding regimes.
- The Millewa forests are likely to transform into a river red gum woodland stand over the long term. However, they are large and heterogeneous and therefore likely to be more resilient to the impacts of climate change compared with other river red gum forests in the Riverina bioregion. They are likely to be a future refuge for threatened species such as superb parrot, barking owl, fishing bat and brush-tailed phascogale.
- The Koondrook-Perricoota and Campbells Island forests are also likely to transform into a river red gum woodland stand over the long term. Around 20 per cent of the river red gum community could transition to a derived scrub on the outer floodplain in the absence of future floods. However, like Millewa, the forests and woodlands provide further habitat security for threatened species.
- The Werai forests are likely to be the most degraded by reduced flooding and water scarcity. Over 40 per cent of the river red gum stand and associated wetlands could be lost within 50 years if current conditions persist. The overall area of functional habitat may not be sufficient to support key threatened species such as the barking owl and white bellied sea-eagle.
- The Murrumbidgee forests are likely to continue to decline with the loss of major wetlands fed by the Murrumbidgee River. Tall red gum forests will contract to areas regularly flooded and with access to subsurface aquifers. Some stands of red gum forests will also be lost on the outer floodplain.
- The Lachlan forests are under severe stress and are likely to continue to decline. Key species, such as the blue-billed duck, freckled duck and superb parrot, may disappear from this forest group over coming decades.
- The Barooga forests (and other State Forests immediately west of Albury) are least likely to change in terms of vegetation type or species composition (fauna and flora) due to relatively high water availability.

Australian Painted Snipe – source Wikipedia

- Wakool and Edward forests are likely to transform into a river red gum woodland stand over the long term with up to 40 per cent of river red gum woodland transitioning from red gum to derived copperburr or grassland in the next 50 years.

- The implication of ecosystem changes for species such as the regent parrot in the western river red gum stands is very unclear. The present range of the superb parrot in this area could decline by more than 99 per cent, unless it is able to respond by moving east.

9.2 Context

Predicting the future effects of climate change on Australia's biodiversity is a major challenge for various reasons:

- Climate change will interact with other stressors that are currently influencing biodiversity.

- Responses to the biophysical changes associated with climate change occur at the level of the individual species as well as whole ecosystems.

- Properties of ecosystems are often non-linear and can be difficult to understand and predict. A change in the average value of a variable, for example temperature, may not be as important ecologically as a change in the variability or extremes of that variable.

- Basic knowledge is generally lacking about limiting factors, genetics, dispersal and interactions among species that comprise Australian communities and ecosystems (Biodiversity and Climate Change Expert Advisory Group, 2009).

Despite this, it is understood that traits that make a species vulnerable to disturbance generally will also predispose that species to risk from rapid climate change (Biodiversity and Climate Change Expert Advisory Group, 2009), and that ecological systems and the biota they support will have to adapt rapidly to cope with climate change (for example, Brereton et al., 1995; Hughes, 2003).

Species most vulnerable will be those with:

- a narrow range of physiological tolerance to:
    - temperature
    - water availability
    - fire
- low genetic variability
- long generation times
- long time to sexual maturity
- specialised requirements for:
    - other species, for example, for a disperser, prey species or pollinator
    - particular habitat that may itself be restricted
- narrow geographic ranges
- poor dispersal strategies (Biodiversity and Climate Change Expert Advisory Group, 2009).

A number of studies in south-eastern Australia provide evidence that ecosystems and species are already responding to climate change. For example, the potential impacts of climate change on Australian vertebrates, including possible changes in competitive regimes, sex ratios and parasite transmission, have been reviewed by Stott (1994). Most recent studies have modelled the impacts of rainfall and temperature changes using BIOCLIM and have generally focused on threatened and vulnerable species (Hughes, 2003). Brereton et al. (1995) examined the impact of five greenhouse climate scenarios (CSIRO, 1992) on the distribution of 42 vertebrate species, most with threatened status, from south-east Australia. Of the 42 species studied, 24 were predicted to lose 90–100 per cent of their bioclimate with a 3°C rise in temperature. Similar general conclusions were reached by Dexter et al. (1995) for 58 species of threatened vertebrates, with more than 80 per cent of species predicted to experience contractions in their core climatic habitat under each of three scenarios used (cited in Hughes, 2003).

For Australia's birds, climate change is leading to changes in distribution of species, migration patterns, local abundance, phenology, community composition, and physiology, morphology and behaviour (Chambers et al., 2005). Examples of species likely to be severely affected by predicted increases in temperature include malleefowl, red-lored whistler and regent parrot (Chambers et al., 2005). Severe drought coupled with overgrazing from stock and rabbits are thought to be responsible for the dramatic decline and range contraction of the eastern subspecies of the thick-billed grasswren (NPWS, 2002). Soil moisture levels are expected to fall as a result of climate change, affecting frogs, skinks and soil invertebrates, thus directly affecting birds via their food supply (Williams et al., 2003).

The potential impact of climate change on Australian invertebrates has received less attention than for vertebrates (Hughes, 2003), although it could have major implications for ecological dynamics and species' capacity to adapt. Beaumont and Hughes (2002) used BIOCLIM to determine the current climatic ranges of 77 butterfly species restricted to Australia. They found that under an extreme scenario (temperature increase of 2.1–3.9°C by 2050), 92 per cent of species bioclimates were predicted to decrease, with 83 per cent declining by at least 50 per cent. Many herbivorous invertebrates are also likely be affected by reductions in plant quality as atmospheric CO_2 increases (Hughes, 2003). Reduced nitrogen content and increased carbon/nitrogen ratios in eucalyptus foliage, for example, have been associated with increased mortality and reduced digestive efficiency in the chrysomelid beetle (*Chrysophtharta flaveola*), consistent with studies for non-Australian insect species (Lawler et al., 1997).

The way ecosystems and species respond to a warming climate is not likely to be linear, but is likely to occur in rapid transformations after a long period of little change. Such rapid transformations usually occur when tipping points or critical thresholds are crossed. Increasing frequency and intensity of extreme climate events have the potential to more readily breach tipping points and thresholds. Most current projections of future climatic conditions are couched in terms of average temperature and rainfall, while researchers assessing impacts on particular systems and species are more likely to be interested in information on the extreme events (Biodiversity and Climate Change Expert Advisory Group, 2009).

Formation of novel ecosystems, abrupt changes in ecosystem structure and functioning, and surprising, counterintuitive outcomes will become more commonplace features of ecosystem responses to climate change in future. Over the next 100 years Australia could well experience changes in ecosystem type and distribution at least as great as those associated with the transition from the last glacial maximum to the present – a period of at least 5,000 years (Biodiversity and Climate Change Expert Advisory Group, 2009).

9.3 Implications for ecological attributes of the forests

The NRC has predicted the likely impact of climate change, including altered flooding regimes, on the five key ecological attributes of river red gum forest ecosystems outlined in **Chapter 4**:

- refugia/connectivity
- wetlands
- vegetation mosaics
- hollow-bearing trees
- coarse woody debris.

9.3.1 Refugia and connectivity

The forests provide significant areas of refugia for many species in the bioregion, and are the predominant forest remnants between and across which species are able to move in the landscape, via functional corridors (see **Chapter 4**).

For forests to survive over time it is necessary for young saplings to be recruited to the population of mature trees (eucalypts live for 200–500 years) which over time naturally thin to mature forests of greater inter-tree spacing (Sutherland et al., 2004).

In the absence of rejuvenating floods, the health of the river red gum forests will decline to a point at which the canopy will senesce completely, and the forest will no longer be able to produce seed and propagate. The limit of resilience of these river red gum forests will have been surpassed, resulting in long-term structural and floristic modification and loss of their capacity to support certain species.

If all the trees die without seeding, then in the absence of flooding the stand is likely to assume the structure of a derived community dominated by native tussock grasses and perhaps a few native shrubs, with possible influx of more arid understorey species (for example, chenopods such as copperburr) and weed species. It is not likely that other native canopy species such as black box will assume dominance or transition into these forests unless they are already present in the stand, or unless planting is considered as part of a silvicultural response, as seeds of most eucalypts fall close to the canopy of the parent tree (Binns, D, FNSW, pers. comm., 2009).

Given the above, and in light of assessments of river flows presented in **Chapter 8**, it is likely that climate change will result in some loss of refugia and functional connectivity on the higher floodplains, and that this loss may be amplified if other stressors such as overgrazing and habitat loss persist.

Conversely, the limit of resilience of river red gum forests on inner parts of the floodplains, which require relatively low commence-to-flows, is not likely to be breached in the absence of major disturbance factors. Instead, these areas should persist into the future, and will provide core areas of refugia in the Riverina over the longer term. Increased emphasis on protecting these climatic refugia and providing functional connectivity will be needed (Noss, 2001). SLATS analysis may be effective in the identification of potential refugia (Pennay, 2009).

Stressed river red gum in Niemur State Forest

9.3.2 Wetlands

Projected changes to rainfall and temperature in the lower Murray-Darling Basin will result in decreased surface water flows (Beare and Heaney, 2002), and a reduction in the frequency and size of flooding events. The magnitude of change to flooding frequency, extent and duration for selected forest stands and wetlands is discussed in **Chapter 8**. This will translate to a reduction in the net area of wetland, the duration or persistence of floodwater, and the frequency of wetland replenishment. These factors will impact on wetland fauna species, with less frequent breeding opportunities and possible declines or extinctions of local populations (Kingsford and Norman, 2002). The problem may be compounded by the recent incursion of the native giant rush (*Juncus ingens*) into open water wetlands and wetlands dominated by aquatic macrophytes (Webster, R, pers. comm., 2009).

The extent of wetland loss in the Riverina bioregion is difficult to predict although recent modelling studies in other areas provide clues as to the likely magnitude of the problem. For example, a study of the heavily regulated Macquarie River system and the associated Macquarie Marshes (Johnson, 1998; Australian Greenhouse Office, 2002; Herron et al., 2002) suggests that future decreases in mean annual flow may result in a 20–40 per cent reduction in area of the semi-permanent and ephemeral wetlands of the Macquarie Marshes by the year 2030. Rainfall decline is projected to be more acute in southern NSW than in northern NSW. Green (2003) reports a 30 per cent reduction in snow cover in the Snowy Mountains has been evident over the last 45 years, with reductions in snow cover expected to continue (Hughes, 2003).

Notwithstanding potential loss or reduction in numbers of some species, wetlands of the Riverina bioregion may also be able to support species not historically recorded in the region. Baxter et al. (2001) documented recent observations of the black-necked stork in the Channel Country in north-eastern South Australia, well to the south of its customary range. They suggested that monsoon flooding in Queensland and far-northern South Australia during the summer–autumn of 2001 may explain this unusual occurrence. Recent observations of the magpie goose in this region, a vagrant well outside its usual range, have also been noted (Baxter et al., 2001), with small numbers of this species turning up in the bioregion in the last few years (Webster, R, pers. comm., 2009). As species move parallel to climate gradients (Chambers et al., 2005), particularly from north to south and potentially from arid and semi-arid regions toward more temperate regions, they may well begin to use the river red gum forests.

9.3.3 Vegetation mosaics

The importance of vegetation mosaics in the river red gum forests was summarised in **Chapter 4**. The likely impact of climate change is difficult to predict, but the following is likely:

- incursion of river red gum onto the periphery of the larger, more open wetlands as they contract, with possible invasion of the native giant rush
- transition of the structure of river red gum communities from tall river red gum forests into open river red gum woodlands as ecosystem productivity declines as a result of loss of moisture
- possible senescence and mortality of river red gum and river red gum–black box woodlands on the higher floodplains, replaced by derived shrublands or grasslands, with periodic episodes of river red gum regrowth when flooding occurs, and/or
- maintenance of extent and location of sandplains woodlands dominated by cypress communities.

These points are discussed in more detail below in relation to individual responses of the major forests to climate change. The important consideration in the context of response to climate change is that the structural and floristic heterogeneity of the vegetation mosaic may not change over time, but its spatial configuration will. If the structural complexity of ecotones and vegetation mosaics is retained, even if they shift over time, then this will assist in protecting individual species reliant on ecosystem interfaces, including many woodland birds.

Another important benefit of mosaics is their capacity to buffer against phenological changes which are likely to have a major influence on dynamics of bird populations. Keatley and Hudson (2005) observed changes in flowering dates of 56 species of Australian plants over 22 years; 24 species had mean advancement of 13.6 days; remaining species had mean flowering of 20.8 days later. Greater floristic richness associated with vegetation mosaics provides a wider range of flowering times, and thus improves the capacity of species to persist.

9.3.4 Hollow-bearing trees

The importance of hollow-bearing trees in the river red gum forests is summarised in **Chapter 4**.

The density of hollow-bearing trees required to sustain viable populations of vertebrates is a function of the diversity of competing fauna species at a site, population densities, number of hollows required by each individual over the long term, and the number of hollows with suitable characteristics occurring in each tree. Accurately estimating hollow requirements in a given habitat is currently difficult due to the lack of this baseline information, and attempts at modelling have been limited. However, there is much circumstantial and some experimental evidence to indicate that hollows are a limiting resource, and that recovery of threatened hollow-using fauna would benefit from their greater availability (NSW Scientific Committee, 2007).

Abundance and species richness of hollow-dependent fauna have been correlated with the density of hollow-bearing trees in a wide range of studies (e.g. McIlroy, 1978; Meredith, 1984, Lindenmayer et al., 1991; Traill, 1991; Smith et al., 1994; Eyre and Smith, 1997; Kavanagh and Stanton, 1998; Alexander et al. 2002; Gibbons and Lindenmayer, 2002; Kavanagh and Wheeler, 2004). Evidence that hollows are a limiting resource in eucalypt forests includes fighting for hollow possession within and between species, successive use of the same hollow by different pairs of breeding birds, and progressively greater use of poor-quality hollows as population density increases or hollow availability decreases (Newton, 1994; Gibbons and Lindenmayer, 2002; Heinsohn et al., 2003). In some instances it is the prey species of a threatened predator that is limited by hollow availability. For example, in dry open forest habitats the common ringtail possum (*Pseudocheirus peregrinus*) is dependent on large hollows and only abundant in areas with large trees (Soderquist et al., 1999). As this species is an important prey item of the powerful owl (*Ninox strenua*), loss of hollows indirectly hinders recovery efforts for the predator.

Hollow-bearing trees in the river red gum forests provide nesting sites for several mammals and birds such as the brush-tailed phascogale, squirrel glider, inland forest bat, barking owl, regent parrot and superb parrot, and are associated with large, old river red gum trees. Yet the prognosis for retention of hollows in some of these forests is uncertain. The impact of climate change on hollow-bearing trees is difficult to predict. There may be a reduction in the area of the forest that supports hollow-bearing trees as old trees occupying infrequently flooded areas senesce and die. The dead stags may stand in the landscape and provide a resource for some hollow-dependent fauna over the medium term (possibly up to 50 years). However, as the large dead trees eventually rot and fall, these former forests will be devoid of hollows for many decades or centuries given the time taken to grow hollows suitable for refuge and nesting, and may never do so if trees fail to reach maturity after sporadic regeneration events. Even where hollows persist, declining canopy health and thus decreasing levels of nutrients in the foliage, nectar and pollen may preclude some species that normally occupy them.

Given a likely contraction of forests supporting hollow-bearing trees to areas of long-term refugia (as discussed earlier), accelerating the control or eliminating the existing stressors on availability of hollows provides a ‘starting point’ in building resilience in these systems (Biodiversity and Climate Change Expert Advisory Group, 2009). As outlined in Chapter 4 the natural density of hollow-bearing trees in mature and relatively undisturbed river red gum forests is in the range of 6–25 per hectare.

9.3.5 Coarse woody debris

Retention of coarse woody debris on the forest floor is important for ecological function in river red gum forests. It is likely that the major risk to fallen timber with climate change will be wildfire, and fire risk management, which can both renew and degrade environmental values. Changes in fire regimes as a response to climate change are highly likely in the future (Hughes, 2003). Increased temperatures will increase fuel dryness and reduce relative humidity, and this will be exacerbated in those regions where rainfall decreases (Howden et al., 1999).

Beer and Williams (1995) used the Macarthur Forest Fire Danger Index and the CSIRO (1992) used climate scenarios to predict changes in future fire incidence. The Macarthur Index incorporates climatic parameters such as air temperature, relative humidity and days since rain and fuel load to predict fire danger. The models indicate an increase in fire risk over much of Australia. More quantitative modelling by Williams et al. (2001) confirmed this general result, indicating an increase in the number of days of very high and extreme fire danger.

Management of coarse woody debris in the river red gum forests will need to balance ecological function and fire risk. Use of fire itself in periods of low-fire risk may provide an adaptive management response to fuel load build-up, recognising that retention of large fallen logs on the forest floor is important for these forests.

Timber residue after harvesting operation

Koala in Barooga State Forest

9.4 Implications for threatened species

The NRC has assessed the possible of impact on EPBC- and TSC-listed species known to be dependent on the key ecological attributes of the river red gum forests. Impacts of silviculture on hollow-bearing trees and dead fallen timber in river red gum forest are discussed in **Chapter 11**. These more site-specific impacts or stressors are relevant because the ecological function of disturbed forests is more vulnerable to climate change (for example, Noss, 2001; Biodiversity and Climate Change Expert Advisory Group, 2009).

It is recognised that climate change is likely to impact on individual species through other effects including:

- increased temperatures
- changes to rainfall seasonality
- changes in foliage nutrient properties
- impacts on herbivorous animals including invertebrates
- changes in nutrient cycling and soil nitrification
- introduction of novel pests
- changes in fire.

It is beyond the scope of this document to analyse species' responses to these additional effects and limited data is available to support such analyses.

A total of 68 species, species groups or populations listed under the EPBC or TSC Acts are tabulated in **Chapter 4**. **Table 9.1** below outlines the likely impacts to these species from predicted reductions in flooding. The level of impact (high, medium or low) generally reflects the species' reliance on the river red gum forests, and the effect of reduced flows on its habitat. Analysis in this table is drawn largely from species profiles provided by DECCW and available on its website.

Twenty-three listed species are considered to be at moderate to high risk of regional population decline as a result of the likely impacts of climate change and river regulation on flooding regimes. Twenty of these are listed as 'key species' in **Chapter 4**.

Reduced flooding and the increased frequency of high intensity fire are major threats to river red gum fauna, as they lead to contraction of habitat arising from senescence and mortality of forest and woodland, or transition of forest and woodland structures and distribution.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Ardea alba	Eastern Great Egret	Changes to flood regimes drying out previously damp grassland and wetland areas for foraging and breeding.	H	Migratory species that can move large distances to available water sources. Commonly occurs in disturbed environments provided water is present. Feeds in disturbed habitat but reliant on treed wetlands for breeding.
Botaurus poiciloptilus	Australasian Bittern	Reduced flow into wetland habitats, leading to reduction in current habitat health and further loss of suitable habitat.	H	Widely distributed but declining over south-eastern Australia. Likely to be listed in the future as endangered in NSW.
Crinia sloanei	Sloane's Froglet	Potential impacts to breeding habitat caused by reduced water quality and availability.	H	DECCW lists the following threats that are regionally relevant to this species: 1. Degradation of habitat and water quality through clearing and grazing 2. Changes in water availability, flow and flooding regimes in creeks, rivers, floodplains and wetlands (Cogger, 2000). The only recent records of this species are concentrated in the Murray region – it has disappeared from the northern part of its range.
Litoria raniformis	Southern Bell Frog	Potential impacts on timing of breeding as influenced by flooding and water levels. Impacts also likely on breeding habitat caused by reduced water quality and availability.	H	DECCW lists the following threats that are regionally relevant to this species: 1. Lack of appropriate flooding regime, i.e. flooding at the wrong time of the year, infrequent flooding, e.g. once every five or 10 years, waterbodies not lasting long enough for tadpoles to develop. 2. Alteration to natural flooding regimes from irrigation and river regulation, which may either divert water away from previously flooded wetlands or cause some areas to become permanently flooded and no longer receive rising water levels to trigger breeding. 3. Introduction of chemicals (pesticides, defoliants, etc.) either into waterbodies or directly onto animals. 4. Loss of aquatic and/or terrestrial habitat through draining of waterbodies or clearing for agricultural development.
Myotis macropus	Large-footed Myotis	Potential reduction in roosting and nesting habitat due to reduced water table.	H	DECCW lists the following threats that are regionally relevant to this species: 1. Reduction in stream water quality affecting food resources 2. Clearing adjacent to foraging areas.
Ninox connivens	Barking Owl	Potential significant reduction in nesting habitat due to reduced water table.	H	Found in river red gums in the region. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing and degradation of habitat, mostly through cultivation, intense grazing and the establishment of exotic pastures 2. Inappropriate forest harvesting practices that have changed forest structure and removed old-growth hollow-bearing trees.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Petaurus norfolcensis	Squirrel Glider	Significant impacts through reduction in river red gum (RRG) health, reduced tree hollows and nectar abundance due to reduced water table.	H	Prefers mixed species stands with a shrub midstorey. Requires abundant tree hollows for refuge and nest sites. DECCW lists the following threats that are regionally relevant to this species: 1. Loss and fragmentation of habitat 2. Loss of hollow-bearing trees 3. Loss of flowering understorey and midstorey shrubs in forests.
Phascolarctos cinereus	Koala	Potentially significant reduction in foliage quality due to reduced water table.	H	Koala has selective feeding habits in terms of foliage selection. Some natural populations along the Murray and translocated population near Narrandera in river red gums.
Polytelis anthopeplus monarchoides	Regent Parrot (eastern subspecies)	Significant impact on long-term reduction in forage and breeding habitat.	H	RRG forest is breeding habitat. Species distribution is restricted. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005). Climate change may constrain the ease of movement of this species between breeding and foraging habitats.
Polytelis swainsonii	Superb Parrot	Long-term reduction in forage and breeding habitat will have a significant impact.	H	River red gum forest is breeding habitat. Species distribution is restricted. Climate change will add additional impacts to movement corridors from breeding to foraging habitats.
Rostratula australis	Australian Painted Snipe	Changes to flood regimes impacting on inland wetland water levels.	H	The Murray-Darling drainage system appears to have been a key area for this species, as many records of this species come from this region.
Stictonetta naevosa	Freckled Duck	Potential impacts on roost sites due to changes to flood and flow regimes.	H	Breeds in large temporary swamps created by floods in the Bulloo and Lake Eyre basins and the Murray-Darling system, particularly along the Paroo and Lachlan rivers, and other rivers within the Riverina. The duck is forced to disperse during extensive inland droughts when wetlands in the Murray River basin provide important habitat. DECCW lists the following threats that are regionally relevant to this species: 1. Draining and clearing of wetland and swamp habitat 2. Changes to natural river flows and flood patterns as a result of dams, weirs and irrigation. Garnett and Crowley (2000) identified that the El Niño Southern Oscillation Index influences the abundance of this species.
Burhinus grallarius	Bush Stone-curlew	Change in flow may reduce condition of understorey for this species	M	Widely distributed over NSW and wider mainland Australia. Not limited to, but many records from river red gum forests.
Grus rubicunda	Brolga	Potential local impacts due to loss of foraging and breeding habitat caused by reduced flow and flooding.	M	A significant threat is the loss of wetland habitat through clearing and draining for flood mitigation and agriculture.
Grus spp.	Cranes (1 species in bioregion)	Drying of wetlands due to changes in flow regimes.	M	Refer to brolga above.
Haliaeetus leucogaster	White-bellied Sea-Eagle	Drying of wetlands will reduce foraging areas and reduced flood flows will impact on quality of breeding habitat.	M	Suitable habitat along the major rivers and permanent wetlands.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Lophoictinia isura	Square-tailed Kite	Potential indirect impacts on breeding habitat due to reduction in river red gum health due to flow changes.	**M**	DECCW lists the following threats that are regionally relevant to this species: 1. Disturbance to or removal of potential nest trees near watercourses 2. Clearing, logging, burning and grazing of habitats resulting in a reduction in nesting and feeding resources.
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	Potential indirect impacts on breeding/foraging habitat due to reduction in river red gum health due to flow changes.	**M**	Western edge of the species distribution utilising higher site quality RRG communities. Marginal habitat as this species occupies mostly upper levels of drier open forests or woodlands dominated by box and ironbark eucalypts, especially mugga ironbark (*Eucalyptus sideroxylon*), white box (*Eucalyptus albens*), grey box (*Eucalyptus microcarpa*), yellow box (*Eucalyptus melliodora*) and forest red gum (*Eucalyptus tereticornis*).
Ninox strenua	Powerful Owl	Potential significant reduction in nesting habitat due to reduced water table.	**M**	DECCW lists the following threats that are regionally relevant to this species: 1. Historical loss and fragmentation of suitable forest and woodland habitat from land clearing for residential and agricultural development. This loss also affects the populations of arboreal prey species, particularly the greater glider which reduces food availability for the powerful owl. 2. Inappropriate forest-harvesting practices that have changed forest structure and removed old-growth hollow-bearing trees. Loss of hollow-bearing trees reduces the availability of suitable nest sites and prey habitat. 3. Can be extremely sensitive to disturbance around the nest site, particularly during pre-laying, laying and downy chick stages. Disturbance during the breeding period may affect breeding success. Change in flows will result in reduction of tree health and availability of mature hollow-bearing trees, and will affect prey species' habitat condition.
Phascogale tapoatafa	Brush-tailed Phascogale	Significant impacts through reduction in river red gum health, reduced tree hollows and nectar abundance due to reduced water table.	**M**	Preferentially forages in large rough-barked trees, therefore river red gum is not the preferred food source. Females have exclusive territories of approximately 20–60 ha, while males have overlapping territories of up to 100 ha.
Plegadis falcinellus	Glossy Ibis	Drying of wetlands due to changes in flow regimes.	**M**	Breeds in the Lowbidgee floodplain.
Oxyura australis	Blue-billed Duck	Impacts to lakes and wetlands in which species resides. Reduction of foraging and breeding habitat due to reduced flow and water quality.	**M**	Non-breeding areas are present on the Murray River system. Breeding is normally in large permanent freshwater lakes, dams and swamps with dense aquatic vegetation.
Pachycephala inornata	Gilbert's Whistler	Declining state of river red gum, black box and associated shrub layer resulting from a reduction in flows may have an impact.	**M**	This species requires an intact shrub layer and therefore vegetation clearance would reduce potential habitat for this species. There are only three separate populations remaining in NSW, including the Edward River (McGregor, 2009) and lower Murray Valley forests. Whistlers do not make any regular large-scale movements. The pair holds and defends the territory all year round.
Anatidae	Waterfowl	Drying of wetlands due to changes in flow regimes.	**L–M**	Potential low to moderate impacts from altered flow regimes on species (excluding those mentioned above).

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Pyrrholaemus sagittatus	Speckled Warbler	Unlikely	**L–M**	There has been a decline in population density throughout its range, with the decline exceeding 40 per cent where no vegetation remnants larger than 100 ha survive. Large, relatively undisturbed remnants are required for the species to persist in an area. DECCW lists the following threats that are regionally relevant to this species: 1. Due to the fragmented nature of the populations and their small size the species is susceptible to catastrophic events and localised extinction. 2. Clearance of remnant grassy woodland habitat for paddock management reasons and for firewood. 3. Poor regeneration of grassy woodland habitats. 4. Modification and destruction of ground habitat through removal of litter and fallen timber, introduction of exotic pasture grasses, heavy grazing and compaction by stock and frequent fire. 5. Habitat is lost and further fragmented as land is being cleared for residential and agricultural developments. In particular, nest predation increases significantly, to nest failure rates of over 80 per cent, in isolated fragments.
Accipitridae	Raptors (3 species in bioregion)	Unlikely	**L**	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Amytornis textilis ssp modestus	Thick-billed Grasswren (eastern subspecies)	Unlikely	**L**	Prefers saltbush and shrubland habitats, and has not been recorded in the Riverina for approximately 90 years.
Anthochaera phrygia	Regent Honeyeater	Unlikely impact as the species in highly nomadic and is not known to be strongly associated with river red gum forests.	**L**	While the species has been recorded in river red gum forests, only three key breeding regions are known, in north-east Victoria (Chiltern-Albury), in NSW at Capertee Valley, and in the Bundarra-Barraba region of NSW. In NSW the distribution is very patchy and mainly confined to the two main breeding areas and surrounding fragmented woodlands.
Apus pacificus	Fork-tailed Swift	Unlikely	**L**	Unlikely to be impacted. Rarely on land.
Ardea ibis	Cattle Egret	Changes to pasture composition and drying of wetland breeding areas due to changes in flood regimes.	**L**	Adaptable migratory species that inhabits a variety of habitats. Potential impacts on breeding due to changes in flow as it utilises wetlands.
Cacatua leadbeateri	Major Mitchell's Cockatoo	Low/medium (locally) impact potential due to reduced availability of local drinking water impacts adjacent to breeding habitat.	**L**	Widely distributed over a broad range of habitat types in NSW and wider south-eastern mainland Australia (Simpson and Day, 2004), and not limited to river red gum forests. More likely in drier woodlands.
Calidris acuminata	Sharp-tailed Sandpiper	Drying of wetlands due to changes in flow regimes.	**L**	The sharp-tailed sandpiper is a summer migrant from Arctic Siberia, being found on wetlands throughout Australia.
Calidris ruficollis	Red-necked Stint	Drying of wetlands due to changes in flow regimes.	**L**	Utilises the margins of lakes and swamps.
Calyptorhynchus lathami	Glossy Black-cockatoo	Low impact potential due to reduced availability of local drinking water.	**L**	Widely distributed over a broad range of habitat types in NSW and wider eastern mainland Australia (Simpson and Day, 2004), and not likely in river red gum forests.
Chalinolobus picatus	Little Pied Bat	Impacts to vegetation health in river red gum sites.	**L**	Occurs in a range of vegetation communities.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Cinclosoma castanotus	Chestnut Quail-thrush	Unlikely	L	Prefers semi-arid open woodlands such as Mallee and Mulga (Simpson and Day, 2004), therefore RRG represents marginal habitat at best.
Climacteris picumnus victoriae	Brown Treecreeper (eastern subsp.)	Impacts on RRG forest health.	L	Distribution of this subspecies is relatively restricted to Victoria and eastern NSW (Simpson and Day, 2004).
Climactis affinis	White-browed Treecreeper population in the Carrathool LGA south of the Lachlan River and Griffith LGA	Potential reduction in roosting habitat due to reduced water table.	L	Marginal habitat as primarily occurs in a range of semi-arid and arid tall shrublands and woodlands across the southern half of Australia although it may also occur in habitats adjacent to those detailed above, including coolibah, river red gum and black box. DECCW lists the following threat as regionally relevant to this species: 1. Past overclearing of habitat resulting in fragmentation of remnants has been the main cause of decline of this population although ongoing decline in habitat quality is currently the major threatening process.
Dasyurus maculatus	Spotted-tailed Quoll	Potential impacts to quality of foraging and breeding habitat.	L	Few records in RRG forests along inland rivers (Menkhorst and Knight, 2004). DECCW lists significant threats to the species as being loss, degradation and fragmentation of habitat.
Falco hypoleucos	Grey Falcon	Unlikely	L	Occurs in a wide variety woodlands in arid and semi-arid habitats. RRG represents limited marginal habitat at best, given the extent of this species distribution throughout wider arid mainland Australia.
Gallinago hardwickii	Latham's Snipe	Drying of wetlands due to changes in flow regimes, loss of lignum and fringing vegetation.	L	Utilises the vegetated margins of lakes and swamps.
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	Potential reduction in foraging habitat (nectar abundance).	L	Prefers drier open forests, woodlands and Mallee. Two major threats include loss of nectar-producing eucalypts due to clearing of woodlands, and loss of hollows through tree-clearing.
Grantiella picta	Painted Honeyeater	Unlikely	L	Major threats to this species include removal of large, old trees with heavy mistletoe infestations; and degradation of open forest and woodland remnants, including thinning of trees bearing mistletoe.
Hamirostra melanosternon	Black-breasted Buzzard	Unlikely	L	Significant threats include the degradation of foraging habitat through tree clearing, and clearing of trees along inland watercourses.
Hirundapus caudacutus	White-throated Needletail	Unlikely	L	A migratory species; unlikely to be impacted. Rarely on land.
Hydropogne caspia	Caspian Tern	Drying of wetlands due to changes in flow regimes.	L	Nomadic species that utilises large water bodies opportunistically.
Hylacola cauta	Shy Heathwren	Unlikely	L	Significant threats include loss of habitat due to clearing, leading to a decline in distribution and abundance; and fragmentation, resulting from clearing or degradation of habitat, leading to a reduction in size of populations and increase the extent to which they are isolated.
*Lasiorhinus krefftii**	Northern Hairy-nosed Wombat	Unlikely	L	Unlikely to be present – presumed extinct (in NSW).
Lathamus discolor	Swift Parrot	Unlikely	L	River red gum flowering occurs outside the peak period of seasonal occurrence of Swift Parrot in NSW; however, it may feed on lerps in river red gums. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Leipoa ocellata	Malleefowl	N/A	**L**	Marginal habitat – predominantly inhabit mallee communities, preferring the tall, dense and floristically rich mallee found in higher rainfall (300–450 mm mean annual rainfall) areas. Less frequently found in other eucalypt woodlands (e.g. mixed Inland grey box and yellow gum or bimble box, ironbark-callitris pine, callitris pine, mulga (*Acacia aneura*), and gidgee (*A. cambagei*). Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	Unlikely	**L**	DECCW lists the following threat that is regionally relevant to this species: 1. Clearing of woodlands, resulting in loss and fragmentation of habitat.
Neobatrachus pictus	Painted Burrowing Frog	Impacts on breeding timing due to changes in flood regimes, but not often associated with flooding along major channels.	**L**	This species has been found in only two locations in NSW – 120 km north-west of Mildura on the private land managed for conservation by Australian Wildlife Conservancy, and Scotia Sanctuary, adjacent to the South Australian border and 22 km west of Pooncarie. To date, less than 30 individuals have been found in NSW. DECCW lists the following threats that are regionally relevant to this species: 1. Sand mining and other activities, e.g. cultivation, that disturb the soil in which this species burrows. 2. Altered flooding regimes (timing, frequency and extent of flooding) may prevent the emergence and breeding activities of this species. 3. Soil compaction from machinery and domestic stock. 4. Loss of leaf litter, fallen timber, bark and other groundcover. 5. Pollution of water bodies from farming and industrial chemicals.
Neophema pulchella	Turquoise Parrot	Potential reduction in habitat due to reduced water table.	**L**	Infrequently occurs in river red gums. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing of grassy-woodland and open forest habitat 2. Loss of hollow-bearing trees.
Nyctophilus corbeni	Greater Long-eared Bat (south-eastern form)	Potential reduction in roosting habitat due to reduced water table.	**L**	Marginal habitat – inhabits a variety of vegetation types, including mallee, bulloke (*Allocasuarina leuhmanni*) and box eucalypt dominated communities, but it is distinctly more common in box/ironbark/cypress-pine vegetation that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland.
Pachycephala rufogularis	Red-lored Whistler	Unlikely	**L**	Found in mallee woodland with a shrub layer, usually of broombush and native pine such as mallee pine (*Callitris verrucosa*), with occasional patches of spinifex and emergent mallee, forming a relatively dispersed canopy. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Pedionomus torquatus	Plains-wanderer	Unlikely	**L**	Occurs in grassland. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Petroica rodinogaster	Pink Robin	Unlikely	**L**	On the mainland, the species disperses north and west and into more open habitats in winter. Breeds in rainforest and therefore breeding habitat unlikely to be impacted.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	Unlikely	L	Primarily inhabits open box-gum woodlands on the slopes, and box-cypress-pine and open box woodlands on alluvial plains. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing of woodland remnants 2. Heavy grazing and removal of coarse, woody debris within woodland remnants.
Recurvirostridae, Charadriidae	Shorebirds (Six species in bioregion)	Drying of wetlands due to changes in flow regimes.	L	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Saccolaimus flaviventris	Yellow-bellied Sheathtail bat	Potential reduction in roosting habitat due to reduced water table.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Foraging habitats are being cleared for residential and agricultural developments, including clearing by residents within rural subdivisions. 2. Loss of hollow-bearing trees; clearing and fragmentation of forest and woodland habitat.
Scolopacidae	Snipe	Drying of wetlands due to changes in flow regimes.	L	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Stagonopleura guttata	Diamond Firetail	Indirect impacts on groundcover composition (foraging) due to changes to flood regimes.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Clearing and fragmentation of woodland, open forest, grassland and mallee habitat for agriculture and residential development, and firewood collection 2. Modification and destruction of ground and shrub layers within habitat through removal of native plants, litter and fallen timber; introduction of exotic pasture grasses; heavy grazing and compaction by stock; and frequent fire 3. Risk of local extinction due to small, isolated populations.
Tiliqua occipitalis	Western Blue-tongued Lizard	Unlikely	L	Prefers arid and semi-arid sandy habitats; river red gum represents marginal habitat at best. Widely distributed through southern mainland Australia (Cogger, 2000).
Tringa nebularia	Greenshank	Drying of wetlands due to changes in flow regimes.	L	Utilises the margins of lakes and swamps.
Tringa stagnatilis	Marsh Sandpiper	Drying of wetlands due to changes in flow regimes.	L	Utilises the margins of lakes and swamps.
Tyto novaehollandiae	Masked Owl	Potential reduction in nesting habitat due to reduced water table.	L	Usually breeds in moist eucalypt forested gullies, therefore impacts on breeding habitat are unlikely. DECCW lists the following threats that are regionally relevant to this species: 1. Loss of mature hollow-bearing trees and changes to forest and woodland structure, which leads to fewer such trees in the future. 2. Clearing of habitat for grazing, agriculture, forestry or other development.
Vespadelus baverstocki	Inland Forest Bat	Potential reduction in roosting habitat due to reduced water table.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Removal of old hollow trees 2. Predation by feral cats at roost sites 3. Degradation of vegetation and the consequent reduction in arthropod prey diversity and abundance.

9.5 Likely impacts on the environmental values of water management units

9.5.1 Likely impacts on the Millewa forests

Summary

The Millewa forests are likely to be more resilient to adverse impacts of climate change compared with other river red gum forests in the Riverina bioregion, as indicated by recent analyses of condition change (for example, Pennay, 2009). The forest is large and heterogeneous, providing opportunities for species to move and adapt within it.

The forests require relatively low flows (compared with downstream forests) to achieve reasonable levels of flooding, so a large proportion will retain its ecological structure and function. As flows > 25,000 ML/day are unlikely to occur under climate change at the frequency and duration required for sustaining river red gum forest in its current form, it is likely that some tall river red gum forest will transition to river red gum woodland, but with critical habitat such as large hollow trees and coarse woody debris persisting. Up to 5 per cent of river red gum and some wetland may be lost, but most will remain to provide a major refuge for species using river red gum. Together with the Barmah Forest to the south, Millewa is likely to be a future refuge for threatened species such as superb parrot, barking owl, fishing bat and brush-tailed phascogale.

Vegetation distribution response

In presenting the likely ecological response to reduced flows through the Millewa forests, it is assumed that 18,300 ML/day can be delivered to the Barmah-Millewa forest into the future at the frequency and duration required for sustaining river red gum vegetation. This flow is below that required to achieve the interim ecological objectives stated within the Icon Site Management Plan for the Barmah-Millewa forest to 'ensure healthy vegetation in at least 55 per cent of the area of the forest (including virtually all of the giant rush, moira grass, river red gum forest, and some river red gum woodland)' (MDBC, 2006a).

Modelled inundation extents (**Chapter 8**) indicate that only 46 per cent of river red gum very tall forest, 14 per cent of river red gum tall open forest and 3 per cent of river red gum–box woodland will be regularly inundated in Millewa at 18,300 ML/day.[1] The implications of this reduced extent of inundation on changes to vegetation structure and composition within the Millewa forests is difficult to predict in the absence of long-term monitoring data, and is complicated by a poorly understood sub-surface hydrology. However, broad assertions can be made about the distributional and structural response of vegetation communities in Millewa to changed flooding regimes, and likely ecological responses of key species that characterise these communities.

Along with the Albury to Tocumwal cluster of forests, the Millewa forests are arguably more resilient to adverse impacts of climate change as commence-to-flow volumes are generally lower. Thus it is expected that a relatively high proportion of the Millewa forests will retain their broad structure and composition, particularly those forests areas inundated by the 18,300 ML/day flood.

Southern Bell frog

The magnitude and type of change to river red gum forests occupying more elevated parts of the Millewa floodplain, such as areas immediately to the north and south of Moira Lake, are dependent on hydrological behaviour and access to sub-surface water. Change is likely to vary considerably across the extent of forest, with some pockets supported over a longer period by sub-surface aquifer flow while others are not.

It is difficult to quantify the extent of the Millewa forests that are susceptible to complete loss of river red gum forest and woodland through water stress. Given the relative ease of securing environmental flows in this forest it is unlikely that more than 10 per cent of the forests will be lost over the next 50 years unless flow conditions worsen considerably. Those lost are likely to be largely river red gum woodland stands, some of which may continue to support scattered black box or other box species.

It is likely that a proportion of very tall river red gum forest and tall open river red gum forest will assume a structure and vigour of river red gum woodland stands over the long term. Trees will generally survive but regenerating trees may not achieve the size and height of the parent trees. Sedge and herb elements of the understorey are also likely to be replaced by tussock grasses, and possibly native hardy shrubs.

Other vegetation communities in the Millewa forests are likely to respond in different ways to a changed flooding regime. The various wetlands are likely to contract and be replaced by river red gum at their margins, with the exception of those subject to regular flooding. The river red gum–box communities may persist, with box species becoming more dominant over the long term. Areas of derived grassland or scrub may replace dying river red gum forest on the outer floodplain over the long term.

Ecological attributes response

The Millewa forests contain a complex mosaic of integrated flood-dependent communities including:

- Swamps and marshes in the lower, frequently flooded areas where water can pond to a degree.

[1] Only 16 per cent when very tall river red gum forest and tall open river red gum forest are combined.

- Rush beds surrounding swamps and marshes, providing nesting and feeding habitat for egrets, spoonbills, ibis, waterfowl and frogs.
- Lakes and billabongs, generally deeper water environments, providing habitat for biota such as fish and macro-invertebrates. These are also important in providing feeding areas for large colonial bird breeding events.
- Localised Moira grass plains which during floods are highly significant as breeding and feeding habitat for colonial breeding waterbirds like egrets, herons, spoonbills and marsh terns.
- River red gum forest of various types depending on inundation, with the lower elevation areas supporting larger and denser river red gum forest.
- Black box woodland in the high, drier zones (MDBC, 2006a).

The relatively large size of the Millewa forests (in combination with the Barmah Forest to the immediate south) and its heterogeneity, as well as the comparatively low flows required to flood large sections of the forest, provide its flora and fauna residents with a reasonable level of long-term security against the impacts of climate change. This is important as they provide habitat for large numbers and a diverse group of fauna, with 54 species of waterbird known to breed (Leslie, 2001), and many arboreal and ground-dwelling fauna (Webster et al., 2003). Amphibia, mammals and fish all benefit from the diversity of habitat, its large size, and frequent flooding. Millewa is arguably the best refuge for many fauna species dependent on river red gums along the Murray, particularly when considered in the context of the adjacent Barmah Forest, which adds to the overall extent of contiguous forest.

Top: Superb parrot. Bottom: Barking owl.

9.5.2 Likely impacts on the Koondrook-Perricoota forests

Summary

Koondrook-Perricoota forests and Campbells Island forests provide further habitat security for ecological communities and individual species associated with river red gum in the Riverina bioregion. The forests will continue to provide habitat for a range of resident communities and species into the future. Modification to vegetation community structure is likely to be significant given recent trends (Pennay, 2009), with much of the river red gum forests likely to transition to lower-productivity river red gum woodland. Critical habitat containing large trees and fallen dead timber is likely to persist across the majority of the forest. Perhaps 20 per cent of the river red gum community is likely to transition to a derived scrub on the outer floodplain in the absence of future floods, but sufficient core habitat is likely to remain to provide a second major refuge for native species, particularly considering its adjacency to the Gunbower forests in Victoria. Species such as barking owl, Gilbert's whistler, and hooded robin should be supported in Koondrook-Perricoota forests under projected flood regimes.

Vegetation distribution response

In presenting the likely ecological response to reduced flows through the Koondrook-Perricoota forests, the minimum regime as modelled under the Works and Measures Program of 2,000 ML/day is selected, delivered into the forest via the Koondrook-Perricoota Forest Flood Enhancement Works. An estimated 34 per cent of the forest would be inundated under this scenario. It is acknowledged that a range of flows would be delivered to the forest through operation of the Enhancement Works. This assessment adopts this event as a base and also considers the range of factors influencing flows to the forests.

The implications of this reduced volume on changes to vegetation structure and composition within Koondrook-Perricoota is difficult to predict in the absence of long-term monitoring data, and is complicated by a poorly understood sub-surface hydrology. However, broad assertions can be made about the distributional and structural response of vegetation communities to changed flooding regimes, and likely ecological responses of key species that characterise these communities.

Located downstream of the Millewa forests, the Koondrook-Perricoota forests are likely to change somewhat more dramatically than Millewa in future, despite the proposed engineering works.

In general terms it is likely that a considerable proportion of the tall and very tall open red gum forests will transition over time to a structure and vigour of typical river red gum woodland stands. Trees will generally survive but regenerating trees may not achieve the size and height of the parent trees. Sedge and herb elements of the understorey are also likely to be replaced by tussock grasses. In the absence of regular flooding the health of the river red gum woodland is likely to continue to decline to a point at which the canopy may senesce completely, with the forest no longer be able to produce seed and propagate. Similar to Millewa, parts of the stand are likely to assume the structure of a derived grassland or chenopod community.

It is difficult to quantify the extent of the Koondrook-Perricoota forests which are susceptible to complete loss of river red gum forest and woodland through water stress. However, it is possible that 20–25 per cent of the river red gum forest may be lost over the next 50 years, possibly more if flow conditions worsen. Those areas lost would most likely be within the woodland communities dominated by river red gum, some of which may continue to support scattered black box or other box species, but some of which may convert to shrubland or grassland.

Other vegetation communities in the Koondrook-Perricoota forests are likely to respond in different ways to a changed flooding regime. The various wetlands are likely to contract and be replaced by river red gum, with the exception of those subject to regular flooding. The river red gum–box communities would likely persist, however, with box species likely to become more dominant over the long term.

Ecological attributes response

The river red gum forest in Koondrook-Perricoota is the second largest in Australia behind Barmah-Millewa, with black box woodlands, inland grey box woodlands, reed beds and less-dominant grassland communities. The region comprises a diverse assemblage of flora and fauna, including species of state, national and international significance, and the wetlands themselves are of international importance. The site has particular significance for breeding colonies of intermediate egret, little egret, eastern great egret and nankeen night heron (MDBC, 2006b).

Most of the ecological values documented for these forests concern vegetation and birds (MDBC, 2006b). These ecological values are threatened by water regulation, weeds, timber harvesting, in-stream barriers to fish and water movement, inappropriate fire regimes, pests and grazing. Water regulation and altered flow regimes present one of the highest risks to ecological function. There has been a 58 per cent reduction in small floods, 77 per cent reduction in medium to large floods and 55 per cent reduction to large floods (URS, 2001, cited in MDBC, 2005), resulting in a decline in forest health (Turner and Kathuria, 2008; Pennay, 2008). Impacts from the altered flow regime include:

- reduced connectivity between wetlands and the river
- reduced fish breeding
- decreased diversity
- loss of wetland types
- reduction in wetland extent
- increased weed invasion (MDBC, 2005).

Similar to Millewa, the Koondrook-Perricoota forests are reasonably large and should offer a reasonable level of resilient habitat for fauna assemblages in the future. Habitat should be retained in the long term for hollow-dependent species such as barking owl, arboreal mammals and various microchiropteran bats. Much of the forest is likely to retain a structure and mosaic which facilitates continued movement of these species. The diversity of permanent wetlands subject to planned environmental flows should also provide refuge for wetland-dependent species such as egret and heron species and the giant banjo frog.

9.5.3 Likely impacts on the Werai forests

Summary

Of the three Ramsar sites, Werai forests are likely to be most degraded by reduced flooding and water scarcity. Over 40 per cent of the river red gum stand and associated wetlands could be lost within 50 years if current conditions persist, or worse if conditions deteriorate. As a result resident species are likely to be forced into a contracting area of core habitat. Most of the black box woodland is likely to persist in the Werai forests, as this does not appear to have declined in the past 20 years relative to river red gum (Pennay, 2009). However, the overall area of functional habitat may not be sufficient to support species with large home ranges such as the barking owl, and may not support the breeding requirements of wetland-dependent fauna such as colonial nesting waterbirds and white-bellied sea-eagle. Breeding success and the continued existence of such species within the southern bioregion may depend on the health and persistence of other functional forests, where change is likely to be less severe.

Vegetation distribution and ecological values response

While no specific hydrologic modelling is available, the potential ecological impact of hydrological change in the Werai forests is likely to be more severe than that in the Millewa and Koondrook-Perricoota forests. Flows of between 3,000 and 13,000 ML/day downstream of Steven's Weir are required for broad-scale inundation of the Werai Forests (GHD, 2009).

If predicted flow reductions (Scenario Cmid, see **Chapter 8**) eventuate, the likely implication for the Werai forests is at least a 50 per cent decline in the distribution of very tall and tall open river red gum forests as they transition to either:

- river red gum woodland (and assume a changed floristic composition in the understorey), or
- derived grassland/chenopod scrub with widespread canopy mortality.

The overall area of river red gum is also likely to decline as the woodland stands on the less frequently watered parts of the forest senesce and die, replaced by a derived grassland/ chenopod scrub. The extent of loss of woodland areas might be as much as 40 per cent in the Werai forests over the next 50 years if current flow projections are maintained. Over 90 per cent of river red gum stands these forests are currently unhealthy (GHD, 2009).

The forecast magnitude of change in the Werai forests raises questions about the capacity of some species to persist, particularly those with large home ranges such as forest owls and raptors, and wetland-dependent species such as little pied cormorant. Of the three Ramsar sites, Werai is most susceptible to major ecological change and local species extinction.

Despite the unfavourable outlook for the Werai forests it is important to consider that the contraction of the river red gum ecosystem does not necessarily mean that rejuvenation in future is not possible if long-term flooding regimes are restored. The geomorphic characteristics of these and other areas, to which river red gum stands have adapted over thousands of years, are not themselves likely to shift in response to climate change. Because river red gum seeds are sometimes carried significant distances by floodwaters, severely stressed and dead stands of river red gum could conceivably recover following a major flood, as a result of deposition of seed from elsewhere on the floodplain and subsequent regeneration. However, the ecological function of such a stand is likely to be compromised as large hollow trees are replaced by regenerating saplings of lower habitat value, and given persistence of favourable conditions, stands might not assume an adequate level of functional habitat until 200–500 years (for example, Sutherland et al., 2004).

9.5.4 Likely impacts on the Murrumbidgee wetlands

Summary

The Murrumbidgee wetland areas have declined appreciably over the past 50 years, largely as a result of clearing and draining for irrigation, with consequent decline in waterbird numbers in the catchment. This trend is likely to continue with climate change as central-west NSW experiences drier, hotter conditions. Important wetland species such as Australasian bittern, blue-billed duck, freckled duck and southern bell frog are likely to decline further as breeding habitat contracts.

Vegetation distribution and ecological attributes response

While no specific hydrologic modelling is available, the Murrumbidgee system is forecast to receive less floodwater, with negative implications for the Mid-Murrumbidgee and the Lowbidgee Floodplain Wetlands. As with other river red gum communities, the vegetation response to lower flows is likely to be a contraction of tall red gum forests to regularly flooded zones and sub-surface aquifers, and loss of some stands on the outer floodplain. Ultimately black box may not survive because the flow regime to these parts of the floodplain has changed so much from when they were recruited (Kingsford and Thomas, 2001). These are likely to transition into native grasslands.

There is also likely to be continued loss of the extent of the major wetlands fed by the Murrumbidgee. Kingsford and Thomas (2001) used satellite imagery (Landsat MSS) for the period 1975 to 1998 to determine the extent of wetland loss in the Lowbidgee Wetlands, and bird counts to record losses in bird numbers from previous bird censes. The research found that to 2001, around 58 per cent of the floodplain wetlands had been lost, much of the damage occurring between 1975 and 1998. Of those remaining at the time, 44 per cent were degraded, with the floodplain vegetation having little chance of returning to health. The authors observed that flood-dependent aquatic vegetation at the margin of wetlands exhibited reduced health and poor canopy growth. Aquatic macrophytes were unlikely to establish except during extreme events. Even within core areas of the wetlands, reduced health with poor canopy growth was observed, apart from along the floodways where macrophytes such as cumbungi were well established in response to increased flows. Correspondingly lignum was observed to be in poor health in floodways because of increased flooding.

Waterbird numbers were observed by Kingsford and Thomas (2001) to have collapsed by more than 80 per cent since 1983. Maher (1990) considered that the Lower Murrumbidgee floodplain was of national importance for nine species of waterbird (including Australasian bittern and freckled duck). For the six species for which data were available, Kinsgford and Thomas (2001) provided evidence that numbers of all six had declined, particularly after 1995, and that most other individual waterbird species had declined in numbers over an 18-year period. Kingsford and Thomas (2001) also suggest that invertebrates, fish, frogs (including the nationally significant southern bell frog) and water plants which the birds feed on are in decline because of reduced habitat area, and that long-term reduction in breeding is expected.

Wetlands in Wilbriggie State Forest on the Murrumbidgee River

Other studies have also shown a general decline in the condition of the Murrumbidgee River forests and their wetlands and floodplain (for example, Jansen and Robertson, 2005; Hillman et al., 2000). This is supported by SLATS data presented by Pennay (2009), which shows that open wetland areas such as Coononcoocabil Lagoon and Yaradda Lagoon have declined in the past 20 years mainly through clearing for cropping and irrigation.

9.5.5 Impacts on the Lachlan wetlands

Summary

The Lachlan River feeds the Booligal Wetlands and Great Cumbung Swamp. Similar to the Lowbidgee Wetlands on the Murrumbidgee to the south, these wetlands are under severe stress as a result of river regulation and climate change, with flood events, breeding populations of waterbirds and canopy cover in decline (Pennay, 2009). Wetland fauna such as blue-billed duck and freckled duck may not be supported by these wetlands in the future. The associated river red gum stands of the Lachlan River are known to support superb parrot and other key species. If the condition of the Lachlan deteriorates further, such species may also disappear from the Lachlan over coming decades.

Vegetation distribution and ecological values response

The major implication for reduced flows into the Booligal Wetlands and Great Cumbung Swamp relates to amphibian habitat and waterbird breeding habitat. The Great Cumbung Swamp comprises one of the largest reed beds in south-eastern Australia and provides important habitat for waterbirds, amphibians and other fauna (Inland Rivers Network, 2007).

River regulation of these systems has resulted in an increase in the number of trees exhibiting signs of stress in the Booligal Wetlands (Armstrong et al., 2009; Pennay, 2009). Without periodic flooding (as frequent as one in three years for optimal growth), the health of river red gums will decline and continued drought will result in loss of seed production, recruitment and crown cover. These changes will have flow-on effects through the ecosystem, with implications for the food chain and thus function of the system. In the absence of a healthy tree crown there will be insufficient leaf fall to form a detritus layer, which flows onto the abundance of detritus-dependent flora and fauna, affecting the food supply of higher organisms such as fish and waterbirds. Quantifying the impact is not possible.

The breeding cue for many of the waterbirds and migratory shorebirds recorded in Booligal Swamp is flooding (Scott, 1997) so that loss of species from these systems (such as the blue-billed duck and freckled duck) may be anticipated in the absence of periodic flooding events. Without substantial change to water allocation and flooding, there will be continual demise in the health of water-dependent vegetation communities, irregular instances of breeding in waterbirds and declines in amphibian species. Terrestrial vegetation dominated by grasses and shrubs are likely to encroach into former wetlands and riparian sites.

Tree marked for retention in Superb Parrot habitat

9.5.6 Impacts on other forests and riparian zones

The relatively reliable floodwater received in Barooga and other State Forests immediately west of Albury, and its relatively high annual rainfall, suggests that this system is least likely to change in terms of vegetation type or species composition (fauna and flora). Tall river red gum forest and river red gum–yellow box woodland stands should maintain their level of productivity and regeneration potential, and should continue to support key ecological values. These small forests provide a refuge for several fauna species known to rely on river red gum along the Murray, including powerful and barking owls, koala, brush-tailed phascogale and squirrel glider.

In contrast, the Wakool and Edward forests are relatively low in an over-allocated catchment and are thus susceptible to low water allocations, as water is fed downstream for irrigation and domestic supply, or is absorbed upstream for irrigation or environment. They also receive a low annual rainfall. The vegetation response in the Wakool and Edward forests is likely to be considerable, with most of the very tall and tall open river red gum forest assuming a structure and productivity of open river red gum woodland over the long term, and up to 40 per cent of river red gum woodland transitioning from red gum to derived copperburr or grassland in the next 50 years.

The major icon species of the lower Murray is the regent parrot which is reliant on hollow-bearing trees within river red gum forests. The implication of a changing ecology in the western river red gum stands for species such as the regent parrot is unclear. Chambers et al. (2005) predict that under certain climate change scenarios the present range of the species could decline by more than 99 per cent, unless it is able to respond by moving east. Based on Pennay (2009) and the likely predicted flows in the lower Murray, available habitat within the regent parrot's current range are likely to be reduced over the long term.

Dead habitat tree in Booligal State Forest

Chapter 10

Implications of water scarcity for economic and social values

10.1 Overview

A sustainable future for the Riverina will depend on the development of less water-dependent industries. The decline in the irrigated agricultural industry has already had a large impact on the bioregion, and the future of the regional economy and its communities will ultimately depend on the transformation of primary industries in response to a future with less water.

This chapter looks at the likely social and economic impacts on the Riverina bioregion of less water through river regulation and a changing and variable climate, by:

- considering the general socio-economic impacts of water scarcity on the region
- assessing likely sustainable yields in the forestry industry
- considering possible alternatives for the forestry industry under a water-scarce future
- analysing the adaptive capacity of forestry-dependent towns and communities
- proposing approaches for building the adaptive capacity of the region's communities.

It supports Steps 3 and 4 of the analytical framework by:

- assessing long-term sustainable yields of timber able to be supported under predicted future flooding regimes
- assessing the implications for the future of the forestry industry of changes in quality and quantity of timber yields
- assessing the ability of local communities to adapt to changes in the forestry industry and, more broadly, to the predicted impacts of climate change.

The key findings of this chapter are:

- While the Riverina bioregion as a whole is likely to have the capacity to adapt to the impacts of changes in climate through the development of new technology and new industries, some existing industries – including the red gum forestry industry – are particularly vulnerable to futures with scarce water.
- Long-term sustainable yields of quota and ex-quota sawlogs are expected to be reduced by up to 70 per cent due to the combined effects of river regulation, enhanced forest management prescriptions, the current drought and climate change. The quality and size of sawlogs is also likely to decline. However, evidence clearly suggests that higher yields are possible if more favourable flooding regimes can be achieved. It would also be possible to continue higher levels of sawlog harvesting in the near term, for a defined period of time, as part of a managed industry transition strategy.
- Short-term increases in volumes of low quality timber and firewood may be realised if ecological thinning, consistent with the principles identified in **Chapter 11**, is applied in some areas of the river red gum forests. This may benefit businesses which are able to utilise this resource.
- The future river red gum sawmilling and processing industry is likely to be smaller than at present. On the basis of current sawmill operations, long term sustainable yields of sawlogs from public land under assumed likely flooding regimes are expected to be sufficient to support only one, or perhaps, two fixed location sawmills. In the short to medium term, it would be possible sustain higher volumes of sawlogs than are available over the long term as part of a managed industry transition strategy. New technologies may also help recover greater value from smaller and poorer quality logs.
- The long term yield estimates presented in this chapter are conservative, but realistic on the basis of the available evidence. Further modelling, using Forests NSW's FRAMES and related software at a Water Management Unit level and adjusted for the changed forest structure and growth rates of contemporary river red gum forests, will provide more precise estimates of future yields, product classes, and wood supply options.
- There is potential for the establishment of new forestry-based industries given a sufficiently high carbon price, technology development and industry innovation. New energy generation technologies and appropriately sited forest plantations for carbon sequestration are two possible examples.
- While forest-based industries are a small part of the NSW Riverina regional economy[1], the potential decline in size of the current red gum forestry industry would have a significant impact on some smaller towns.
- The twin towns of Barham-Koondrook and the town of Mathoura have less capacity to adapt to changes in climate than other towns and have the highest reliance on the red gum forestry industry. Conversely, Deniliquin appears to exhibit the greatest resilience to potential climate change impacts, with a lower vulnerability to change, a greater degree of industry diversity and low reliance on the red gum forestry industry.
- The capacity of industries in the region and their dependent communities to adapt to changes in climate could be supported through a variety of approaches. These include information provision, skills and capacity development, and investment in infrastructure and programs to support regional development.

10.2 Potential socio-economic impacts of water scarcity

The combined impacts of river regulation, climate variability and predicted climate change are expected to reduce water availability in the Riverina bioregion. This could result in increased competition for available water and further reductions in water to river red gum forests. Responding to potential water scarcity may be within the adaptive capacity of the broad Riverina bioregion. However, there are likely to be significant socio-economic impacts at a local level.

10.2.1 Broad impacts on the Riverina bioregion

Within the Riverina bioregion, employment is dominated by the following sectors: agriculture, fisheries and forestry and

[1] The size and structure of the NSW Riverina regional economy is discussed in more detail in **Chapter 5**.

related processing operations; education and training; and retail (discussed in **Chapter 5**). Tourism is also an important contributor to the NSW Riverina regional economy.

The socio-economic impacts on the region from less water may potentially include the following:

- changes in land use
- changes in industry productivity
- impacts on export earnings and the viability of rural communities
- dislocation of industries, infrastructure and regional economies as current economic activities cease to be viable
- increased competition for water, leading to reduced economic and/or environmental sustainability
- insufficient water to sustain existing highly water-dependent industries (e.g. dairy operations)
- reduction in agricultural crop production and associated increases in annual crop variability (quality and quantity)
- reduction in sustainable forestry yield due to lower growth rates from reduced flooding
- a reduction in viability of dairy, pig and poultry (meat and egg) production due to an increase in feed prices
- increased loss of infrastructure from extreme natural events
- changes in water quality as a result of rising river salinity and associated decline in river health affecting agriculture due to the reduced productivity of water used for irrigation – impacting on industrial and residential users (Hacker et al., 2006; Beare and Hearney, 2002).

The industries that are the most significant water users in the region are agriculture and associated manufacturing activities. Given the climate's influence on agricultural productivity, the agriculture industry is projected to be one of the most adversely affected from a change in water availability (DECC, 2009b).

Table 10.1 below provides a summary of the possible implications of climate change impacts on water availability relevant for industry sectors in the Riverina bioregion.

The agricultural commodities that used the most water in the Riverina bioregion include rice production, dairy farming and irrigated pasture for other livestock and rice cultivation. A recent report by CARE (2009) scoped the impacts that may arise from climate change over the next 50 years. The report concludes that there are likely to be significant impacts on the Riverina over the next 50 years due to reductions in available water, the high level of agricultural production, and the dependence upon irrigation. This will affect agriculture, particularly the rice and irrigated dairy industries and, compounded by water licence buybacks, these impacts are likely to have flow-on effects across the region.

In summarising the impact of climate change (incorporating climate variability and Government adjustment through water buybacks) on the Riverina economy, CARE (2009) reports that there are a number of factors that will minimise the impacts, including:

- there is some input substitution that offsets the reduced water use
- there are transfers of water under the trading arrangements that result in some water being transferred to higher value users
- revenue obtained from the buybacks will be spent on the adjustments made by the recipients.

Table 10.1: Possible climate change impacts on water availability and implications for the Riverina bioregion

Climate Variable	Implications
Temperature	• Decline in grape quality in the viticulture industry
Rainfall patterns and evaporation rates	• Reduction in water availability • Impacts on production of agricultural industries relying on irrigation/water • Impacts on production of rain-fed and irrigated fodder and grain production
Hydrological change/ water resources	• Increased variability of rainfall and, particularly, river flow due to climate change will reduce the reliability of water supply for irrigation industries • Impacts on agricultural industries relying on irrigation – decreases in the value of irrigated agricultural production • Anticipated that by 2030 the value of agriculture in the Basin could fall by 12 per cent and this loss could increase to 49 per cent by 2050 and 92 per cent by 2100 • Impacts on settlements that depend on the Murray-Darling system for water supplies
Landscapes and ecosystems	• Additional pressures on natural systems in the Murray-Darling Basin which are already under pressure from reduced inflows from a drying climate and over-allocated water for irrigation • Increased woody weed invasions, erosion, loss of biodiversity and impacts on aquatic species, with flow-on effects to communities and industry sectors depending on healthy ecosystems, including forestry and tourism sectors • Impacts to river red gum forests due to decreased flooding events and flow-on effects to forestry and tourism sectors

Sources: Commonwealth Department of Climate Change, 2009; DECC, 2009; Webb, 2006; Hacker et al., 2007; Jones and Hennessy 2000; Hafo et al., 2009)

CARE (2009) finds that there is significant capacity for adaptation across the Riverina. It reports that the reduction in water availability is likely to be within the adaptive range of many producers who are already developing new technologies for drier and more variable climate conditions.

10.2.2 Localised impacts within the Riverina bioregion

While the impacts of a reduction in water availability may be within the adaptive capacity of the broader region (CARE, 2009), there are likely to be significant impacts at a local level. CARE (2009) states that climate change will have most impact on those businesses that have the highest dependence on primary industries. It adds that in the major centres, the existence of entrepreneurial people, capital and technology are increasingly driving business growth and these have little to do with climate change.

The most vulnerable businesses will be those that are the highest users of water, or those that:

- are already stressed – either economically or biophysically, as a result of, for example, land degradation, salinisation and loss of biodiversity
- are at the edge of their climate tolerance
- have made large and long-lived investments such as dedicated irrigation systems, slow-growing cultivars or processing facilities (Allen Consulting, 2005)
- generate less value per unit ($/GL) of water – as water becomes more scare and potentially more expensive, these commodities may be the first to exit the market.

CARE (2009) reports that many smaller centres located in the dryland farming areas are likely to continue to struggle, and businesses in those towns will have difficulty remaining viable. It concludes that these towns and their businesses will need to find new economic activities that fit with trends in the economy and make use of new technologies that enable businesses to reach beyond their local market area.

10.2.3 Impacts on forestry towns within the Riverina bioregion

Some industries including the red gum forestry industry are particularly vulnerable to futures with scarce water. While forestry is a small part of the NSW Riverina regional economy, a decline in the red gum forestry industry would have a considerable impact on some readily identified smaller towns. These towns include Barham-Koondrook (in Victoria), Mathoura, Deniliquin, Balranald, Darlington Point and Merbein (in Victoria). These towns are already dealing with the impacts of ongoing drought on their agricultural businesses.

Qualitative evidence from submissions to, and discussions held by, the NRC in the bioregion suggest that businesses directly or indirectly dependent on river red gum forest industries are vulnerable.

CARE (2009) summarised short term impacts on local businesses and communities, which included (among other impacts):

- reduced production
- flow-on effects from reduced production to other related industries
- flow-on effects to households through reduced employment and wages, and reduced business earnings
- reduced expenditure by households
- an intensification of the competition for water among the various users.

CARE (2009) goes on to say that the effect of reduced supply of a variable (such as timber) will usually be a net reduction in production, Gross Regional Product and possibly some deterioration in social conditions related to lower household income, reduced job opportunities and increased costs associated with the new production and consumption systems.

Submissions to the NRC from forestry related businesses and local shires in the Riverina raise these concerns and place them in the context of the local communities that will be impacted. They express concern that changes to the red gum forestry industry will impact in a negative way on local communities.

Balranald Shire says that the "forestry industry provides a diversity of income streams for local communities. Removal of a significant industry will mean that the capacity of the community to survive downturns in other key economic activities will be substantially diminished. In addition, the social fabric of the communities will diminish as the forestry industry is the keystone of fundraising for most clubs."

Other submissions discussed the impact of a likely loss of jobs and the lack of other employment options in many small centres, especially following a downturn in agriculture due to the recent drought. They discussed the flow-on impacts to the smaller towns including loss of businesses, income and people from towns and loss of services and clubs and associated community cohesion. Many submissions described the risks to these communities in detail and with concern for the survival of several smaller towns.

CARE (2009) says that the severity of those effects will be related to the importance of the affected industries in the economy and the opportunities that exist for developing alternative business activity that can offset the reductions. Submissions to the NRC have highlighted the importance of forestry related businesses to their towns and argued that other business activities are not available to them.

It is important to note that the cumulative flow-on impacts of river regulation, national water reform, climate variability and climate change on communities are uncertain.

There are opportunities for regional communities through the water reform process and these should be fully explored. Through The Living Murray program, environmental water will be delivered to the icon sites and there will be opportunities for governments, water users and communities to manipulate those flows to get the best outcomes for the river red gum forests. This may include, for example, 'piggy-backing' environmental flows onto natural unregulated flows through the system to achieve a longer flooding event. There are good examples of this being undertaken on a small scale in the past with good ecological outcomes.

Opportunistic and pre-planned flooding events may have the potential to support not only ecological values but also socio-economic outcomes, and may be one pathway toward a new sustainable future for communities in the Riverina bioregion.

A discussion of what climate variability and climate change means for forest industries, particularly timber production, follows. The sensitivity of Riverina towns to these impacts, the opportunities available to them and the structural adjustment that may be required in response, is provided at the end of this chapter.

10.3 Implications for timber supply

In considering the implications of reduced water availability on the timber yields that can be sustained by the river red gum forests, the NRC has focused on a long-term (100-year) timeframe. Over this timeframe, a reduction of up to 70 per cent in yields is estimated due to the combined effects of river regulation, enhanced forest management prescriptions, climate variability and climate change. Higher volumes of timber could be harvested in the near term, for a defined period of time, as part of a managed industry transition strategy. This may assist the red gum forestry industry to adjust to the sustainable yields available over the longer term. Further modelling using FRAMES, taking account of likely changes in forest structure and growth rates at a water management unit level, will provide more precise estimates of future yields, product classes and wood supply options.

10.3.1 Factors impacting timber production

The long-term sustainable yield of sawlogs is already being impacted by the combination of increased river regulation, forest management prescriptions to protect habitat trees and threatened species, and the current drought. Reductions in the extent and frequency of flooding under future climate change scenarios are expected to further reduce long-term yields.

The sustainable level of timber production from the river red gum forests of the Riverina bioregion depends on both the area available for harvest, growth rate and regeneration of trees on those areas. As a water dependent species, growth rates of river red gums depend primarily on water availability. Silvicultural practices can also have an impact on long-term growth rates, for example, by reducing competition for available water and promoting tree regeneration.

Current base allocations of high quality (quota) sawlogs reflect yield estimates of merchantable[2] sawlogs nominated in Management Area plans in the mid 1980s for the Murray and Mildura Management Areas (Forests NSW, 2008). Base allocations for the Murrumbidgee and Narrandera Management Areas were revised downward between 2005 and 2009. The long-term yields estimated in these plans are based on estimates of growth rates over the medium term, in line with ability of forests to sustainably produce primary product of quota sawlogs (GHD, 2009). Supply of low quality (ex-quota) timber products and residue is in conjunction with the production of high quality sawlogs and silvicultural operations, in accordance with current and future market demands (Forests NSW, 2008).[3]

Forests NSW is currently conducting a review of long-term yield of all classes of product from the river red gum forests using a strategic planning tool called FRAMES (Forest Resource And Management Evaluation System). An Auditor-General's Performance Audit in 2009 concluded that FRAMES is robust in its operational aspects and that procedures for collecting data to calibrate the model are sound (Auditor General, 2009)[4]. This was confirmed by a peer review of FRAMES conducted by the NRC.

However, the NRC's analysis of FRAMES outputs for the river red gum Management Areas, informed by consultation with Forests NSW, suggests a number of key issues for estimates of future timber yields. Firstly, although underlying sustainable yield estimates are based on long-term non-declining yields over a 200-year period, current base allocations have been set on a 70-year planning horizon within that context. This has the effect of allowing a higher level of harvesting earlier in the period, which would be balanced by reduced levels of harvesting later in the period. However, the 70-year planning horizon is less than the river red gum timber production rotation age of 90-120 years; a planning horizon within that range would be more appropriate for the assessment of long-term sustained yield that the NRC has been asked to conduct. Doing so would reduce levels of harvesting compared to current allocations.

Secondly, previous calculations of long-term sustainable yields were based on growth and mortality rates achieved under historic flooding regimes. A recent review of growth and mortality rates since 2003 by Forests NSW indicates these figures need to be revised for water-stressed forests. When compared to the period 1970–2002, post-2003 growth rates have halved and mortality rates have doubled, and this is assumed to be due to the ongoing drought (Forests NSW, pers. comm., 2009). These drought impacted growth and mortality rates are indicative of those likely in river red gum forests that no longer receive regular watering because of river regulation, and have to survive in the drier future predicted for the bioregion under predicted climate change scenarios.

Thirdly, increasing constraints on harvesting to protect other forest values (for example, potential expansion of the reserve system) are likely to reduce the sustainable yield of sawlogs from river red gum forests.

Taken together, these factors suggest that current sustainable yields from NSW river red gum forests need to be revised downwards, to reflect the combined influence of historical factors, policy decisions to maintain historical levels of timber allocation in all but the Murrumbidgee Management Area, and future climate change.

The following section considers the impact of these factors, in the context of expected climate change, on likely long-term sustainable yields.

[2] Merchantable sawlogs referred to in the Murray Management Area Plan include quota and ex-quota sawlogs (Forestry Commission of NSW, 1985).

[3] Actual harvest of ex-quota sawlogs have recently been above base allocations due to the poorer quality stands that have been harvested over the past 2-3 years. These annual overcuts are being debited against a small historic undercut in ex-quota sawlogs over the past decade or so, ensuring that the harvest of ex-quota sawlogs is within the long term sustainable yield. This is not the case for quota grade sawlogs, for which actual volumes cut have been close to base allocations, once consideration is made for the revision of base allocations for Murrumbidgee and Narrandera Management Areas.

[4] The Auditor-General's Performance Audit also concluded that Forests NSW has adequate estimates of how much timber is available from native forests, but that more could be done to improve reliability (Auditor General, 2009). Forests NSW advised the Auditor General that yield estimates have not been routinely compared to actual harvest results because there are significant variations between individual harvest areas within a region, thereby making it difficult to compare the actual with predicted volumes (Auditor General, 2009). Forests NSW has accepted the Auditor General's recommendation to compare harvest results to yield estimates over five-year periods as a means of testing the accuracy of estimates and to report the results annually commencing June 2010 (Forests NSW, pers. comm., 2009).

10.3.2 Review of long-term sustainable yield estimates

As part of this assessment, the NRC reviewed the impact of future climate change scenarios on the long term (100-year plus) sustainable supply of timber expected to be available from various forests. As the FRAMES model used by Forests NSW is not currently able to model timber yields at the level of Water Management Units for which climate change impacts on water availability were modelled, an alternative approach was used. The FRAMES model used by Forests NSW predicts stand characteristics and timber yields at a 'forest estate' level, namely each Management Area within the Riverina bioregion. FRAMES does not provide estimates at the level of individual forests or, in the terms of the NRC's assessment, water management units.

As an alternative to FRAMES, long-term (approximately 100 year) sustainable yields were estimated by applying growth rates in m^3 per hectare per year to areas expected to continue to produce timber. The NRC developed a simple spreadsheet model to undertake these analyses, and used independent expert review to corroborate the approach and results.

Methodology

The methodology that the NRC used focused on quota and ex-quota sawlogs, and comprised:

1. estimating the area[5] of Site Quality 1 and Site Quality 2 in each water management unit predicted to receive regular watering under the likely future environmental watering commitments discussed in **Chapter 8**
2. assuming that historical growth (1970–2002), mortality and other stand parameters would continue to apply in these parts of the forest receiving regular watering
3. assuming that net growth in those Site Quality 1 and Site Quality 2 areas of the forest that did not receive regular watering (step 1) would be 25 per cent of the growth rate of regularly watered area
4. assuming that there was no net growth of quota quality sawlogs in Site Quality 3 areas
5. varying assumptions of the extent of water management units watered (step 1) on the basis of expert opinion from forest managers.

The rationale for the assumptions is outlined below. The resultant estimates are indicative, but the methodology is amenable to modelling alternative assumptions.

This methodology was applied to estimate long-term sustainable yields for the Millewa forests[6] and Koondrook-Perricoota/Campbells Island forests. The NRC conducted detailed long-term sustainable yield analysis only for these Central Murray State Forests, for two reasons. First, as shown in **Table 10.2** below, some 86 per cent of long-term sustained

Table 10.2: Proportion of Murray Management Area (MA) timber yields by water management unit[7]

Water management unit	Timber yield (percentage of long term sustainable yield for Murray MA)
Millewa forests	56
Koondrook-Perricoota and Campbells Island forests	30
Werai forests	8
Upper Murray River riparian zone	3
Edward/Wakool and Edward River riparian zone	3

Table 10.3: Area (ha) by Site Quality (SQ) in Millewa forests and Koondrook-Perricoota forests
(NRC analysis of data supplied by Forests NSW)

	SQ 1 (ha)	SQ 2 (ha)	SQ 3 (ha)	Total (ha)
Millewa forests	8,960	17,227	4,000	30,187
Koondrook-Perricoota and Campbells Island forests	3,286	19,098	6,252	28,636
Total[8]	12,246	36,325	10,252	58,823

[5] Areas of State Forest were classified by Site Quality by Forests NSW in the 1970s. These classifications are still in use for the purposes of managing forest areas.

[6] The Millewa forests for which long term sustainable yields were estimated include Millewa, Moira and Gulpa Island.

[7] Figures generated by FRAMES on the relative contributions to long term sustained yield in the Central Murray forests. Care should be taken in translating these to volumes. Contributions do not include the relative quality of the sawlogs produced. In general terms, the higher quality sawlogs required for veneer and furniture tend to be sourced from the Millewa forests.

[8] These figures are lower than the total 69,000 hectares of net harvestable area reported by Forests NSW as being managed for timber production in the Murray Management Area as they do not include smaller areas of productive forests such as Werai.

yield in the Murray Management Area originates from these forests; secondly, predicted flood regime mapping was available only for these forests.

Assumptions

The total areas of river red gum forests assumed in the NRC's modelling are shown in **Table 10.3** below. Areas of Site Quality 1 and 2 were included as they produce almost all current quota timber. Areas of Site Quality 3 were not included in the estimates as they produce little quota or ex-quota timber, which reflects their position in the landscape and historic lack of access to water.

The percentage of Site Quality 1 and Site Quality 2 areas predicted to receive regular watering under future climate change scenarios were estimated using the climate scenarios outlined in **Chapter 7** of this report and the hydrological modelling outlined in **Chapter 8**. While all modelling has inherent uncertainty as to its accuracy, the future climate scenarios used in this report are intended to adequately represent the range of possible impacts under climate change (as discussed in **Section 7.5**). Based on these predicted climate scenarios, the flooding regimes discussed in **Chapter 8** indicate a substantial reduction in the magnitude, frequency and duration of floods can be expected for the majority of forest stands, particularly the larger forest groups of Millewa and Koondrook-Perricoota. Without the delivery of additional environmental water to these forests, growth rates could be expected to continue the decline observed since 2003.

Two scenarios of future flow regimes were considered and compared to estimates of long-term yield based on applying historic growth rates across all areas of Site Quality 1 and

Perricoota State Forest

Table 10.4: Modelled extent of flooding in Millewa forests by Site Quality (SQ)
(NRC analysis using a River Analysis Package and Water Technology modelling)

Flow regime (60+ days duration)	Modelled inundation extent for combined Millewa forests*		
	SQ1	SQ2	SQ3
18,300 ML/d	32%	12%	2%
25,300 ML/d	48%	33%	19%
35,000 ML/d	58%	46%	30%

* This was applied to Site Quality definitions based on older mapping by Forests NSW, rather than more recent mapping used in **Chapter 8**.

Table 10.5: Modelled extent with flood enhancement works in Koondrook-Perricoota forests by Site Quality (SQ)
(NRC analysis using data from DHI Water and Environment, 2008)

Flow regime	Modelled inundation extent for combined Koondrook-Perricoota forests*		
	SQ1	SQ2	SQ3
Minimum operating strategy of 2,000 ML/d diversion for 100 days	46%	42%	33%
Preferred operating strategy of up to 6,000 ML/d diversion for 105 days**	57%	63%	45%

* Modelling for the scenario without flood enhancement works is for the combined Gunbower, Koondrook and Perricoota forests.

** Preferred operating regime is for 6,000 ML/d for 50 days then 3,400 ML/d for 55 days. Inundation extents are shown for 6,000 ML/day diversion.

[9] The areas derived for this assessment are consistent with those used by Forests NSW FRAMES model and are within 1 per cent or 2 per cent of figures provided by NSW FPA (pers. comm., 19 November 2009).

Site Quality 2:

- A 'Minimum watering' scenario which assumed 18,300 ML/day for the Millewa forests and the minimum operating strategy of 2,000 ML/d for the Koondrook-Perricoota forests
- An 'Upper bound' scenario which assumed 35,000 ML/day for the Millewa forests and the preferred operating strategy of up to 6,000 ML/d for the Koondrook-Perricoota forests.

Tables 10.4 and **10.5** show the modelled inundation extents for the Millewa forests and the Koondrook-Perricoota forests under these scenarios. Numbers differ slightly from those in **Chapter 8** as the Site Quality was defined based on data from Forests NSW mapping conducted in the 1970s, rather than more recent mapping used to determine Benson vegetation classes.[9]

Growth rates used in calculating yield estimates (as shown in **Table 10.6**) were based on the following assumptions:

- Historic growth rates (1970–2002) derived from Forests NSW Permanent Growth Plots were used for flooded areas of Site Quality 1 and Site Quality 2. Growth rates for Quota sawlogs for areas of Site Quality 1 and Site Quality 2 expected to be regularly flooded were based on the basal area growth model used in FRAMES.[10] Growth rates for Ex-quota sawlogs were assumed to be 70 per cent of the rate for Quota sawlogs. This is consistent with the ratio of base allocation of Ex-quota to Quota sawlogs.
- For areas of Site Quality 1 and Site Quality 2 not predicted to be flooded, a growth rate of 25 per cent of the historic growth rate (1970–2002) was assumed for the 100-year planning period. Areas not predicted to directly receive flooding may still achieve some growth due to the effect of flood water extending beyond the mapped extent of the flood, or through access to groundwater. The estimated growth rate for these areas was derived from data from Forests NSW Permanent Growth Plots in the period 2003–08, which show a 50 per cent drought-induced reduction in growth rates and doubling of drought-induced mortality rates to 1.5 per cent per year. The interaction of drought and mortality over a 100-year planning period is difficult to predict without further FRAMES modelling. For the indicative purposes of this exercise, a growth rate of 25 per cent of the historic growth rate was assumed, corresponding to the equivalent of 50 per cent of historic growth rates applied to 50 per cent of the trees over the 100-year period.
- Areas of Site Quality 3 were assumed to have negligible growth rates for quota timber, whether watered or not. This is consistent with results from strategic inventory sampling by Forests NSW, which indicates these areas do not currently produce significant amounts of quota quality timber.

These historic growth rates (1970–2002) are considered to be the most appropriate to use in this assessment as they are based on monitoring conducted by Forests NSW for the Central Murray State Forests. They therefore reflect the influence of the stand structure and historical silvicultural management of these specific forests on their growth rates. A range of other growth rates have been estimated by previous studies under different assumptions regarding watering and silvicultural regimes, as shown in **Table 10.7**. Growth rates at the upper end of the range are indicative of the yields that could be achieved under more favourable flooding regimes. It is also possible that selective thinning to favour the growth of dominant trees could increase the yields of higher quality timber. These two issues are discussed in more detail below, together with the results of the NRC's estimates of the long-term sustainable yield of red gum timber.

The likelihood of historic growth rates (1970–2002) being achieved on flooded areas was assessed by considering:

- The likelihood of modelled flow rates being achieved given operating and regulatory constraints
- Whether the modelled frequency of flooding under climate change scenarios is likely to be regular enough to maintain historical growth rates (1970–2002) for forests receiving water.

As shown in **Table 10.8**, for the Millewa forests, available volumes of environmental water, existing infrastructure and the extent of preparation for implementing the Barmah-Millewa Icon Site Management Plan provide reasonable confidence that 18,300 ML/d can be delivered in the future. However, given the current easement constraints of 25,000 ML/d between Hume Dam and Lake Mulwala, there is limited potential to artificially deliver larger floods to the forest unless easements are increased. The delivery of floods larger than 25,000 ML/d to Millewa forests depends on contributing natural flood flows from the unregulated Ovens River being passed downstream of Lake Mulwala/Yarrawonga Weir. It is possible that larger floods could be achieved if current easement constraints were removed, or if environmental water releases from the Hume Dam were timed to supplement flows from the Ovens River. These changes may be supported by future funding or management plans. Therefore the 'Upper bound' scenario is considered to be within the bounds of possible outcomes, but less likely than the 'Minimum watering' scenario.

For the Koondrook-Perricoota forests, proposed flood enhancement works are needed to allow floods of the necessary frequency, volume and duration to maintain the health of the forests. There is a reasonable level of confidence the flood enhancement works will be implemented; however, it will be several years before regular operation of the works is expected to improve the health of the forests. As shown in **Table 10.9**, there is reasonable likelihood the extent of flooding modelled for the 'Minimum watering' scenario of 2,000 ML/day diversion will be achieved, as this represents the minimum water requirement to deliver the environmental outcomes required to support the investment. However, the extent of flooding modelled for the 'Upper bound' scenario is

[10] Growth rates were derived over a 50-year period for current standing stock, assuming no silviculture and therefore no silviculture induced regeneration of new trees. Without the introduction of regenerating trees, the average growth rates could be expected to be slower over a 100-year period as the average tree age increases. However, if active but conservative silviculture is applied, rates close to the 50 year growth rate could be achieved over a 100-year period by reducing competition and reducing the average tree age. By comparison, the growth rate for quota quality sawlogs estimated in the 1985 Murray Area Management Plan (Forestry Commission of NSW 1985) was "between about 0.40 and 0.53 m3 gross/ ha/year", based on permanent growth plot data over the period 1971–1982.

[11] Growth rates for current standing trees were derived from Forests NSW FRAMES model over a 50 year period.

Table 10.6: Growth rates of Quota-grade timber assumed in NRC modelling of long-term sustainable yields by Site Quality (SQ)

Growth rates (m3/ha/year)	SQ 1 (ha)	SQ 2 (ha)	SQ 3 (ha)
Areas flooded	0.60	0.26*	0
Areas not flooded	0.15	0.06	0

*Average across SQ2 sites. A growth rate of 0.40m^3/hectare/year was used for more productive sites and 0.20m^3/hectare/year for less productive sites.

Table 10.7: Range of reported growth rates or production rates for river red gums

Growth rate or production rate (m3/ha/yr)	Timber quality	Site Quality (SQ)	Watering regime	Other factors impacting growth	Source
3.5	Merchantable logs	High quality	Pre-regulation (1940s and 50s), regular flooding	Selective thinning	Jacobs, 1955
Up to 4.8	NA	SQ1	Pre-regulation, natural flood regimes	Even aged stands	Baur, 1983
Up to 3.2	NA	SQ2	Pre-regulation, natural flood regimes	Even aged stands	Baur, 1983
1.43–0.67	Merchantable logs	All	Annual (winter) flooding, upper end of range for forest in flood water, lower end of range for areas up to 75m from flood	Data for Gulpa Island	Bacon et al., 1992
0.78	Saw logs	Average for SQ1- 3	Flooding 7–8 years in 10	Barmah forest, with 'current' forest management	Maunsell, 2003
0.60	High quality saw logs	SQ1	Pre-drought (1970–2002)	Data for Central Murray State forests	Forests NSW[11]
0.22	Saw logs	Average for SQ1- 3	Flooding 4 or 5 years in 10	Barmah forest, with 'current' forest management	Maunsell, 2003
0.18–0.16	Merchantable logs	All	No flood for 2 years, upper end of range for forest in flood water, lower end of range for areas up to 75m from flood area	Data for Gulpa Island	Bacon et al., 1992
Negligible	Saw logs	SQ1, 2, 3	2 years out of 10	Barmah forest, with 'current' forest management	Maunsell, 2003

Table 10.8: Likelihood of modelled flow rates being achieved for the Millewa forests

Scenario	Flow rates	Factors required to achieve flow rates	Likelihood
Minimum watering	18,300 ML/day	100 GL/yr environmental water entitlements plus 50 GL/yr lower security allocations provided for Millewa.	Reasonable
Upper bound watering	35,000 ML/day	As above for Millewa, but with either expansion of legal operating constraints for regulated flows between Hume Dam and Lake Mulwala, or natural flooding from the Ovens River.	Low

Table 10.9: Likelihood of modelled flow rates being achieved for the Koondrook-Perricoota forests

Scenario	Flow rates	Factors required to achieve flow rates	Likelihood
Minimum watering	2,000 ML/day	Koondrook-Perricoota Flood Enhancement works built at capital cost of $56m and minimum 2,000 ML/day operating strategy implemented.	Reasonable
Upper bound watering	Up to 6,000 ML/day	As above, but preferred (maximum) 6,000 ML/day operating strategy implemented at Koondrook-Perricoota.	Low

considered less likely. While the proposed scheme is capable of inundating up to 52 per cent of the forest (with the 6,000 ML/d event), this extent of flooding cannot be maintained. The maximum maintainable extent across the whole forest is 41 per cent, with this reducing quickly during the flood recession.

It is likely that flooding frequencies of every 2–3 years for Millewa and up to every four years for Koondrook-Perricoota are close to those experienced post-river regulation but prior to the current drought. **Table 10.10** below shows a range of reference frequencies of flooding both pre-river regulation and post-river regulation. For the Millewa forests, as discussed in **Section 8.7** of this report, CSIRO MDBSY modelled floods exceeding 18,300 ML/day[12] as likely to occur on average each 2.6 years with current levels of water resource extractions and historic (1895–2006) climate conditions. For the Koondrook-Perricoota and Campbells Island forests, as discussed in **Section 8.8** of this report, CSIRO MDBSY modelled floods exceeding 30,000 ML/day as likely to occur once every 3.8 years on average under historic (1895–2006) climate conditions but with current levels of water resource extraction. As river inflows during 1970–2002 (prior to the current drought) were similar to the long-term historic levels (see **Section 7.2**), it is reasonable to assume that flooding frequencies would have been similar to these modelled rates. Flooding frequencies of every five years of less frequently are unlikely to be sufficient to maintain historic growth rates (Maunsell, 2003).

The modelled frequency of different flows for Millewa forests is shown in **Table 10.11** below under two climate change scenarios (as outlined in **Chapter 8**):

- Scenario B – recent climate (1997 to 2006, 'step-change') with current water resource development extractions
- Scenario Cmid – best estimate (median) future climate to 2030 with current water resource development extractions.

Table 10.10: Reference flooding frequency (Dexter and Poynter, 2005 and NRC analysis)

Flooding regime	Average period between floods	Source
Barmah forest		
Pre-river regulation (1891–1934)	1.4–1.6 years*	Dexter and Poynter (2005)
Pre-drought (1955–2001)		
• 25%–50% of forest	2–2.5 years**	Dexter and Poynter (2005)
• up to 75% of forest	>5 years***	Dexter and Poynter (2005)
Millewa forests Historic climate (1895–2006) with current water resource development extractions (18,300 ML/day)	2.6	NRC analysis using CSIRO and Water Technology modelling
Koondrook-Perricoota forests Historic climate (1895–2006) with current development (30,000 ML/day for 30 days)	3.8	NRC analysis using CSIRO and TLM modelling

* Estimated from flooding frequency of 7–8 years in 10 observed pre-river regulation.

** Estimated from flooding frequency of 4–5 years in 10 as a result of actual Murray River flows below Yarrawonga/Tocumwal since 1955.

*** Estimated from flooding frequency of less than or equal to 2 years in 10, which was present/predicted as a consequence of MDBMC and NSW and Victoria state land and water management policy decisions.

Table 10.11: Modelled frequency of flooding in Millewa forests
(NRC analysis using a River Analysis Package and Water Technology modelling)

	Average period between floods in years (assuming current levels of development)	
Flow regime (60+ days duration)	Cmid	B
18,300 ML/d ('Minimum watering')	3.5	8.2
25,300 ML/d	5.4	14.2
35,000 ML/d ('Upper bound watering')	Not available	Not available

[12] As discussed in **Section 8.4.1** of this report, a summer–spring flood of more than 18,300 ML/day is likely to be needed to achieve 55 per cent inundation of the Barmah-Millewa forests.

Based on these frequencies, the 'minimum watering' scenario for the Millewa forest group is reasonably likely to maintain pre-drought growth rates under the best estimate (median) future climate to 2030 for the 32 per cent of Site Quality 1 and 12 per cent of Site Quality 2 that is inundated. However, under Scenario B (recent 'step-change' climate), flooding is unlikely to be frequent enough to maintain historical growth rates (observed between 1970 and 2002). Flooding frequencies under the 'upper bound' watering scenario are also unlikely to maintain historical growth rates.

The frequency of flooding in the Koondrook-Perricoota forests will depend on the actual operating strategies put in place following the proposed engineering works; flood frequencies of one in three years (or around 3.3 years between events) were modelled in investment proposals. The acceptable minimum target for reduced flood frequency is considered to be half of the natural frequency, or around one year in three (TLM, 2008). If these rates are achieved, pre-drought growth rates may be maintained in Koondrook-Perricoota.

Results

Based on this methodology, a range of estimated long-term sustainable yields were modelled under different scenarios, as shown in **Table 10.12** and **Table 10.13**. Given the simplified nature of the methodology used, these estimates should be regarded only as indicative, and it would be desirable to substantiate the indicative estimates by using FRAMES for a more comprehensive analysis than was possible within the timeframe of this assessment.

The likelihood of each scenario being realised has also been assessed based on judgements about the delivery of water volumes required for the assumptions behind each scenario. The 'Minimum watering' scenario is considered to have reasonable likelihood, as there is some confidence the factors required to achieve the assumed flooding regimes are feasible. The 'Upper bound' watering scenario is considered less likely, as the required flooding is at the upper end of what is considered feasible given current water policy settings. The

Table 10.12: Summary of yield estimates for the combined Millewa, Koondrook-Perricoota and Campbells Island forests

Scenario	Estimated yield of Quota and Ex-quota sawlogs (m^3/year)			Assumptions	Likelihood of modelled flow rates being achieved	Likelihood of sufficient flooding frequency to achieve pre-drought growth rates
	Areas flooded*	Areas not flooded**	Total			
Minimum watering	7,700	5,000	12,700	• Millewa forests inundated per modelled 18,300 ML/day flow regime (32% Site Quality 1 and 12% Site Quality 2 areas inundated). • Koondrook-Perricoota forests inundated per modelled 2,000 ML/day diversion rate (46% Site Quality 1 and 42% Site Quality 2 areas inundated). • Same percentage inundation assumptions for Campbells Island forest as for Koondrook-Perricoota forests.	Reasonable	Reasonable
Upper bound watering	14,400	3,300	17,700	• Millewa forests inundated per modelled 35,500 ML/day flow regime (58% Site Quality 1 and 46% Site Quality 2 areas inundated). • Koondrook-Perricoota forests inundated per modelled 6,000 ML/day diversion rate (57% Site Quality 1 and 63% Site Quality 2 areas inundated). • Same percentage inundation assumptions for Campbells Island forest as for Koondrook-Perricoota forests.	Low	Low
Continuation of historic growth	NA	NA	27,600***	• All of Site Quality 1 and Site Quality 2 areas in Millewa forests, Koondrook-Perricoota and Campbells Island forests achieve historic growth rates.	Unlikely	Unlikely

* Assumes inundation occurs at sufficient frequency and duration to sustain growth rates of river red gums based on 1970–2002 PGP data.

** Assumes growth rates of 25% of those in flooded areas.

*** This estimate was derived by applying the growth rates shown in **Table 10.6** to the 48,571 hectares of Site Quality 1 and Site Quality 2 in the Millewa forests, Koondrook-Perricoota forests and Campbells Island forest shown in **Table 10.3**. Estimates for other areas of forest in the Murray Management Area were not included as it is the NRC's assessment that they are unlikely to provide substantial long-term yields. By comparison, the long-term sustained yield of merchantable sawlogs (quota and ex-quota) in the 1985 Murray Management Area Plan (Forestry Commission of NSW, 1985), was estimated between 22,400 and 29,700 m^3/year from 56,000 hectares of Site Quality 1 and Site Quality 2 in the Millewa, Koondrook, Werai, Mulwala and Wakool forests.

'Continuation of historic growth' scenario is considered unlikely in the long term as it would imply a return to the higher growth rates experienced between the 1970s and 2002. These were achieved under pre-drought conditions which are contrary to the climate change predictions for south-eastern Australia.

For these reasons, the 'Minimum watering' scenario shown in **Table 10.12** and **Table 10.13** is more likely than the 'Upper bound watering' scenario. Consequently, assuming the frequency of inundation is sufficient to maintain historic growth rates in those areas receiving water, long-term sustainable yields of quota and ex-quota sawlogs are more likely to be in the order of 13,000 m^3/year than 18,000 m^3/year. For the reasons discussed in **Chapter 8**, sufficient water is unlikely to be available under future climate change scenarios to support higher yields.

The estimated long-term sustainable yield from the Millewa, Koondrook-Perricoota and Campbells Island forests, of around 13,000 m^3/year, represents only 30 per cent of the 2008–09 base allocations of quota and ex-quota timber from these forests of around 41,000 m^3 (including small volumes from the Werai forests)[13]. While information on future water availability was not available for other areas of State Forest, reductions of a similar order of magnitude are likely given the substantial reduction in the magnitude, frequency and duration of floods under future climate change scenarios discussed in **Chapter 8**.

However, some submissions have suggested that growth rates substantially greater than those realised historically could be achieved through more frequent and prolonged watering. For example, Dexter and TCA (Maunsell, 2003) estimated a range of yields, assuming various watering and silvicultural regimes, for the Barmah forest in Victoria. Yield estimates for those flooding regimes nominated by Dexter and TCA (Maunsell, 2003) which the NRC considers most likely (flooding frequency 2–2.5 years/decade) generated yields comparable to those from Forests NSW data used in the NRC's modelling. Higher yields nominated by Dexter and TCA required much more frequent flooding, of 7-8 years every decade. At these very frequent flooding rates, and under a silvicultural regime approximating that which the NRC recommends in **Chapter 11**, Dexter and TCA's estimates might generate yields of 2 m^3/ha/yr across all site quality classes[14]. Dexter and TCA (Maunsell, 2003) noted that achieving this outcome would require substantial engineering works and water, and so implementation may be limited in practice. At slightly lesser flooding frequencies, of 6–7 years every decade, the comparable estimate is 1.55 m^3/ha/yr[15].

If these estimates of higher growth rates were applied to the 40 per cent of Koondrook-Perricoota flooded under the 2,000 ML/day scenario, long-term sustained yield would rise from around 5,700m^3/year (estimated on the basis above)to between 15,500 and 20,000 m^3/year. These figures demonstrate the potential for adequate watering to enhance river red gum yields, as well as the health of the forest more generally. This result applies similarly to other areas of river red gum forest.

There is evidence from previous studies (Baur, 1984; Dexter 1970; Horner et al., 2009), and empirical evidence in a number

Table 10.13: Range of possible yield estimates from Millewa, Koondrook-Perricoota and Campbells Island forests, by timber quality (m3/year)

	Areas flooded		Areas not flooded (assumed to produce ex-quota sawlogs)	Total
	Quota	Ex-quota		
Minimum watering scenario				
Millewa forests	2,000	1,400	3,600	7,000
Koondrook-Perricoota and Campbells Island forests	2,500	1,700	1,400	5,700
Total	**4,500**	**3,200**	**5,000**	**12,700**
Upper bound watering scenario				
Millewa forests	5,000	3,500	2,300	10,700
Koondrook-Perricoota and Campbells Island forests	3,500	2,500	1,000	7,000
Total	**8,500**	**6,000**	**3,300**	**17,700**
Continuation of historic growth				
Millewa forests	10,500	7,300		17,800
Koondrook-Perricoota and Campbells Island forests	5,700	4,100		9,800
Total	**16,200**	**11,400**		**27,600**

13 Based on the minimum watering scenario which is considered more likely.

14 Dexter and TCA's Scenario 2, without Low Bank Works, gives yield estimates of 1.35 m^3/ha/year for sawlogs only to 2.35 m^3/ha/year for sawlogs plus other products (Maunsell, 2003).

15 Per NSW FPA pers. comm., 25 November 2009.

Inspection of sawlogs at Gulpa Mill

of submissions, that yields of higher quality timber could be improved by thinning (**Chapter 11**). To the extent that the thinning practiced previously in the Central Murray State Forests has impacted on the stand growth assessed by the Forests NSW Permanent Growth Plot network, some of these impacts will have been captured in that data. Further research will be necessary to determine the extent to which this is the case, and to clarify the impacts of thinning on both watered and unwatered stands on growth and yield of different log quality classes.

Other submissions have suggested that sustainable long-term yields may be achieved from areas of the forests that are not regularly inundated with flood water, but which have access to groundwater sources. There is evidence that river red gums opportunistically use groundwater as a water source in some forests of the Riverina bioregion. Shallow floodplain groundwater systems are recharged by flooding, which is likely to be more significant than recharge from rainfall and regional groundwater flow in some areas. However, as discussed in **Section 8.13** of this report, groundwater levels in both deep and shallow aquifers in the Riverina bioregion are falling due to groundwater extraction and recent climatic conditions. Therefore it is likely that groundwater has and will become less accessible as a source of water for vegetation.

Conclusion

On the basis of the scenarios modelled above, the NRC's assessment is that long-term sustainable yields (of quota and ex-quota logs combined) are in the order of 13,000 m^3/year may be available from the Central Murray State Forests if the planned Millewa Icon Site Watering Plan and Koondrook-Perricoota flood enhancement works are implemented. In the NRC's view, the river red gum stands along the majority of the Murrumbidgee River, along the Lachlan River, and along the Edward, Wakool and Murray rivers downstream of Koondrook-Perricoota forests, are unlikely to provide substantial long-term sustainable yields. A significant reduction in flood extent, duration and frequency under climate change scenarios is expected for the majority of these forests, as discussed in **Chapter 8**. Many of the forests along the Lachlan and lower reaches of the other river systems are already in poor health and productivity because of lack of flooding and drought. The river red gum stands along the Upper Murray River, and possibly the Upper Murrumbidgee, are likely to be more resilient to climate change as they have better prospects of receiving what water is available. However, the Upper Murray River forests cover only very small areas and are unlikely to provide significant volumes of timber, and those in the Upper Murrumbidgee have been heavily logged in the past decade.

10.3.3 Transition to sustainable yields

These estimates are for long-term sawlog yields that could be maintained over a 100-year timeframe, should conditions required for growth be maintained. However, as at present, forest managers or government can also opt to maintain a higher level of harvest than the long-term sustained yield for some defined period of time. This is a defensible management option as long as:

- the basis for that decision is transparent

[16] Once these principles are codified in an Integrated Forestry Operations Agreement, the NRC considers they will maintain the ecological character of the forests, and protect matters of National Environmental Significance, while continuing to support production values.

- the silvicultural principles[16] enunciated in **Chapter 11** are respected
- the consequences in terms of the ultimate reduction in yield are similarly clear
- a strategy is put in place to manage the ultimate decline in timber volumes available to the red gum forestry industry.

Modelling using FRAMES, adjusted for areas at a water management unit level and to model for changes in vegetation structure and growth rates, would be required to provide adequate information to understand the implications of harvesting at higher rates over the near to medium term. As an example of the way in which yield might be 'brought forward', Forests NSW quota allocations for the Central Murray State Forests based on a 70-year planning cycle, of around 23,000 m^3/year, are around 40 per cent higher than those for the same forests based on a 100-year planning cycle. The current allocations reflect a conscious decision by Forests NSW to optimise production from these forests, given their uneven age structure which is dominated by standing stock generated in the 1880s.

There is less certainty about the future yield of ex-quota sawlogs, and about short- to medium-term volumes of lower quality logs that may be available as a result of declining stand health in many forests. However, field observations by the NRC, and a number of submissions, suggest these volumes may be substantial. Provided the principles outlined in **Chapter 11** are respected, there is no reason why these volumes should not be available to industry from forests managed for production. There may also be commercially viable volumes available from other tenures in which ecological thinning is permissible in line with the principles outlined in **Chapter 11**. Further modelling using FRAMES is necessary to clarify the volumes likely to be available. Accessing some proportion of this currently standing resource would provide a further means of assisting the red gum forestry industry to adjust to the sustainable yields available in the longer term.

10.4 Implications for industry future

The unprecedented changes in the river red gum forests of the Riverina bioregion in response to river regulation, climate variability and predicted climate change will have profound implications for the future of the forest-based industries which currently rely on them. A return to the conditions under which the current forests, and associated red gum forestry industry structure developed, will not be possible. Change is inevitable as some elements of the industry adapt and others choose to exit. Completely new industries may develop in response to the opportunities afforded by the changing situation, and in doing so transform the nature of the forest-based industry. Either way, the future forest-based industry in the region will look very different from how it does today.

10.4.1 Implications for the current industry structure

Indicative estimates of long-term sustainable yields of sawlogs that might be expected to be available from the Millewa and Koondrook-Perricoota Forests under climate change scenarios represent substantial reductions, of up to 70 per cent, compared to current base allocations. Equally substantial reductions can be expected for other forest groups in the Riverina bioregion. Base allocations of quota and ex-quota sawlogs will need to be reduced to reflect long term sustainable yields, prior to any consideration of changes in land tenure. In the short to medium term, at least, timber production from the river red gum forests

Furniture made from river red gum

will shift significantly toward lower quality timber as reductions in growth rates and increases in mortality observed during the current drought reduce the availability of high quality quota sawlogs. However, significant volumes of lower quality timber are still likely to be available from both public and private land. In addition, substantial volumes of lower grade timber may be available on a short- to medium-term basis if ecological thinning, consistent with the principles outlined in **Chapter 11**, is carried out in particular forests.

The current forestry industry structure will need to change in response to reduced quality and quantity of timber yields. There may also be an increased variability in supply, reflecting a different mix of land tenures and management objectives in the future. The overall impact on the industry will depend on the diversity of responses of individual business. This in turn will depend on the flexibility of their business strategy and on the extent to which technological change and product markets develop to optimise the use of the future river red gum resources. While it is not possible to predict the exact outcome of these changes, some broad general trends can be considered likely.

The future river red gum sawmilling and processing industry is likely to be smaller than at present. It will have a much more limited resource base to draw on, particularly of high quality logs in the short-medium term as a consequence of the legacy of river regulation and drought. In contrast, the legacies of river regulation and drought are likely to provide a substantial resource of lower quality timber, suitable mostly for residual products. The reduced availability of high quality timber may favour businesses with low capital intensity, given the lower product margins associated with lower grade timber products, or businesses which are able to recover greater value from lower grade products.

However, in the short to medium term, it would be possible to sustain higher volumes of sawlogs than are available over the long term as part of a managed industry transition strategy discussed in **10.3.3**. New technologies may also help recover greater value from smaller and poorer quality logs, and partially offset the decline in the traditional higher quality log resource.

If base allocations are reduced to reflect long-term sustainable timber yields, only one or perhaps two of the current six quota mills are likely to be supported. The eight ex-quota mills currently in operation are also likely to be impacted by reduced ex-quota allocations. However, some of these businesses may benefit from an increase in low quality timber and firewood over the medium term. Residue operators are the most likely to benefit from changes in allocations, and the number or size of existing businesses may increase if large volumes of low quality timber are available from ecologically-focused management of forests and bushfire hazard reduction.

10.4.2 Opportunities for adaptation

The ability of businesses to adapt to changes in timber supply will depend on a range of factors including the flexibility of their current business structure, access to capital, and the strength of their distribution channels and ties to end markets. Forestry industry businesses surveyed during this assessment have implemented a range of strategies to maximise their returns. The current status of plant and equipment, business focus, current supply volumes, and reliance on timber of certain quality varies between businesses in the industry.

Quota mills

Three of the six quota mills have pursued a strategy of investing in value adding equipment to produce kiln dried timber, furniture and veneer products. These mills have a reliance on high quality quota timber. Given future reductions in the availability of Australian native hardwood timber, there is potential for a boutique value-adding industry. However, the low volumes of high quality timber and uncertainty of supply pose significant constraints on investment in equipment, marketing and distribution that are likely to limit the size of industry. Three other mills have opted to adjust to lower quality of timber, with a focus on sleeper and firewood products. These mills are relatively better placed to adapt to higher near term volumes of lower grade timber.

Within the constraints of the quality of the resource, limited resource security and the scale of processing enterprises and ability to finance capital investment, the red gum processing industry has been quite innovative over the last decade. The technology to add value to high quality timber resource is spread across the primary processing industry as most quota mills dry timber, and veneering, laminating and finger jointing is undertaken by various producers as well as the production of traditional products such as strip flooring. Further, new technologies for recovering higher value products from smaller and poorer quality logs[17] may assist all mills to adapt to a resource with these characteristics.

The distinctive appearance of red gum timber, combined with the increasing scarcity of Australian red hardwoods and increasing restrictions on the import of competing tropical timbers, may support a boutique market for high-end, value-added timber products. Red gum timber is a recognised red hardwood used for appearance grade products in Australia and internationally. Supply of Australian alternative red hardwoods (notably jarrah) has been restricted by previous Regional Forest Agreements. Imports of dark red hardwoods from natural forests abroad are diminishing because of over-exploitation (Jaakko Poyry, 2005), and are likely to diminish further as a result of Australian Government policy to curtail the import of illegally harvested timber (DAFF, 2009). Import of red gum hardwood products from plantations abroad, such as those in South East Asia, may increase as solid wood products are increasingly recovered from these plantations. However, these plantations are typically grown by farmers on short (3-10 year) rotations, and generate small-size timber suitable for a limited range of value-added products[18].

One opportunity for adaptation is consolidation between quota mills to optimise current and potential further investment in technology. Technologies such as veneering allow greater volumes of end product from increasingly scarce high quality timber (BIS Shrapnel, 2001). There may also be some opportunity for newer sawing systems to improve the recovery of quality timber from smaller logs or enable a greater focus on production of feature timber from lower quality logs. However, there are limits in the extent to which further investment in value

[17] For example, Buraphawood (www.buraphawood.com) utilises short-rotation plantation-grown red gum timber from Laos to produce architectural and furniture products.

[18] See, for example, www.buraphawood.com

adding equipment can improve the volume recovery of timber suitable for higher value products.

Access to alternative sources of timber from private land may ease adaptation in the short term. However, the low quality and variability of supply means substitution for timber from public land is likely only to make a marginal difference to mills which have invested in value-adding equipment. The two mills which have pursued a strategy of focusing on sleeper and firewood products have already moved to source timber from private land.

Ex-quota mills

The eight ex-quota mills which rely on timber from public land already have inherent flexibility in operations, which is reflected in their responsiveness to the variable markets for lower grade sleepers and firewood. The mobile nature of their operations and lower capital investment in equipment support this flexibility. These operations may benefit from increases in lower quality timber and firewood from ecological thinning of forests.

The mobile ex-quota sawmills are almost exclusively operated by small family companies or partnerships. This element of the forestry industry is characterised by improvisation. Some of the more entrepreneurial operators have diversified and expanded their operations by harvesting and processing forest residues for woodchips, firewood and craftwood (URS, 2001).

Markets for firewood products offer an opportunity for mobile ex-quota mills to adapt to changes in timber supply. The firewood market for native hardwood timber is estimated to be in the order of 5–7 million tonnes (Driscoll et al., 2000). Assuming this demand remains, the market should be able to absorb increases on top of the current supply of approximately 100,000 tonnes per annum of red gum timber from public land. Despite its highly seasonal nature, there is potential for the red gum firewood market to expand to less traditional supply areas of Adelaide and Sydney (BIS Shrapnel, 2001).

Residue operators

Residue operators reliant on public land run flexible businesses with low capital investment. Generally the equipment used by residue operators is mobile as firewood is cut in the forest and capital costs are minimised as equipment is second hand (BIS Shrapnel, 2001). These operators are likely to benefit from the increased volumes of low grade timber available from ecological thinning and bushfire hazard reduction.

10.4.3 Opportunities for transformation

There is potential to drive the establishment of new timber industries given a sufficiently high carbon price, technology development and industry innovation. New energy generation technologies may make it viable to utilise the increased volumes of low quality timber from dead and dying trees, ecological thinning and bushfire hazard reduction. Plantation timber grown for carbon sequestration may also become financially viable with a sufficiently high carbon price. These are opportunities for transformation rather than adaptation of the current industry, given the uncertainty over carbon pricing, water availability and the timeframe involved in investment and development of new technologies and new plantations.

Prospects for energy and chemical feedstock production

Several submissions have suggested an opportunity for further investment in innovative technologies for utilising lower grade wood and residues for energy or biofuels. Adding value to residues currently used for firewood, mulch sawdust and even bark is possible, but would require higher returns than from existing markets to warrant the capital expenditure. However, with a carbon price signal in place, pyrolysis to produce charcoal for use in metallurgical processes, biochar and bio-oil or chemical precursors, as well as production of ethanol from wood, are possible technologies for consideration.

The most suitable technology is likely to be pyrolysis to produce energy from biochar, biogas and electricity; or from biochar and bio-oil. Advances in pyrolysis technology indicate the potential for it to be deployed at smaller or modular less capital intensive scales and utilise feedstock of wider technical specification than in the past. Such technologies should be eligible for renewable energy certificates and would benefit from increased competitiveness against conventional fossil fuels under the planned Carbon Pollution Reduction Scheme.

Production of ethanol from wood is also possible, but the technology to convert eucalypts to ethanol commercially has not yet been demonstrated. Significant capital investment would be required and, as with pyrolysis, the business case would be sensitive to the cost, quality and security of supply of feedstock.

Prospects for forest plantations in the Riverina bioregion

A number of submissions have raised the prospect of planted forest resources, particularly through various forms of farm planting, emerging as an alternative source of wood supply to the native river red gum forests. A body of work over the past decade, including a number of trials, has assessed the prospects for low-rainfall farm forestry of eucalypt species in the NSW Riverina (CSIRO et al., 2001; Stephens et al., 2002; Borschmann and Poynter, 2003; Scott, 2006). The results of these trials confirmed that 'conventional' commercial plantation or farm forestry was not viable in the majority of the Riverina bioregion without access to irrigation (Scott J, former Executive Officer, Murray Riverina Farm Forestry, pers. comm., 2009).

As discussed in **Chapter 7**, the NRC's assessment is that the Riverina is facing a more water-scarce, rather than water-rich, future, and so it seems unlikely that irrigated plantations of red gums could be established on any scale. This conclusion is consistent with that reported by Powell (2009), in his summary of research outcomes from the Joint Venture Agroforestry Program, and with those reported more generally by CSIRO et al (2001). It contrasts with that reported for north-east Victoria by Borschmann and Poynter (2003) principally because of the substantial difference in rainfall, and thus growth rates, between the two regions.

A more promising direction for commercial tree planting may be that directed primarily at carbon sequestration. Such plantations may also provide other environmental services and are likely to involve the establishment of novel tree crops such as oil mallees. Both the Garnaut Climate Change Review (2008) and the Wentworth Group of Concerned Scientists (2009) advocate large-scale reforestation as one of the means to mitigate climate change, and point out that extensive areas of Australia's low rainfall zones may be suitable for such reforestation. The extent to which carbon sequestration-based commercial opportunities

Deniliquin Town Centre

will be realised depends on the future arrangements for any Australian carbon pollution reduction scheme, and possibly on related international arrangements.

In summary, the low rainfall across most of the Riverina bioregion precludes commercial returns from conventional plantation or farm forestry crops unless they can be irrigated. Tree planting which generates returns from novel products, and from carbon sequestration and perhaps other environmental services, are more likely to have potential in the Riverina. Both the growth rates and products from such plantings mean they are unlikely to substitute for red gum timber production in anything other than the very long term.

10.5 Implications for local communities and towns

Towns within the Riverina bioregion are facing a decline in their economic base due to the impacts of ongoing drought on the agricultural industries which form the base of their economies. For those towns in the region with ties to the river red gum forests, river regulation is also impacting the health and productivity of these forests. The predicted impacts of climate change are likely to continue these trends.

The ability of local communities to adapt to such changes is in part dependent on the diversity of industries that support those communities and the varied opportunities available to accommodate industry change. Social research over the past 30 years has shown that while some communities are able to respond to change effectively, others are less able to make a progressive shift.

The NRC has assessed the adaptive capacity of towns in the Riverina and found that several towns have close ties to the forest industry through the employment and local expenditure it provides. Of these, the twin towns of Barham-Koondrook and the town of Mathoura have less capacity to adapt to changes in climate than other towns and have the highest reliance on the red gum forestry industry. Conversely, Deniliquin appears to exhibit the greatest resilience to potential climate change impacts, with a lower vulnerability to change, a greater degree of industry diversity and low reliance on the red gum forestry industry.

10.5.1 Approach to analysing adaptive capacity of Riverina towns

The adaptive capacity of seven towns within the Riverina bioregion which have close links to the red gum forestry industry reliant on public land was assessed using a range of available statistical indicators. These indicators were compared between towns and to an average for outer regional NSW.

The conceptual framework for the analysis was based on the assumption that a community's capacity to adapt to change is dependent on the status of its economic, physical, human and social capitals. Central to the framework is the inter-relationship between capitals. Where one capital is depleted, other community capitals are also likely to become compromised. For example, the depletion of human capital through deterioration of education levels or community health is likely to impact on social and economic capitals.

Brown (undated) highlights that a community's adaptive capacity may be slowed by a number of factors including:

- age profile
- education profile
- employment profile
- income levels
- diversity of current income sources.

Each aspect of economic, physical, human and social capital was assessed using a range of demographic indicators sourced from readily available published information (such as ABS data)

Consultation with forestry industry representitives

and supplemented by primary surveys with forestry industry operators and discussions with local councils undertaken by the NRC. The indicators selected are broadly in line with other similar studies of social vulnerability in communities which rely heavily on a single industry (CARE, 2009).

For the purpose of the current work, the NRC has defined the NSW portion of the Riverina bioregion as including the Statistical Local Areas of Balranald, Berrigan, Conargo, Deniliquin, Griffith, Murray, Murrumbidgee, Wakool and Wentworth. The location of the Riverina bioregion is described in more detail in **Chapter 2**.

The towns of Barham-Koondrook (which functions as one community), Deniliquin, Mathoura, Darlington Point, Balranald and Merbein were assessed as being likely to have the most reliance on the forests. These were towns with 1 per cent employment or greater in the red gum forestry industry. Echuca-Moama was not included as a town of interest as it does not have direct employment in the forestry industry. This selection of towns was cross-checked with NSW Forest Products Association, the peak representative body for the forestry industry.

10.5.2 Indicators of adaptive capacity

Economic capital and associated variables

The status of a town's economic resources has significant implications in relation to its ability to cope with change. Moreover, a town with strained economic resources at an individual or household level is likely to be more vulnerable to change or a disruption in industry activities, especially if the town is heavily dependent upon that specific industry for economic sustainability. Low levels of individual or household economic capital will also adversely affect individual abilities to recover from the impacts of significant change in the structure of their local economies, as well as their capabilities to adapt to new economic activities.

The diversity and range of industry or commercial economic activities is a key indicator of a community's capacity to accommodate further industry diversification and hence, economic growth. For example, a community with a predominant dependency on the forestry sector, and with limited diversification across other industry sectors, is likely to be particularly sensitive to changes within the forestry industry.

Economic variables used in this assessment include, but are not limited to:

- home ownership (whereby a high proportion of residents renting from Government or community organisations would suggest a lack of capital investment at an individual or household level)
- income levels (whereby a high proportion of income earners earning less than $500 per week is considered to indicate low levels of economic resources and disadvantage at an individual or household level)
- employment status (including total employment in the forestry industry)
- economic diversity (using the Herfindahl Index[19], where a high index score represents greater industry concentration and limited industrial diversification).

Physical capital and associated variables

The physical resources of a town or community include its built infrastructure and services including hospitals, schools, health care, aged care and child care. These services and resources are important factors in determining a community's adaptive capacity. A highly remote community, which lacks access to basic facilities and other social services, may lack the capacity to enhance its local human skills base, and might also be disadvantaged in capitalising on opportunities for further industry development and economic capital growth.

While it seems logical that larger towns provide more services, other factors are also important considerations. For example, personal mobility and car ownership enable people to travel further and more often and large supermarkets in nearby regional centres reduce the need for general stores in small towns.

Access to information is also important as it enables members of the community to address their information needs, and connect with other members of the community and the broader society.

Physical variables used in this assessment include, but are not limited to:

- distance from regional service centres
- access to internet
- accessibility to public services (for example, a library).

[19] The Herfindahl Index squares the market-share of commercial and industry activities, and then sums those squares. (Bradley and Gans, 1998)

Human capital and associated variables

Human capital can provide an indication of the health and welfare of human beings, their knowledge and skills, as well as their overall capacities to contribute to ongoing community sustainability. A community that has a higher proportion of lower skilled persons and is heavily dependent on a particular industry tends to be more vulnerable to potential risks and threats to its livelihood. Some studies have shown that less skilled communities are also less likely to become motivated in initiating positive change (Arcidiacono, et al., 2008). In the instance where a town is predominantly reliant on the forestry industry, a less educated and lower-skilled community may be more challenged in independently developing new economic opportunities and skill-sets. Therefore, these communities will most likely be in need of external assistance or support.

Another useful indicator is the prevalence of highly vulnerable or at risk minority groups, which may include immigrants and refugees, people with a disability, Indigenous persons, people who do not speak English or elderly persons (aged 65 years and over). A high concentration of vulnerable or at risk minority groups is likely to increase a community's overall vulnerability to significant change and risks. Further to this, recognition of community diversity within and across the towns and region is important when considering how public land is to be used in the future (VEAC, 2006).

Human variables used in this assessment include, but are not limited to:

- post-school qualifications (percentage of persons aged 15 years or over without post-school qualification)
- skills and expertise (percentage of employed persons in low skilled roles)
- minority or vulnerable groups (for example, percentage of total population which is Indigenous, percentage of people aged 65 years or above as a proportion of total population).

Social capital and associated variables

When assessing a community's capacity to adapt to change, it is also important to consider how individuals, groups, organisations and institutions within a community interact and co-operate.

Social capital broadly defines the dynamics and strength of relationships and interactions within a given community (Lochner et al., 1999) and the degree of social cohesion and inter-connectedness between community members.

A key indicator is the degree of community participation, or level of community involvement in processes aimed at maintaining or enhancing community well-being. These processes may include participation in community groups or not-for-profit voluntary activities in addition to professional commitments.

Another useful measure of sense of community is the degree of transience within a given town. Highly transient populations tend to be less socially cohesive. A community with a high proportion of short-term and temporary residents may be less likely to have high levels of community pride, with these residents also likely to be less cohesive in responding to times of adversity or threats to changes in their way of life. In addition, a largely transient population may also be less inclined or likely to contribute towards processes that enhance community well-being, including processes such as voluntary activities, participation in community groups or local governance. This can be measured by assessing the proportion of the population with a different address five years ago.

Social variables used in this assessment include, but are not limited to:

- mobility (percentage of total population with a different address five years ago)
- cultural diversity
- participation in not-for-profit voluntary organisations.

Table 10.14: Indicators, analysis/measurement procedures and data sources

	Indicators	Indicators	Analysis/measurement procedures	Data source
Economic Capital	Household socio-economic status	Home ownership	% of total occupied private dwellings that are renting from government or community organisations.	ABS, 2006
		Income levels	% of households with income of less than $500 per week.	ABS, 2006
		Employment status	% of total persons in the labour force who are unemployed.	ABS, 2006
		Child dependency	Number of dependent aged children as a proportion of employed persons.	ABS, 2006
		Family structure	% of total number of families who comprise one-parent families with dependent children.	ABS, 2006
	Commercial economic activities	Economic diversity	Herfindahl Industry Diversity Index, which squares the market share of commercial and industrial companies, and then sums those squares. Scores range from 0 to 1 (but have been multiplied by 100 for ease of comparison) where 1 indicates high industry concentration and low diversity.	ABS, 2006
		Employment in the forestry industry	Proportion of total employment in relevant urban locality employed by businesses with licences to harvest red gum timber from public land[20].	Survey conducted by NRC and ABS, 2006

[20] A survey was conducted to assess the number of full-time equivalent employees in businesses with a licence to harvest red gum timber from public land.

Table 10.14: Indicators, analysis/measurement procedures and data sources (continued)

	Indicators	Indicators	Analysis/measurement procedure	Data source
Physical capital	Service accessibility	Index of remoteness	ARIA+, which is the standard ABS endorsed measure of remoteness, derived from measures of road distance between populated localities and service centres. It has score values ranging from 0–15 where the higher the score, the more remote a locality.	GISCA Applications
	Information accessibility	Internet access	% of total population who do not have access to the internet.	ABS, 2006
		Accessibility to public library services	Yes or no.	State Libraries of NSW
Human capital	Education	Post-school qualifications	% of persons aged 15 years or over without post-school qualifications.	ABS, 2006
		School completion	% of persons aged 15 years or over who left school before Year 10.	ABS, 2006
		School attendance	% of persons aged 15 years or over who never attended school.	ABS, 2006
	Skills and expertise	Low skilled occupations	% of employed persons over the aged of 15 years who are employed as labourers or community and personal service workers.	ABS, 2006
	At-risk groups	Minority/ vulnerability groups	% of total population who are Indigenous. % of total population who are disabled and require care. % of people aged 65 years or above as proportion of total population. % of people aged over 15 years who provide unpaid care or assistance to people with disabilities.	ABS, 2006
Social capital	Sense of community	Mobility	% of total population with a different address five years ago.	ABS, 2006
		Cultural diversity	% of total population who were not born in Australia who speak English not well or not at all.	ABS, 2006
	Community participation	Participation in not-for-profit voluntary organisations	% of total population who do not provide voluntary services to not-for-profit organisations.	ABS, 2006

Table 10.14 summarises the indicators that have been selected for use in the current study on the basis of a literature review. Variables used to assess each indicator, the analysis or measurement procedure utilised and the data source are also defined. All raw variable scores (e.g. proportions and percentages) have been standardised to enable relative comparison across the seven identified towns with dependencies or linkages to the forestry industry.

10.5.3 Adaptive capacity of towns linked to the red gum forestry industry

Overall, towns in the NSW Riverina bioregion are facing similar pressures to the majority of regional NSW. Over the last decade, the NSW Riverina bioregion has seen a plateau in population growth. Population in the region as a whole was down 0.2 per cent between 2001 and 2006, compared to a 0.3 per cent increase for regional NSW (ABS, 2006). The impact of the current drought on the agricultural industries on which regional economies are based is similar for towns in the Riverina bioregion and those elsewhere in NSW. As discussed in **Section 10.2**, there are a wide range of socio-economic implications of predicted climate change for the Riverina bioregion, and these will be equally applicable to the towns with close ties to the red gum forestry industry. The level of significance of these effects will depend largely on the towns' reliance on those industries most likely to be impacted, particularly those that rely on supply of water, such as irrigation and forestry.

Within this context, the seven towns identified as having close links to the red gum forestry industry reliant on public land appear to vary in their capacity to adjust to further changes. **Table 10.15** displays the results for each of the indicators for the seven towns of interest, as well as for 'outer regional NSW'as it is defined by the ABS. This table enables comparisons between towns on the basis of their raw figures, as well as between each town and the regional average.

It is important to note that Barham and Koondrook appear separately in the statistical analyses only because they are treated separately by the ABS. For all practical purposes, they are interdependent and function as one community with the well-being and survival of one depending on the other. Consequently, while **Table 10.15** list Barham and Koondrook individually, the narrative below focuses on the Barham-Koondrook community.

[21] Indicators are based on the locality of the specific towns identified, as defined by the ABS 2006 Census data.

It is also relevant to consider the distance of each town from major regional centres which may provide access to services and employment opportunities that are not available in the towns themselves[21]. Merbein, in particular, is located 12 kilometres from Mildura and may be considered as a suburb of this regional city. Darlington Point is located 38 kilometres from Griffith and Mathoura is 42 kilometres from Echuca-Moama. Barham-Koondrook and Balranald are 75 kilometres and 92 kilometres respectively from Swan Hill.

A comparison of the adaptive capacity of each of the seven towns, based on the indicators of their economic, human, physical and social capital, is discussed below.

Deniliquin

Based on the indicators of economic capital shown in **Table 10.15**, Deniliquin can be considered the town most resilient to changes in economic resources or industry activity. It has the highest degree of industry diversity and other indicators of economic capital are also relatively strong. Its relatively large size as a regional economic centre with a population of 7,500 (ABS, 2006) suggests it can offer a greater diversity of employment opportunities than some other towns.

Deniliquin has relatively strong indicators of social capital, with a high proportion of the population having completed school and having post-school qualifications. It also has strong indicators of skills and expertise (based on the low levels of the population employed in low skilled occupations). In general, these are comparable to outer regional NSW.

Deniliquin has the lowest reliance on the red gum forestry industry of all the towns linked to the red gum forestry industry. Based on location of employment, employees of businesses with licences to harvest timber from public land account for less than 1 per cent of total employment in the town. This suggests Deniliquin is likely to be able to adapt to changes in the forestry industry.

Balranald

Balranald is also likely to be more resilient to change than other towns. It has similarly strong indicators of economic, physical and human capital to Deniliquin. Of all the towns, Balranald has the strongest indicators of social capital, with the lowest levels of population mobility at 31.5 per cent and the highest proportion of the population involved in volunteering with not-for-profit organisations.

With 4.6 per cent of total employment in the red gum forestry industry, Balranald is likely to be able to adapt to changes in this industry.

Merbein

Merbein has indicators of lower economic and human capital compared to other towns in outer regional NSW. All indicators of economic capital are higher than the average for outer regional NSW, with unemployment at 8.3 per cent being the highest of all the towns (at the same level as Mathoura). Its population has relatively low levels of education with 92 per cent having no post-school qualification. The proportion of the population in low skilled employment is higher than the regional average at 34.8 per cent.

However, being only 12 kilometres from Mildura, it has access to services and employment which will support its capacity to adapt to change.

Merbein has relatively low reliance on the red gum forestry industry on public land. Based on location of employment, employees of businesses with licences to harvest timber from public land account for 3.4 per cent of total employment. This suggests Merbein is likely to be able to adapt to changes in this industry.

Darlington Point

In general, Darlington Point has stronger indicators of economic and human capital than the average for outer regional NSW. It has a low unemployment rate at 4.2 per cent, and at 20.8 per cent, the proportion of the adult population with household income below $500 per week is low compared to the outer regional NSW average of 28.5 per cent.

Darlington Point stands out for its relatively high levels of population mobility, which may suggest low levels of social cohesion. Darlington Point is also notable for its relatively low level of volunteering, compared to the other towns and the outer regional NSW average. These indicators could be due to the population growth of 3.3 per cent experienced in the five years to 2006 (ABS, 2006).

Many residents of Darlington Point are families which have moved to the town in recent years due to its low property prices (GHD, 2009). This is reflected in the significantly younger population compared to other towns, high childhood burden (57.0 per cent) and high proportion of one-parent families (14.7 per cent).

Darlington Point is 38 kilometres from Griffith. It can be considered as a satellite town of this regional centre to which some residents commute for work.

The low levels of employment in the red gum forestry industry on public land (4.6 per cent) suggest Darlington Point is likely to be able to adapt to changes in this industry.

Barham-Koondrook

The twin towns of Barham-Koondrook may be considered less resilient to change than other towns. Their economic capital appears to be low given their high proportion of low income households at an average of 31.6 per cent compared to outer regional NSW at 28.5 per cent. They have lower human capital than the other towns, reflected in a high proportion of individuals without post-school education and relatively high proportions of retirees and unskilled workers.

On the other hand, the towns of Barham-Koondrook have the lowest unemployment rate of all the towns reliant on the red gum forestry industry. Their relatively low population mobility and higher level of participation in volunteer activities than the average for outer regional NSW suggest relatively high levels of social capital.

The two towns are notable for their high dependence on the red gum forestry industry. Based on location of employment, employees of businesses with licences to harvest timber from public land account for 16 per cent of total employment in the combined towns. This suggests these towns may have lower ability to adapt to changes in the red gum forestry industry than the other towns considered.

Table 10.15: Results for CSI indicators for each of the towns as well as the outer regional NSW area

	Barham	Koondrook	Deniliquin	Mathoura	Darlington Point	Balranald	Merbein	Outer regional
Economic capital								
Proportion renting from Government or community organisations	7.0%	5.6%	20.4%	7.7%	23.5%	23.8%	24.2%	15.6%
Proportion of total adult population earning weekly household income of less than $500	28.5%	34.6%	26.1%	38.6%	20.8%	26.7%	33.9%	28.5%
Unemployment rate – Proportion of total adult population who are unemployed	2.2%	4.5%	5.2%	8.3%	4.2%	6.1%	8.3%	7.0%
Childhood burden – Number of dependent aged children as a proportion of employed persons	45.5%	36.1%	47.4%	48.6%	57.0%	47.8%	56.1%	51.8%
Proportion of one-parent families with dependent children	5.6%	7.4%	10.6%	8.5%	14.7%	12.7%	14.1%	9.5%
Herfindahl Industrial Diversity Index (multiplied by 100 for ease of comparison)	2.0	2.2	1.3	3.2	2.4	2.8	2.5	1.3
Dependency on the red gum forestry industry (proportion of total town employment*)	17.2%	15.4%	0.9%	13.8%	4.6%	4.6%	3.4%	N/A
Physical capital								
ARIA+ remoteness	3.1	3.1	2.2	2.7	4.2	4.6	2.6	N/A
No accessibility to the internet	54.2%	61.2%	48.6%	66.9%	53.5%	54.4%	56.7%	46.7%
Accessibility to a public library	Yes	Yes (Barham)	Yes	Yes	No	Yes	Yes	N/A
Human Capital								
Proportion of total adult population with no post-school qualification	87.7%	93.4%	86.2%	94.6%	93.5%	87.8%	92.0%	85.5%
Proportion of total adult population who left school before Year 10	26.1%	30.8%	22.7%	33.0%	28.2%	25.5%	30.7%	22.4%
Proportion who never attended school	0.0%	0.0%	0.5%	1.1%	0.5%	0.6%	0.6%	0.5%
Proportion employed as labourers or related workers	16.1%	23.4%	14.2%	25.0%	31.3%	17.9%	24.9%	14.6%
Proportion employed as community and personal service workers	10.5%	14.6%	10.4%	10.5%	9.2%	11.9%	9.9%	8.6%
Proportion of total population who are Indigenous persons	2.0%	0.0%	2.8%	1.8%	17.2%	8.1%	4.9%	6.0%
Proportion of total population who are disabled and require care	5.1%	5.7%	5.2%	6.0%	5.1%	5.2%	5.5%	5.0%
Proportion of retirees (people aged 65 years and over)	33.2%	25.5%	19.4%	25.2%	12.4%	19.1%	18.1%	16.9%
Proportion who provide unpaid assistance to people with disabilities	8.7%	11.2%	11.2%	10.9%	10.6%	10.2%	11.6%	11.7%
Social capital								
Population mobility – Proportion with a different address five years ago	40.2%	33.4%	38.5%	34.4%	40.5%	31.5%	35.9%	35.5%
Cultural diversity (% of immigrants who do not speak English)	0.0%	7.0%	3.4%	0.0%	0.0%	0.0%	0.0%	4.8%
Proportion who do not volunteer at not-for-profit organisations	57.2%	64.9%	65.1%	64.6%	71.6%	54.8%	67.3%	64.6%

* Surveyed full-time equivalent employees of businesses with licences to harvest timber from public land compared to total employment in the relevant urban locality.

Mathoura

In terms of economic capital, Mathoura has the lowest industry diversity and could be considered the most vulnerable to changes in industry activity. It has the highest proportion of the adult population with a household income of less than $500 per week and a high unemployment rate of 8.3 per cent. However, indicators such as home ownership are strong compared to the outer regional NSW average.

Mathoura may also have lower human capital compared to other towns. It has a greater proportion of the population without school completion (33 per cent) or post-school qualifications (94.6 per cent). Consistent with this, it also has a greater proportion of the population employed in low skilled occupations (35.5 per cent) compared to the outer regional NSW average (23.2 per cent). Mathoura is also notable in that only one-third of the population have access to the internet.

However, Mathoura has relatively strong indicators of social capital. Population mobility is lower than for outer regional NSW. Approximately 35 per cent of the population are involved in volunteer activities.

Mathoura has the second highest dependence on the red gum forestry industry after Barham-Koondrook. Based on location of employment, employees of businesses with licences to harvest timber from public land account for 13.8 per cent of total employment in the town. It could therefore be considered reasonably vulnerable to changes in this industry.

Millewa State Forest

10.6 Building adaptive capacity of communities in the Riverina bioregion

Given the expected general socio-economic impacts of climate change, and the predicted localised impacts of changes in water availability on the forestry industry, communities in the Riverina bioregion face a future quite different from what has been experienced in the past. In general, a sustainable future for the region will depend on the development of less water-dependent industries. The ability of the region's communities to address the impacts of climate change, and transition to a new water-scarce future will depend on their resilience and adaptive capacity. Both communities and governments have roles in working through this transition.

In situations of transformation, communities have choices. On the one hand, they can resist change and attempt to maintain the status quo. In general, water-dependent industries can be expected to try to retain their profitability, and communities can be expected to resist change to retain their quality of life. This may be possible over short time scales, however over longer time scales, this position is not sustainable. The alternative is that communities prepare for and adapt to a future with less water. This is a more viable alternative over the longer term, which can be facilitated by government support for building adaptive capacity to assist a smoother transition to alternative states.

In situations of structural change due to policy decisions, governments have historically taken a role in assisting the transformation of industries and the communities that rely upon them. Structural adjustment policy in the past has generally been focused on facilitating industry exit and compensation. However, a variety of approaches is possible. Structural adjustment could focus on building adaptive capacity in communities, through continual and iterative processes.

Building adaptive capacity gives communities the ability to cope with sudden or gradual changes and to take advantage of potential market opportunities that may arise as a result of changes. Adaptive capacity can be targeted at industry, local government or community levels. It means fostering flexibility, localised solutions and leadership, strong networks and linkages, and diversity in socio-economic systems.

The capacity of industries in the Riverina and their dependent communities to adapt to climate change could be supported through a variety of approaches. These include information provision, skills and capacity development, and investment in infrastructure and programs to support regional development. These are discussed further below.

10.6.1 Information provision

There is currently a limited understanding of how climate change may potentially affect local environments and community way of life. Governments can play a key role in addressing this knowledge gap by providing relevant, frequent and timely information regarding the projected impacts of climate change. This can assist the development of effective adaptive capacity at a local and regional level and assist industry in making appropriate business decisions.

Specific initiatives which may be relevant include:

- development of a community risk assessment framework that can be applied at a local government level, to assess the implications of climate change on local communities
- adoption of a regional approach to climate change, whereby various local government bodies within a region come together to engage in the implementation of adaptation actions and to share resources and knowledge
- formation of partnerships between industry and Government, e.g. private industries partnering with different levels of government to establish a localised climate change action fund, which would assist regional

and remote communities in further optimising their capital towards effective climate change adaptation

- improved modelling of climate change scenarios at a scale relevant to local communities
- assessment of community understanding of climate change and use the outcomes to design education/ information materials to promote greater awareness of the issue and its impacts
- infrastructure and support to enhance the capacity of communities to deal with extreme weather and fire events that may occur as a result of climate variability and predicted climate change.

The NSW Government, through DECCW, is commencing a cross-sectoral Integrated Regional Vulnerability Assessment for climate change in the south-west of NSW. As the part of NSW most likely to be impacted by climate change, the study will seek to work with local government, industry and the community of south-western NSW to identify those sectors and communities most vulnerable to climate change, and ultimately lead to the identification of adaptation strategies designed to reduce regional vulnerability. This study and the subsequent adaptation strategies will build on the strengths of the region to develop communities with greater capacity to adapt and grow in the face of change.

10.6.2 Skills and capacity development

Small towns can be assisted to become more resilient and economically sustainable in the face of climate change impacts through alternate skills development and employment opportunities (NSW Department of Planning, 2009). Providing improved training opportunities can encourage workforce skill diversity and facilitate greater industrial diversification. This would assist members of the community to be more flexible in their employment – and better able to flexibly respond to new employment and business opportunities.

River red gum logs ready for milling

Beckley et al., (2002) in discussing a community's capacity to cope with, and subsequently adapt to, resource management changes, placed a particular emphasis on human and social capital. These authors highlighted the important role that these capital play in determining overall community capacity. They suggest that more strategic investments in formal and informal education and support for social networks and infrastructure that links community and industry leaders across different localities, is a fundamental element of community capacity building.

Regional and local programs could be identified and/or implemented that emphasise development of local social and human capital and facilitate the development of strong networks and partnerships among key stakeholders. This would further develop a community's adaptive and ongoing capacity to manage change.

10.6.3 Diversification of industry

In general, the ability of the Riverina bioregion to adapt to the impacts of climate change can be enhanced by the diversification of industry through the investment in infrastructure and technology to optimise the use of available water and through the development of less water-dependent industries. To address this issue, strategies may include diversification of commercial activities away from highly vulnerable environmental assets, and into areas that are unlikely to move in the same direction at the same time.

Governments can assist communities to develop a greater diversity of industries by providing infrastructure and programs to encourage private sector development. Regional development initiatives may include:

- training programs, incentives for industry to diversify or investments in intensification of higher value production systems
- enhanced water management infrastructure and support for the development of water efficiency technologies and practices
- strategies to increase the tourism industry such as promoting of regional NSW as a tourist destination, improving road infrastructure, providing opportunities for private sector investment in tourist accommodation and developing specific events as tourism attractions.

Chapter 11

Managing red gum floodplain ecosystems

11.1 Overview

The river red gum floodplain ecosystems of the Riverina bioregion are under high stress, and in some cases are transitioning to alternative states. They will require various levels of direct intervention to maintain their resilience, and to continue to provide ecosystem services that the community values.

We need to rethink our current approach to forest management. The NRC considers that management approaches for the river red gum forests of the Riverina bioregion should be based on recognition of ongoing water scarcity, clear management objectives, and build upon past forest conditions and management activities (rather than attempting to replicate them). In particular, we need to learn as we go by trialling and testing different approaches for these ecosystems.

This chapter recommends management approaches for the red gum floodplain ecosystems. The implementation of these approaches should help to achieve conservation outcomes, and a sustainable future for the forests and the industries and communities that are dependent upon them. It supports Step 5 of the analytical framework by:

- describing goals for future management
- proposing a set of principles for the management of red gum floodplain ecosystems.

The key findings of this chapter are:

- River red gum forests are a component of a dynamic floodplain ecosystem. Future management under all forms of tenure must address the ecosystem as a whole, which no longer receives sufficient flood flows or groundwater to sustain some forest components and values of those ecosystems.
- Naturally occurring processes will contribute to changes in red gum floodplain ecosystems. However, targeted and active management interventions can achieve outcomes with a greater degree of control and certainty than naturally occurring processes and/or passive approaches. This applies across both private land and all public tenures.
- In some forest areas, ecological thinning can be a useful tool to enhance conservation outcomes. However, little research has been undertaken on the effects of different thinning techniques on conservation values, and outcomes are subject to considerable uncertainty. There is a strong imperative to develop robust, prudent adaptive management frameworks to guide ecological thinning in river red gum forests in both production and reserved areas.
- The current implementation of Australian Group Selection (AGS) in river red gum forests should be modified to better:
    - reflect the availability of water in river red gum forests
    - maintain the ecological character of the forests (DEWHA, 2008)
    - protect matters of National Environmental Significance[1].
- AGS remains an appropriate silvicultural system for river red gum forests managed for production, as well as for other values as long as management prescriptions are improved. These include prescriptions for adequate watering regimes, the provision and maintenance of ecological values (principally the retention of habitat trees and coarse woody debris), and the intensity of its implementation.

11.2 Goal for red gum floodplain ecosystem management

The NSW Government has adopted a long-term, aspirational goal to achieve:

resilient, ecologically sustainable landscapes functioning effectively at all scales and supporting the environmental, economic, social and cultural values of communities (NRC, 2005).

The NRC considers that a general goal for the future management of red gum floodplain ecosystems should be:

to implement activities that maximise the potential to maintain resilient, diverse, sustainable ecosystems, which continue to deliver ecosystem services, under anticipated changes to water availability and climate.

This goal is consistent with NSW's aspirational goal and other strategies for biodiversity conservation under climate change (Biodiversity and Climate Change Expert Advisory Group 2009; Commonwealth of Australia, 2009).

This goal could be pursued in different ways across the Riverina bioregion, according to the current and desired balance between uses – for example conservation and production. It should be applied to ensure that ecosystems function to support the communities' values for the environment, economy, society and culture. An integrated and adaptive approach to red gum forest management based on sound scientific knowledge is the best way to sustain the diversity and values of these floodplain ecosystems over the long term.

11.3 Management principles for resilient river red gum forests

River red gum forests are components of dynamic floodplain ecosystems. These ecosystems have been shaped by geomorphic processes and human interventions – especially river regulation, timber harvesting, silvicultural management, fire management and grazing. These ecosystems will continue to be affected by past interventions, as well as by changes and variability in climate, changes in water availability, human activities and other disturbances.

The Murray Darling Basin Authority (MDBA) has characterised the ecosystem functions that underpin the Basin's river systems in relation to three interdependent physical processes listed in **Table 11.1** (MDBA, 2009).

Natural resource management actions are often focused on one component of a system in isolation of others (NRC, 2007; NRC, 2008). While this can deliver measurable benefits for that component, it can fail to recognise both positive and negative changes in the larger system. From a landscape perspective, the different parts of an ecosystem, its productivity, and its

[1] Environmental Protection and Biodiversity Conservation Act 1999 (C'th)

Table 11.1: Physical processes that underpin the Murray-Darling Basin's key ecosystem functions (MDBA, 2009)

Physical process	Examples of dependent key ecosystem functions
Inundation of river beds, banks and floodplains	• Creation of physical habitats for plants and animals • Mobilisation of carbon and nutrients
Material mobilisation, transport and dispersal	• Creation and maintenance of physical habitats (e.g. scouring of river beds to create pools, deposition of materials to create bed formations and bank formations) • Mobilisation, transport and dispersal of minerals and nutrients to wetland and floodplain ecosystems
Lateral, longitudinal and vertical flow connectivity	• Transport of carbon, nutrients and minerals • Dispersal of seeds • Migration of aquatic animals for reproduction or foraging • Export of pollutants (e.g. salt) from key parts of the river system (e.g. Murray mouth) • Connectivity with groundwater

ecological components are all interconnected and need to be managed in an integrated manner. For example, groundwater resources have been historically managed in isolation from surface water, yet both are important for the health and persistence of many river red gum forests.

A general principle of landscape management is to manage ecosystem processes within the range of historical variability (Wallin et al., 1996). However, in landscapes that have been changed substantially since European settlement and which are subject to ongoing change, novel management approaches are often required to enhance resilience and maintain conservation values (Walker *et. al*., 2009; Walker and Salt, 2006).

For example, in some conservation reserves in south-eastern Australia, active management interventions such as livestock grazing and ecological thinning have been proposed to achieve conservation goals (Lunt et al., 2007; VEAC, 2008; Parks Victoria, 2009). Similarly, in water-dependent systems, such as river red gum forests and wetlands, flooding regimes are commonly manipulated to achieve specific conservation goals.

In altered and changing forests, active management interventions are not necessarily more ecologically harmful or less appropriate than allowing natural processes to occur. Instead, active and targeted interventions can provide greater certainty and a greater degree of control in achieving the desired outcomes, than management approaches relying on natural processes or more 'passive' interventions.

As has been outlined in this report, river red gum floodplain ecosystems are likely to transition to new ecological states under climate change and water scarcity. The NRC considers that a range of active management approaches across all tenures will be required to maintain the health and resilience of these systems. The most appropriate management approach will depend on whether the ecosystems are being managed primarily for conservation or production or other purposes. For example, ecological thinning can be a useful technique to achieve conservation goals in some river red gum forests – it can promote the creation or retention of large hollow-bearing trees in areas dominated by dense regrowth (Horner et al., in press). This thinning can be implemented differently from that in areas managed primarily for production, for which prescriptions are already well established (Forestry Commission of NSW, 1984).

The NRC has developed a set of principles to guide a range of management activities in red gum floodplain ecosystems, including ecological thinning, grazing, fire management, silviculture and firewood collection (**Table 11.2**). The principles are intended to underpin the management of red gum floodplain ecosystems for both conservation and production outcomes.

These principles have been developed specifically for river red gum forests, within the context of their current condition and expected future trajectory. They build on more general principles for managing ecosystems under changing environmental conditions such as declining water availability or climate change (Lindenmayer et al., 2000; Lindenmayer et al., 2006; Lindenmayer et al., 2008 Millar et al., 2007; Dunlop and Brown, 2008; Mawdsley et al., 2009; Montreal Process Implementation Group, 2008a; NRC, 2005; Commonwealth of Australia, 2009).

If the principles are codified in management plans or formal agreements for all tenures, the NRC considers they will promote resilient, diverse and sustainable red gum floodplain ecosystems, continue to support community values, and drive adaptive management.

The remainder of this section:

- summarises the principles
- discusses the rationale for each in relation to ecological thinning, grazing, fire management and silviculture.

The descriptions do not attempt to cover all possible interventions. Instead they address a number of specific activities that can strongly influence forest sustainability under conservation and production management objectives.

Table 11.2: Principles for red gum floodplain ecosystem management

Principles for red gum floodplain ecosystem management
Principles for all red gum floodplain ecosystem management under environmental change
• **Principle EM1**: Sustain large-scale hydrological and geomorphological processes. • **Principle EM2**: Maintain connectivity between communities, habitats and ecological processes across the bioregion. • **Principle EM3**: Implement a range of management strategies across different spatial, temporal and institutional scales to spread risk. • **Principle EM4**: Implement active management regimes within both protected and production areas. • **Principle EM5**: Maintain forest complexity within production forest areas, including stand complexity, large trees and threshold levels of coarse woody debris, and variability across space and time. • **Principle EM6**: Establish a comprehensive, adequate and representative series of reserved areas. • **Principle EM7**: Enable environmental stewardship by individual and groups on private land. • **Principle EM8**: Involve local communities in strategy development and implementation to ensure greater success in achieving identified goals. • **Principle EM9:** Implement adaptive management in reserves and production forests to allow lessons to be learnt from management actions, and to allow their refinement.
Principles for ecological thinning
• **Principle ET1**: Ecological thinning can provide a valuable tool to achieve specified conservation outcomes in some river red gum forests, including those managed primarily for production and for conservation. • **Principle ET2**: Ecological thinning can be undertaken in many different ways, with different impacts on forest structure, processes and biodiversity. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met. • **Principle ET3**: Ecological thinning should be applied to forest areas where clearly defined outcomes can be reasonably expected. • **Principle ET4**: All ecological thinning should be implemented using an experimental, adaptive management framework to ensure desired outcomes are achieved, maximise learning outcomes and reduce uncertainty. • **Principle ET5**: Thinning, like all other management activities, should be carried out in accordance with accepted principles for landscape management of forested areas (Principles EM1–9).
Principles for fire management
• **Principle FM1**: Prescribed fire can be a valuable tool to control fuel levels and achieve specified ecological outcomes in some forest areas. • **Principle FM2**: In areas managed for conservation rather than production values, prescribed fire can provide a useful tool to achieve management goals, such as manipulating vegetation structure and composition, thinning dense stands, reducing fuel loads, promoting tree and shrub regeneration and controlling the abundance of vigorous dominant wetland plants.
Principles for grazing
• **Principle GM1**: Uncontrolled or poorly managed livestock grazing has caused considerable damage to river red gum forests in the past, and has the potential to further degrade environmental attributes. • **Principle GM2**: Notwithstanding Principle GM1, livestock grazing has potential to achieve positive outcomes for conservation values in limited parts of the forest, especially degraded and weedy areas, where it can help to reduce weed cover and control fuel loads. • **Principle GM3**: Livestock grazing should only be conducted where it achieves clearly specified management goals, and where stock can be contained to designated areas, to prevent unintended outcomes to sensitive features. • **Principle GM4**: Ground vegetation (and fuel) levels vary greatly between seasons and years according to flooding and rainfall. On public lands, livestock grazing should only be permitted when vegetation and fuel levels are appropriate, and licensing or agistment arrangements must enable stock to be removed at short notice, to satisfy land management goals. • **Principle GM5**: Where livestock grazing is conducted, it should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.

Table 11.2: Principles for river red gum ecosystem management

Principles for red gum floodplain ecosystem management	
Principles for silviculture	
• **Principle S1**:	'Group selection' is an appropriate silvicultural technique for river red gum forests managed for production values, subject to the provision and maintenance of ecological values, principally retention of adequate habitat trees and coarse woody debris resources, and other constraints of intensity and implementation described by Principles S2–8.
• **Principle S2**:	Group selection should only be applied to river red gum forests that are expected to receive adequate future watering.
• **Principle S3**:	Habitat trees should be retained permanently and distributed across the forest landscape.
• **Principle S4**:	Gap intensity needs to explicitly consider the ecological character of river red gum forests, particularly those which are Ramsar-listed.
• **Principle S5**:	Selective harvesting in immature forests between 'gapped' areas should be constrained by timing and intensity, and ecological thinning should be guided by ecological principles.
• **Principle S6**:	Coarse woody debris loads should be enhanced to threshold levels where practicable and consistent with other management objectives, such as fire management goals.
• **Principle S7**:	Salvage logging has the potential to be ecologically damaging and should follow recognised best-practice guidelines and adhere to the silviculture principles above.
• **Principle S8**:	Outcomes of river red gum silviculture, and the assumptions underpinning them, need to be monitored and tested in a structured and systematic manner to generate new knowledge and reduce uncertainty over time.
Principles for firewood collection	
• **Principle FC1**:	As per Principle S6, coarse woody debris loads at threshold levels should be retained where practicable and consistent with other (e.g. fire risk) management requirements.
• **Principle FC2**:	Firewood collection is generally inappropriate in conservation areas unless undertaken to achieve specific ecological or management goals (e.g. fire management), or where used for in-park recreational use. In such instances the provisions of Principle FC1 should also be adhered to.

Wetuppa State Forest

11.3.1 Ecological thinning for conservation outcomes

As described in Chapter 8, a substantial proportion of existing river red gum forests will receive less water in the future than in the past. This will impact greatly on forest condition in many parts of the forest.

As water availability declines, river red gum stands can be expected to pass through a number of stages of stand decline – reduced growth rates, less frequent regeneration, decline in foliage cover and 'tree health', and increased mortality. Tree death can lead to an 'opening up' of the canopy and consequently lower stand densities. Under more extreme conditions, this can in turn lead to widespread tree mortality and transformation to another ecosystem type, such as box woodland, saltbush plain or grassland.

In these circumstances, a spectrum of management options exists, from attempting to reverse or prevent the decline in water availability (for example, through engineering works and environmental flows), to allowing ecosystem changes to occur unhindered. Both of these approaches are likely to be used in different parts of the river red gum forests. However, other management approaches can be utilised between these two extremes. In some areas, it may be possible to reduce the adverse impacts of declining water availability on valued forest attributes by manipulating forest stands.

One approach is to attempt to enhance the growth, health or survival of desired trees by thinning competing trees. For over a century, foresters have thinned dense regrowth stands to enhance the growth rate and quality of desired timber-producing trees (Forestry Commission of NSW, 1984).

While thinning has historically been undertaken for timber production reasons, it can also be a valuable tool to achieve conservation goals. For example, Horner et al. (in press) found that thinning increased the rate of production of tree-hollows in thinned stands. In this case, thinning in these regrowth forests greatly enhanced the rate of creation of this important, and increasingly scarce, environmental attribute of river red gum forests.

Ecological thinning can potentially provide positive outcomes for biodiversity (see also **Box 11.1**), by:

- enhancing survival of valuable large trees
- increasing tree growth rates and the rate of creation of habitat trees
- creating coarse woody debris (Killey et al in press)
- enhancing carbon storage
- enhancing habitat quality
- reducing fire hazard from standing live or dead trees.

Several submissions to the NRC's assessment also suggested that ecological thinning can play an important role in enhancing production and conservation values in river red gum forests (for example, Dexter, 2009; Gelletly, 2009). Others pointed out the limits of current knowledge (for example, Cunningham and Mac Nally, 2009; Cunningham et. al., in press).

It is well known that thinning of dense stands can enhance tree growth (Forestry Commission of NSW, 1984; Dexter, 1970; Horner et al., in press). Field experience also suggests that thinning may also benefit tree health in particular circumstances, although this is not well documented in the scientific literature. However, there has been no formal appraisal of the potential positive effects of thinning on conservation values in river red gum forests, especially under a declining water regime (other than Horner et al's (in press) work noted above).

There is an urgent need for managers to develop ecologically appropriate and operationally practical techniques to enhance ecosystem health in many river red gum forests that are already suffering severe stress. This requires robust, prudent management frameworks to guide ecological thinning in river red gum forests – in both production and reserved areas.

The NRC has developed a set of principles as a basis for implementing ecological thinning in river red gum forests (**Table 11.3**). These have been drawn from what is currently known about the potential biodiversity benefits from ecological thinning (**Box 11.1**).

Some of these approaches could also provide positive outcomes for timber production. However, ecological thinning may not enhance forest health in all areas (**Box 11.3**). Some stands experiencing severe declines in water availability may decline regardless of whether thinning is undertaken (Cunningham et al., in press). Adaptive management trials and reporting of results are required to develop a greater degree of certainty about the outcomes that can be achieved.

Large hollow bearing tree

Table 11.3: Principles and rationale for ecological thinning

Ecological thinning principles	
Principle ET1:	**Ecological thinning can provide a valuable tool to achieve specified conservation outcomes in some river red gum forests, including those managed primarily for production and for conservation.**
Thinning is a well established method to enhance production outcomes. Ecological thinning involves the selective removal of trees (usually regrowth or suppressed trees) to achieve specified ecological outcomes. In certain areas, thinning can provide a potentially useful tool to reduce competition among trees and alleviate water stress. Hence, it could play an important role in enhancing survival of key forest attributes (such as old trees) in a drying forest. Ecological thinning could potentially enhance tree growth rates and tree health; tree survival, including large hollow-bearing trees; the rate of formation of tree hollows; coarse woody debris loads; carbon storage; and habitat quality for species that prefer open areas and habitat variability (heterogeneity), although not all of these outcomes have been rigorously tested (see **Box 11.1**) (Dexter, 1970; Forestry Commission of NSW, 1984; Horner et al., 2009, Horner et al., in press, Killey et. al. in press). Many of these attributes in river red gum forests have been depleted by past management – although more recent management has recognised and sought to redress this – or are expected to decline with future reductions in water availability. In this context ecological thinning can be used as a forest restoration tool.	
Principle ET2:	**Ecological thinning can be undertaken in many different ways, with different impacts on forest structure, processes and biodiversity. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met.**
Ecological thinning can be undertaken in many different ways (**Box 11.2**), including: • reducing stocking levels to a uniform, pre-determined level across moderately large areas • creating small open gaps within larger areas of dense regrowth • reducing stocking levels (and/or creating gaps) around specified features (e.g. large trees). Each of these approaches will have different impacts on forest structures, processes and biodiversity. Approaches that may have the greatest utility from a silvicultural perspective are not necessarily the most appropriate to achieve conservation objectives. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met.	
Principle ET3	**Ecological thinning should be applied to forest areas where clearly defined outcomes can be reasonably expected.**
The potential for thinning to enhance tree growth, health or survival will vary across forest areas according to the degree of competition and water availability. Consequently, ecological thinning has potential to enhance forest health in some parts of the forest only. Conceptually, this potential can be explained in terms of patterns of tree stocking and water availability (**Box 11.3**). Thinning should be restricted to forest areas where desired outcomes can be reasonably expected, monitored and assessed.	
Principle ET4:	**All ecological thinning should be implemented using an experimental, adaptive management framework to ensure desired outcomes are achieved, maximise learning outcomes and reduce uncertainty.**
Little research has been undertaken to assess the effects of different thinning techniques on conservation outcomes. Ecological outcomes are subject to considerable uncertainty, especially under a scenario of increasing forest drying. For example, the effects of thinning on arboreal and terrestrial fauna and ground vegetation are unknown. Therefore, all ecological thinning should be implemented using an experimental, adaptive management framework to maximise learning outcomes, consistent with approaches recommended by the Biodiversity and Climate Change Expert Advisory Group (2009). Ecological thinning and other forms of active management involve uncertainties and risks, such as harvest-induced damage to residual trees. However, allowing natural processes to occur also carries considerable risks – particularly in river red gum forests that are undergoing considerable change due to human-induced reductions in water availability. If carefully implemented, active management does not necessarily have higher risks than passive management.	
Principle ET5:	**Thinning, like all other management activities, should be carried out in accordance with accepted principles for landscape management of forested areas (as described in Table 11.2).**
Ecological thinning should be conducted within the context of broader management objectives and systems intended to maximise the potential to maintain resilient, diverse, sustainable ecosystems, which continue to deliver ecosystem services, under anticipated changes to water availability and climate. This is equally important in forests managed for conservation as well as those managed for production and conservation.	

11.1: Potential biodiversity benefits from ecological thinning

Enhanced survival of valuable large trees

Under reduced water conditions, large and small trees are declining in health. In many places, water stress is not just killing small and suppressed trees, it is leading to declines in health and survival of all trees, including old, hollow-bearing trees (Cunningham et al., 2009). In some cases, thinning of small trees in close proximity to stressed large trees may enhance the health and survival of large trees, although further experimental trials are required to assess the utility of this approach. By contrast, if large trees die it will take many decades or centuries to recreate the lost habitat values. Thus, if thinning around individual large trees improves the amount of water availability to them, it may help to maintain existing valuable habitat trees and potentially provide a supply of future habitat trees.

Increased tree growth rates and the rate of creation of habitat trees

Competition slows the rate of growth of trees in dense stands. By thinning stands, remaining trees can grow faster (Horner et al., 2009). This has obvious benefits for production forestry, but could also have conservation benefits in some forests, especially in areas of young regrowth. Large trees are currently relatively rare in many river red gum forests, and they contain habitat values that are not provided by small trees, such as hollows. Thinning early in the tree growth cycle accelerates branch growth, which in turn will lead to faster establishment of hollows, as noted above from Horner et al.'s (2009) work.

Coarse woody debris

Densities and breeding success of some fauna are higher in areas with abundant coarse woody debris (logs and branches on the ground) (Mac Nally, 2006; Mac Nally and Horrocks, 2008). Coarse woody debris accumulates slowly, especially in young forests. Horner et al. (2009) suggest that ecological thinning could increase habitat values for fauna if thinned debris is left on the ground to form coarse woody debris. Killey et al. (in press) highlight the importance of large senescing trees for the production of fallen branch debris, and support the thinning of regrowth stands to promote the growth of retained trees, ensuring they contribute to fallen branch debris stocks with a minimum time lag.

Carbon storage

Forests have a valuable role to play for carbon sequestration and storage. Moderate degrees of thinning can increase above-ground carbon storage levels above levels that are provided by dense, slow-growing, un-thinned stands (Horner et al., 2009).

Enhanced habitat quality

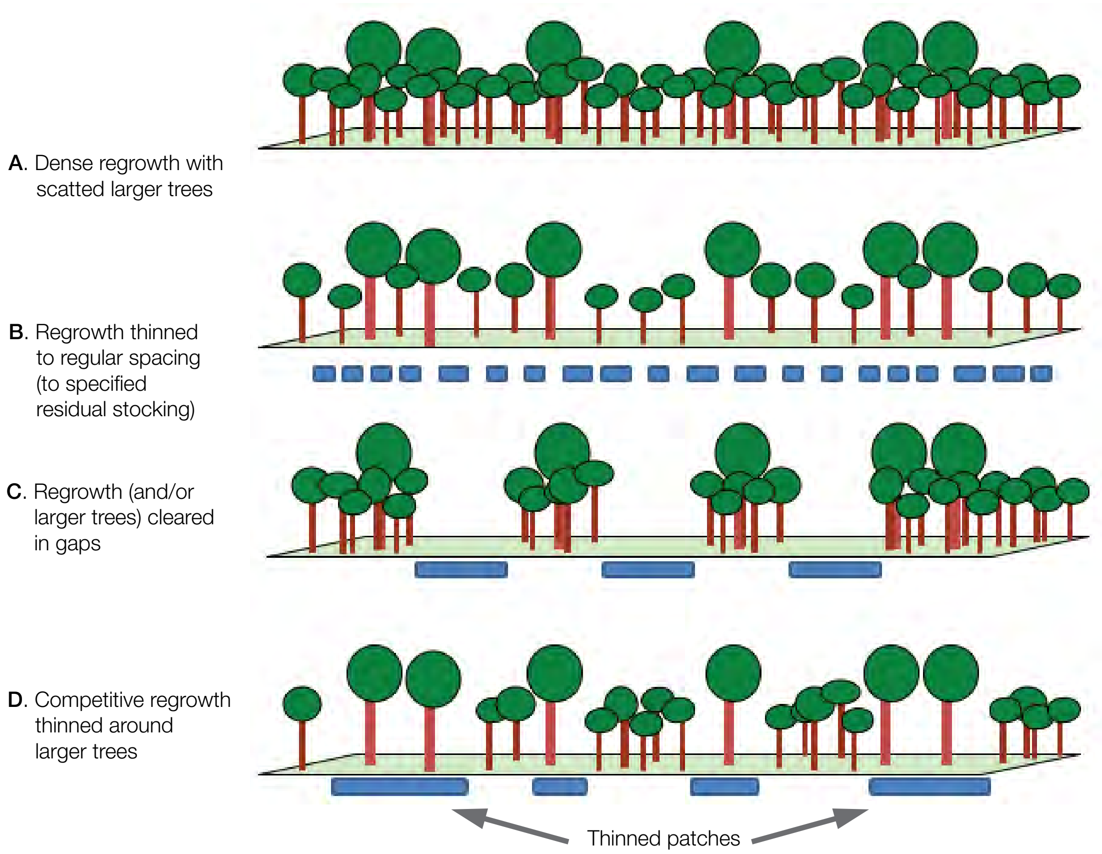
A general guideline for sustainable ecosystem management is to create spatially variable habitats, rather than large uniform stands (Lindenmayer et al., 2006). Different species value different habitat structures, and a diversity of habitat structures enhances species diversity across large areas. In areas dominated by large areas of dense regrowth, thinning has the potential to increase habitat variability, thereby enhancing its habitat suitability for a wider variety of species. This variability can be created through other processes, for example, through tree mortality caused by extreme water stress or severe fires. However, thinning provides greater levels of control over the number and species of trees removed than either process, and could enhance survival of valued habitat attributes such as large trees.

Reduced fire hazards

In some forests overseas, ecological thinning has been used to reduce fuel loads and lower fire hazards (e.g. *Pinus ponderosa* forests in USA; Allen et al., 2002). Thinning in river red gum forests could reduce leaf litter deposition rates and elevated fuel loads in the short to medium term. However, fine fuel levels derived from grasses and levels of coarse woody debris derived from thinned trees may be higher in thinned forests. The net outcome of these changes in river red gum forests is poorly understood and requires further research.

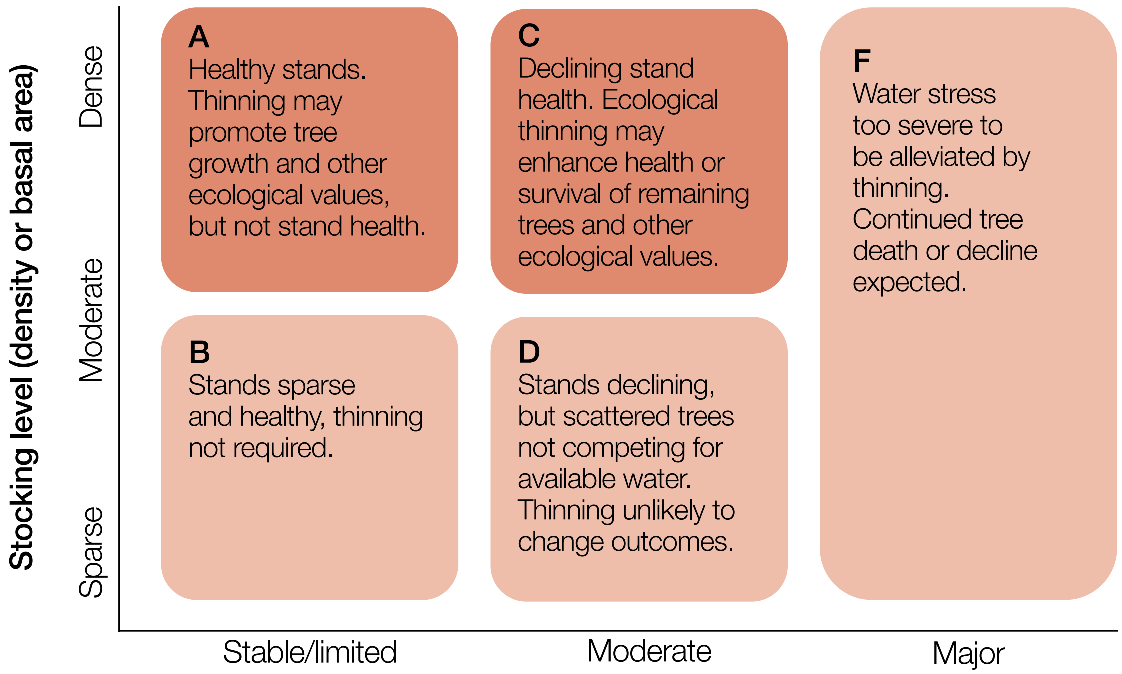
Dense even-aged regrowth

Box 11.2: Illustrative spatial arrangements of ecological thinning in a red gum forest



Each arrangement will have different impacts on ecosystem function, structure and composition.
State A = un-thinned.

Box 11.3: Conceptual model illustrating possible benefits that could be obtained from ecological thinning in stands of contrasting stocking level and water stress



11.3.2 Fire management

River red gum forests supported high densities of indigenous people before European colonisation (**Chapter 6**). Indigenous people used fire extensively in this and other regions (Curr, 1883). As in other grassy woodland and grassland ecosystems across south-eastern Australia, fire regimes in red gum forests are generally believed to have been characterised by frequent, low intensity fires ignited by indigenous people and lightning. Unfortunately, more specific details about particular aspects of pre-settlement fire regimes – in red gum forests as well as other grassland and woodland ecosystems – are unknown (Bren, 1990; Donovan, 1997; Yates and Hobbs, 1997; Lunt and Morgan, 2002; Fensham, 2003), although these questions are actively debated (for example, Benson and Redpath, 1997; Bowman, 1998; Esplin et al., 2003; Jurskis, 2009).

Fire regimes influence river red gum forests in many ways. River red gum trees are more susceptible to fire than most eucalypts. Red gum seedlings can be killed by low intensity fires and mature trees by higher intensity fires (Forestry Commission of NSW, 1984). However, fires can also assist river red gum regeneration by promoting seed fall, improving seedbed condition and removing competition for red gum seedlings (Dexter, 1970; Forestry Commission of NSW, 1984). Fires can also promote germination and establishment of other species such as *Acacia*.

River red gum forests which are regularly inundated are less likely to burn than many other dry eucalypt forests, because of flooding and the associated high moisture contents of soil and litter, and low understorey biomass due to the patchiness of the shrub layer. Crown fires are rare due to the height of the trees and lack of shrubs (Benson et al., 2006). Intense fires can cause death of mature river red gum trees, and loss and degradation of arboreal habitat. For example, wildfire can impact significantly on core breeding habitats of important species such as the superb parrot (Forests NSW, 2009a).

Managed fire is widely used in Australia to reduce forest fuels to protect people and the environment from wildfire. However, because of the susceptibility of river red gums to fire, and the difficulties of managing fire in red gum forests (Forestry Commission of NSW, 1984), small-scale post-harvesting regeneration burning is usually the only managed fire used in river red gum forests. Fuel reduction burning is not usually used in red gum forests managed for wood production (Forests NSW, 2008).

VEAC (2008) proposed the use of ecological burning in the river red gum forest reserves in Victoria. VEAC considered that the managed use of fire was the optimum way to manage understorey biomass while promoting species diversity and thus resilience in the river red gum forests, where there was no livestock grazing. However, this recommendation has not been tested yet.

Table 11.4: Principles and rationale for fire management

Fire management principles	
Principle FM1:	**Prescribed fire can be a valuable tool to control fuel levels and achieve specified ecological outcomes in some forest areas.**
All land managers are required by legislation to ensure that fire hazard is controlled to ensure public safety and asset protection, following legislative requirements for public and private land managers. Prescribed burning has not been widely used in river red gum forests for a number of reasons, including low fuel levels in many places and seasons, potential damage to timber quality, and because fine ground fuel levels have traditionally been controlled using livestock grazing. River red gums are more fire-sensitive than many other eucalypts, and are often killed by medium to high intensity fires. Nevertheless, river red gum ecosystems have always been exposed to fires, and many native species have evolved adaptations to survive or regenerate after single fires. Consequently, fires do not necessarily 'damage' or 'destroy' red gum ecosystems, even though particular attributes (such as valuable large, hollow-bearing trees) may be killed. All natural ecosystems, including river red gum forests, are affected by fire regimes (the succession of fires that occurs over a period of time), and fire managers needs to ensure that fire regimes are managed to achieve management goals (Keith et al., 2002), including human safety, asset protection and other legislative requirements.	
Principle FM2:	**In areas managed for conservation rather than production values, prescribed fire can provide a useful tool to achieve management goals, such as manipulating vegetation structure and composition, thinning dense stands, reducing fuel loads, promoting tree and shrub regeneration and controlling the abundance of vigorous dominant wetland plants.**
In timber production areas, prescribed burning is generally avoided due to damage to merchantable timber. By contrast, in conservation areas, managers may have more flexibility in using prescribed burning to achieve management goals as damage to timber values is less relevant to management goals. Prescribed burning can potentially be used to achieve many management goals in conservation areas. For example, red gum seedlings are fire-sensitive and dense stands can be thinned using prescribed ecological burns. Prescribed fires can be used to reduce fine fuel levels, including eucalypt leaf litter which is not reduced by other methods such as livestock grazing. In wetlands, prescribed fires can be used to restore wetland structure and habitat values by helping to controlling vigorous encroaching species such as giant rush. In all cases, the ecological outcomes of prescribed burning are poorly documented in river red gum forests, and considerable uncertainty surrounds likely fire effects. Consequently, prescribed burning should be subject to Principles Et4 and Et5, which were presented above in relation to ecological thinning. All prescribed burning should be implemented using an experimental, adaptive management framework to maximise learning outcomes, consistent with approaches recommended by the Biodiversity and Climate Change Expert Advisory Group (2009).	

Table 11.4 describes the principles the NRC has developed for fire management for both conservation and production areas.

11.3.3 Grazing management

The majority of river red gum forest riparian areas are in private ownership. These areas have value for stock grazing, not only for their fodder, but as a reliable source of water. The presence of stock in these environments (including riparian zones in public lands) can have a deleterious effect on their condition and ecological values, particularly considering the habits of cattle congregating around watering points (Robertson, 1997).

NSW Forests has developed a strategy to guide its approach to grazing in NSW State Forests (Forests NSW, 2000a). This was developed through a Grazing Review Panel containing local and scientific expertise (Forests NSW, 2000a). In developing recommendations for future management, the panel was asked by Forests NSW to consider:

- the environmental affects of past livestock grazing practices
- the future environmental effects if grazing practices continued in their present form
- what changes are required to sustain present-day environmental values and remedy past grazing impacts (Forests NSW, 2000a).

From this, the panel identified a tactical grazing system and other measures that aim to strike a balance between conservation and production (Forests NSW, 2000a).

Grazing management plans are being developed for occupation permit areas greater than 2,000 hectares. These plans address stocking periods and numbers, sensitive area identification, rehabilitation, pests, environmental monitoring, significant archaeological sites and environmental impact assessment. Grazing management must also seek to address the grazing pressure originating from native and introduced feral herbivores, as well as from domestic stock.

Historically, intensive grazing has had many negative impacts on biodiversity and other environmental values. For example, grazing has altered flora species composition, and contributed to the loss of grazing-sensitive flora species in lower vegetation profiles (Forests NSW, 2009a). It has also reduced reed beds and fringing vegetation that are important habitats for crustaceans, aquatic and terrestrial invertebrates, frogs and waterbirds (Robertson, 1998; Jansen and Healey, 2003). However, on a positive note, Jansen and Robertson (2001) found that riparian and wetland areas in many State Forests were in better condition than those on privately owned lands, due to lower stocking levels over the last century.

In areas that have been subjected to heavy livestock grazing for over a century, pre-existing values may not return following the removal of livestock. Lunt et al. (2007) assessed the effects of grazing exclusion on a degraded understorey dominated by exotic annuals in Gulpa Island State Forest. They found only minor differences in vegetation composition and cover between grazing and ungrazed areas after 12 years of excluding livestock. While the ungrazed plots had slightly more vegetation cover, there was no difference in species richness and little difference in species composition between grazed and ungrazed treatments.

In some native grasslands and grassy woodlands, rotational grazing regimes have been developed into a useful disturbance mechanism to increase species diversity and grassland health, akin to the likely disturbance and benefits of fire (Dorrough et al., 2004; Earl and Jones, 1996; Lunt and Morgan, 1999). However, these benefits have largely occurred in ecosystems that support thick, dense grass or abundant weeds in the absence of grazing, fire or other disturbances (Lunt et al., 2007). By contrast, many river red gum forests support relatively low cover and biomass of grass and other ground plants in many years, and livestock grazing is unlikely to promote ecological values in these cases (Lunt et al., 2007).

Well-managed grazing can be used in particular cases as a management tool to achieve specific management goals, with minimal adverse impact. In particular, livestock grazing may be a practical tool to control exotic annual grasses and herbs, which can accumulate high cover and biomass, particularly in degraded forest areas (Lunt et al., 2007). This may also reduce fine fuel loads for fire management purposes.

Careful consideration of the impact of grazing at the local level is required prior to implementing changes to grazing practices. It is important to consider the potential impacts of current or proposed grazing regimes rather than historical regimes, as future impacts are likely to differ from those that occurred up to a century ago. Understanding the impact of grazing is critical to ensure that informed adaptive management can be introduced (Lunt et al., 2007). Forests NSW recognised these issues in developing and implementing a grazing strategy (Forests NSW, 2000a) in the river red gum and associated forests.

Table 11.5 describes a set of principles the NRC has developed for grazing management of both conservation and production areas.

Livestock grazing

Table 11.5: Principles and rationale for grazing management

Grazing management principles	
Principle GM1:	**Uncontrolled or poorly managed livestock grazing has caused considerable damage to red gum forests in the past, and has the potential to further degrade environmental attributes.**
Livestock grazing has caused considerable damage to many river red gum forests and associated riparian and wetland ecosystems. These impacts are well documented in many ecosystems in southern Australia, including river red gum forests (Jansen and Robertson, 2005). Livestock grazing has caused local erosion, damaged streamsides, changed understorey plant composition by reducing perennial native plants and promoting weeds, and degraded habitat for wetland fauna (Forests NSW, 2009a; Jansen and Robertson, 2005; VEAC, 2008). The removal or control of livestock is widely recommended in riverine and riparian areas (Price and Lovett, 2002). The sensitivity of river red gum forests and associated ecosystems to livestock grazing varies greatly between vegetation types and places. Some ecosystems are highly sensitive to grazing, whereas others (especially degraded areas) are relatively resilient to current grazing levels (Lunt et al., 2007). The Grazing Strategy developed by NSW State Forests, for example, excluded livestock from many highly sensitive areas, such as large wetlands, while permitting grazing in more resilient and less sensitive zones.	
Principle GM2:	**Notwithstanding Principle GM1, livestock grazing has potential to achieve positive outcomes for conservation values in limited parts of the forest, especially degraded and weedy areas, where it can help to reduce weed cover and control fuel loads.**
In some areas, strategic livestock grazing can play a useful role in promoting conservation values (Forests NSW, 2000b; Lunt et al., 2007). This is most relevant in degraded and weedy areas, where livestock grazing can be used to reduce weed levels of exotic grasses and other weeds. This is particularly the case in relatively dry red gum forests and in other woodland ecosystems (Forests NSW, 2000a).	
Principle GM3:	**Livestock grazing should only be conducted where it achieves clearly specified management goals, and stock can be contained to designated areas, to prevent unintended outcomes to sensitive features.**
Given potential adverse impacts of livestock grazing, it is critical that any livestock grazing conducted within river red gum forests is managed to achieve clearly specified goals, and that livestock is constrained to areas of concern. The fine-scale mosaic of different wetland and dryland habitats in some forest areas makes it challenging to restrict livestock to particular areas. In such cases, livestock should be managed to ensure grazing is compatible with the areas of highest environmental sensitivity within the grazed area (Forests NSW, 2000a; Lunt, 2005).	
Principle GM4:	**Ground vegetation (and fuel) levels vary greatly between seasons and years according to flooding and rainfall. On public lands, livestock grazing should only be permitted when vegetation and fuel levels are appropriate, and licensing or agistment arrangements must enable stock to be removed at short notice, to satisfy land management goals.**
The cover and biomass of ground vegetation vary greatly over time as a result of the variable rainfall and flooding regimes experienced in river red gum forests. To maintain both ecosystem health and animal health, livestock grazing must be restricted to periods when grazing is appropriate and necessary to achieve management goals. Consequently, grazing licences, permits or agistment arrangements must enable stock to be removed at short notice, to ensure land management goals are not compromised. This requires considerable flexibility in livestock management and transport capacity by graziers, and necessitates positive interactions and regular communication between licence holders and management agencies. As an example, the Grazing Strategy for the Riverina Region specifically addresses the management of grazing within well defined biomass levels and according to seasonality constraints. This ensures that grazing is able to target introduced annuals and favour the establishment and long-term persistence of native perennials. Assignment of Occupation permits for grazing should only be done via a tender or similar process that reflects the intent of the grazing strategy and is able to give effect to the stated aims in the strategy. Occupation permit conditions should also give legal effect to the intent of the grazing strategy.	
Principle GM5:	**Where livestock grazing is conducted, it should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.**
Unfortunately, while many claims have been made about potential positive or negative impacts of current grazing regimes, these claims often cannot be rigorously evaluated because of the lack of adequate monitoring and evaluation procedures. Many studies have suggested that particular grazing regimes (such as short duration grazing, or protracted spelling) can provide positive environmental outcomes (Dorrough et al, 2004; Earl and Jones, 1996; Lunt et al., 2007). However, little evidence is available on how these grazing regimes affect environmental values in river red gum forests. A grazing monitoring program has been initiated by Forests NSW to address this lack of knowledge. Further trials will greatly increase our understanding of how to manipulate livestock grazing to enhance desired outcomes while reducing potential risks. Consequently, all livestock grazing should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.	

11.4 Silvicultural systems, management practices and principles

Forests NSW is a public trading enterprise which aims to balance commercial, environmental and social objectives. Forests NSW's goal is to manage the river red gum forests

for their conservation and sustainable use to benefit the community in a way that is compatible with the maintenance of the natural properties of their ecosystems and also under the wise use principles of the Ramsar Convention (Forests NSW, 2008a).

The silvicultural systems and management practices applied in river red gum forests have evolved as a result of experience and research since formal forest management began in these forests in the first quarter of the 20th century. Within this context, and subject to other environmental and economic constraints, Forests NSW has developed a range of silvicultural systems and management prescriptions to meet quota sawlog commitments, promote growth and regeneration of the stand remaining after harvesting and reduce impacts on environmental values (Forests NSW, 2000a, 2008, 2008a).

This section describes:

- how silviculture systems have evolved
- current silviculture systems and management prescriptions
- a set of principles for future river red gum silviculture.

11.4.1 Evolution of silviculture systems

The silvicultural systems and management practices applied in river red gum forests have evolved as a result of experience and research since formal forest management began in the first quarter of the 20th century. Jacobs (1955), Forestry Commission of NSW (1984) and Florence (1996) provide overviews of how these systems and practices evolved, and their scientific and management basis.

The silviculture applied since 1947 has been largely in response to very selective harvesting between 1910 and 1945, which left a large number of older trees unsuitable for wood production; these inhibited regeneration (Forestry Commission of NSW, 1984, Jurskis 2009). Consequently, removal of veteran trees by ringbarking (known as 'timber stand improvement') was common until the 1960s. Research had identified the benefits to tree survival and growth of reducing competition with regenerating stands, and so thinning was used increasingly from the 1970s in the forest stands which had regenerated during the 19th century (Forestry Commission of NSW, 1984, Jurskis, 2009).

Australian Group Selection (AGS) – a silvicultural system aimed at promoting vigorous establishment of the next generation of trees – was introduced as these stands approached their intended maturity for timber production of 90 to 120 years. AGS was first implemented in NSW forests in the 1920s (Jacobs, 1955, after Jolly, 1920), and has been applied in a variety of NSW moist and dry eucalypt forests (Florence, 1996). Forestry Commission of NSW (1984) noted that "something akin to a group selection system" was likely to be "quite well suited" to river red gum, and various forms of AGS were applied in river red gum stands originating from the 1870s floods in the 1980s and 1990s (when it was known as "gaps and clusters"). AGS in its current form has been applied in river red gum forests of higher site quality since 2001 (see the next section for a more detailed description of AGS).

Since 2001, there has been only limited seedling regeneration in many AGS gaps in river red gum forests, as a consequence of the extended drought and lack of flooding. The most recent flooding event was in the late 1990s; while environmental flows have been delivered to particular wetlands, these have not been widespread, and consequently seedling regeneration has not yet established in many AGS gaps. Seedling regeneration in river red gum forests is naturally episodic, following flooding or adequate rainfall, and the lack of regeneration in the current drought period reflects this. Coppice regeneration has occupied some parts of AGS gaps.

11.4.2 Application of current silvicultural systems in river red gum forests

The three silvicultural systems applied by Forests NSW in management of river red gum forests – thinning, selective harvesting and AGS – have some common goals and features, but also some differences.

Thinning and selective harvesting are applied principally to reduce competition between trees for water and other site resources, and encourage the growth of tall, straight trees that are valuable for timber. One of the key silvicultural issues for wood production in river red gum forests is that, in the absence of competition between trees of the same cohort to force vertical growth and restrict branch development and forking, young stems typically fork or branch early in their growth and retain low branching, leading to poor sawlog recovery. Therefore, a key management approach in river red gum is to follow natural post-flooding regeneration processes, and grow the regeneration in reasonably dense clumps to force vertical growth and restrict branch development, as straighter trunks and fewer branches are more suitable for timber for high-value uses. Once trees are about 20–30 centimetres in diameter, forest growth form has been attained, and dominant trees have begun to emerge, then thinning may be conducted to remove suppressed trees and reduce competition for dominant trees to grow (Forestry Commission of NSW, 1984).

Competition between trees will also influence regeneration success, and stand health and development, in river red gum forests (as in other eucalypt forests). Mature trees can out-compete new seedlings for soil moisture, and suppress seedlings to an extent of approximately two crown widths from each larger tree. As discussed earlier, reducing the number of trees per unit area through thinning or selective harvesting may improve the health and reduce the mortality of retained trees, although the effects may be relatively localised (Dexter, 1970).

The application of thinning or selective harvesting is unlikely to create gaps large enough for the development of the dense young regrowth stands described above. Therefore, AGS is applied to groups of trees which have reached maturity for production purposes – 90 to 120 years for river red gum – to create the conditions for good regeneration of dense, even-aged cohorts (Forests NSW, 2008a).

All silvicultural systems are required to respect environmental and other values through observing restrictions on harvesting to protect these values. These restrictions are summarised, and compared to those required for river red gum forest management on private land in NSW, in **Appendix 10**.

The three silvicultural methods applied in river red gum forests are described below.

Single Tree Selection (STS)

This silvicultural method is usually applied in mixed aged (or mixed size) or mixed species stands. More dominant trees are usually selected for harvesting from within the stand, leaving subdominant trees that ideally will grow with reduced competition and available light. This method may be applied where there is growing stock scattered amongst a mature stand, or where mature trees are scattered amongst a well-stocked regrowth stand.

The title of 'single tree' selection can be a misnomer, as more than a single tree may be removed at any location, depending on stand characteristics. Although basal area retention requirements in the implementation of STS are not formalised for public red gum forests as they are by the Private Native Forestry (PNF) Code, established practice conforms to those specified in the PNF Code, of retaining a minimum stand basal area of 12 square meters per hectare. Typically a higher stand basal area is retained. STS is only applicable where the stand structure and floristics permit successful regeneration in canopy openings created by removing single trees, or small groups of trees.

Figures 11.1 and **11.2** provide a schematic view of how STS is applied to stands. **Figure 11.1** indicates that single trees within a stand are marked for removal or retention. **Figure 11.2** indicates the composition of the stand following removal of the selected trees (figures taken from Forests NSW, 2008a).

Australian Group Selection (AGS)

AGS is a system applied to eucalypt forests of mixed ages or mixed-size classes (Jacobs, 1955). It involves harvesting groups of commercially mature trees. The objective of the system is to harvest groups of commercially mature trees to promote vigorous establishment of the next generation of trees.

AGS creates canopy gaps of sufficient size to reduce competition from the surrounding forest, while keeping gaps small enough to allow adequate seedfall from surrounding trees to be dispersed to all parts of the gap (Florence, 1996; McElhinny, 2009). The latter feature of AGS, and its concomitant

Figure 11.1: Trees marked for removal or retention using STS

Figure 11.2: Indicative stand composition following removal of trees using STS

smaller gap size, distinguishes AGS from silvicultural systems characterised as clearfelling; it also means that AGS gaps have the potential to regenerate over extended periods, so long as the seed bed is or can be made receptive (through mechanical disturbance or use of low-intensity fire), as seed is not a limiting resource (McElhinny, 2009).

AGS maintains an irregular forest at a patch scale and can be applied to more uniform stands to create a more mixed-aged forest to enhance diversity. The system was developed as a compromise between the need to conserve immature growing stock; regeneration requirements of competition-intolerant species; and the need to consider values other than efficient timber production (Florence, 1996). **Figure 11.3** indicates groups of trees within a stand that are marked for removal or retention. **Figure 11.4** indicates the composition of the stand following removal of the selected trees (figures taken from Forests NSW, 2008).

The maximum area of individual regeneration openings in AGS coupes in river red gum State Forests has been 0.8 hectares, with the constraint that AGS could not be applied over more than 30 per cent of any harvest area. Subsequent to a Land and Environment Court settlement of 2007, the maximum regeneration opening in an AGS coupe was reduced to 0.4 hectares, with a maximum diameter of twice stand height of up to 60 metres, and the proportion of area harvested under AGS to 20 per cent (L&EC, 2007)[2].

Thinning

Forests NSW practices 'thinning from below', where trees with the poorest growth or commercial potential (usually subdominant trees) are removed to promote the growth of retained trees. This practice is intended to realise some future high-value product and/or to produce trees of a specified size in a shorter period of time. It also allows trees that would otherwise die through competition and moisture stresses, to be commercially utilised. Thinning can also enhance the opportunity for the retained trees to survive periods of water stress (Forests NSW, 2009a).

Figure 11.3: Trees marked for retention or removal using AGS

Figure 11.4: Indicative stand composition following removal of trees using AGS

11.4.3 Management prescriptions for forestry operations

Management prescriptions are an important component of Forests NSW's Ecologically Sustainable Forest Management system and have been designed to maintain forest structural diversity to retain and enhance flora and fauna habitat, and protect and maintain soil and water quality, while providing a sustainable timber supply (Forests NSW, 2008).

There are two types of prescriptions generally applied during forestry operations. Tier 1 comprises general, forest wide prescriptions such as riparian buffers and a suite of habitat tree protection measures which are designed to protect key habitat across the landscape. These include prescriptions such as those for retention of habitat trees, found in individual management plans.

Tier 1 prescriptions are supplemented by Tier 2 threatened species specific prescriptions which are designed to maintain habitat for particular species. Prescriptions applying to harvesting in river red gum forests are found in s120 Threatened Species Licences, and in other requirements such as those for protection of cultural heritage.

11.4.4 Principles for future river red gum silviculture

As part of its assessment process, the NRC reviewed the silvicultural systems applied in the river red gum forests, taking particular account of two key factors:

- The concerns raised by environment groups, and pursued in the NSW Land and Environment Court and through the *Environmental Protection and Biodiversity Conservation Act* 1999 (Cth), about the impacts of the implementation of AGS silviculture on forest values. Many of these concerns focused on the potential impacts of AGS on the ecological character of the Ramsar-listed Central Murray State Forests.
- The recognition that the historical flood flows which established and sustained river red gum forests have been substantially changed by river regulation, and in conjunction with the current drought and predicted 'step change' associated with climate, is impacting (and likely to continue to impact) the health and persistence of the Riverina's river red gum forests.

Table 11.6 describes a set of principles the NRC has developed to guide future silviculture of river red gum forests managed for integrated wood production as conservation values. Once these principles are codified in an Integrated Forestry Operations Agreement, the NRC considers they will maintain the ecological character of the forests, and protect matters of National Environmental Significance, while continuing to support production values.

The principles were developed through discussion with forest managers and other agency staff, a literature review and a workshop conducted with independent experts. They have been developed considering the current and likely impacts of river regulation and drought, predicted climate change, and forestry activities.

In addition to the principles presented in **Table 11.6**, the NRC suggests that the riparian exclusion zone for major rivers (Edward, Lachlan, Murray, Murrumbidgee, Wakool) on public land be extended to 50 m, consistent with requirements in other forested regions of NSW. No additional modified harvesting zone would then be necessary in these cases.[2]

Australian Group Selection – Gulpa Island State Forest

[2] The present requirement (**Appendix 10**) is for a 20 m exclusion zone and a 30 m harvesting zone.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles
Principle S1: 'Group selection' is an appropriate silvicultural technique for river red gum forests managed for production values, subject to the provision and maintenance of ecological values, principally retention of adequate habitat trees and coarse woody debris resources, and other constraints of intensity and implementation described by Principles S2-8.
Australian Group Selection is usually applied to even-aged or even-size cohorts in production stands at the end of their intended growing cycle, typically at age 90–120 years, following one or more cycles of thinning and selective harvesting. Concerns about the implementation of AGS in river red gum forests focus on its impact on current and future habitat values, including those for threatened species; its impact on the ecological character of the forests as a whole; the susceptibility of gapped areas to weed invasion; and the appropriateness of the system in the absence of flooding (e.g. National Parks Association, 2008; Attiwill, et al., 1994). These issues were the subject of independent expert advice and review to the Commonwealth Government (Bacon, 2009; McElhinny, 2009; En Chee, 2009). These issues are addressed through the other principles listed below. Provided they are observed, the NRC considers that group selection is an appropriate silvicultural technique for river red gum forests managed for production values. In even-aged or even-sized cohorts of river red gum managed for production, appropriately implemented (i.e. consistent with principles enunciated here) group selection is necessary to maintain productivity over successive harvesting rotations (Baur, 1984; Dexter, 2009; McElhinny, 2009). Specific management prescriptions which give effect to this principle would benefit from further refinement based on expert knowledge of forest ecologists and forest managers, and should be codified into the Integrated Forestry Operations Approval (IFOA).
Principle S2: Group selection should only be applied to river red gum forests that are expected to receive adequate future watering.
River red gum forests are associated with channels and floodplains and are usually located either adjacent to, or in close proximity of, a major watercourse. They are flood-dependent and require certain flooding regimes to maintain ecological health and productive values (Jacobs, 1955; Forestry Commission of NSW, 1984, Florence, 1996; Bacon, 2009; Horner et al., 2009). Seedling regeneration is generally dependent on flooding, although seedlings can become established following adequate rainfall. Consequently, group selection should maintain the ecological character of the river red gum forests – through realising dense seedling regeneration – only when it is followed by adequate flooding or rainfall. Only the former can be predicted with any certainty. It is also likely that, in the absence of watering, coppice regeneration would eventually restore the tree component in the gapped area. Such coppice would also require thinning to maximise its ecological value (e.g. in terms of hollow formation) and its value for wood production. Given the seedling origin of most river red gum stands, coppice is a less preferable alternative to seedlings in maintaining the ecological character of the river red gum forests. This report has established that present drought has profoundly affected the health of most of the river red gum stands in the Riverina. If these conditions continue in line with the 'step-change' prediction of climate change, then much of the existing river red gum forests in the region will not persist in their present extent, structure and condition. Future implementation of group selection should therefore be limited to river red gum forests which are expected to receive adequate flooding through managed watering regimes (i.e. areas of forest predicted to be inundated under specified flood flows that can be delivered under water sharing arrangements). It is reasonable to allow group selection to proceed a number of years ahead of expected watering but the actual period should be clearly stated in both strategic and operational management plans. For example, current Forests NSW growth modelling allows a period of 10 years from harvest for seedlings to become established. The NRC notes that longer delays between harvesting and the establishment of seedling regeneration favours coppice regeneration that develops in the absence of flooding.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued
Principle S3: Habitat trees should be retained permanently and distributed across the forest landscape.
Habitat – principally hollow-bearing trees – provides a key ecological function in Australian forests (e.g. Gibbons and Lindenmayer, 2002). Hollows in both live and dead trees provide essential habitat for many arboreal species in river red gum forests, including those that are threatened (as further described in **Chapter 4**). Occupancy of hollow-bearing trees is related to their position and spatial configuration in the landscape. Literature reviewed by Gibbons and Lindenmayer (2002) reported average occupancy rates of between 43-57 per cent. There has a substantial decline in the numbers of hollow-bearing trees in the river red gum forests as a consequence of historical timber harvesting and silvicultural treatments (Forests NSW, 2009a), with impacts on both arboreal mammal populations (Forests NSW, 2009a) and threatened species (e.g. Forests NSW, 2009a, after Webster, 1998). The NRC notes that specific prescriptions for habitat tree retention and recruitment already exist (**Appendix 10**), both generally and for individual threatened species specifically, and that – provided habitat tree retention is adequate – the population of habitat trees may not be the limiting resource for particular species of concern (e.g. Leslie, 2005). Forests NSW (2009a) noted that: *"whilst there is no evidence that current tree habitat retention management prescriptions in the river red gum forests are not effective in maintaining a sufficient hollow resource to meet the needs of hollow obligate fauna populations over time… there may be a potential for residual or cumulative impacts resulting from current habitat tree retention strategies"* Forests NSW (2009a) suggested further research and peer review to clarify appropriate habitat tree retention strategies. The NRC has identified four key issues in respect to habitat trees: • The need to ensure adequate numbers of habitat trees are retained, and that these trees are distributed across the forest landscape. Expert opinion (Forests NSW, 2009a, Gibbons, P, ANU, pers. comm., 2009) suggest that numbers of habitat trees in unlogged river red gum forests are in the range of 6–25 trees per hectare. On the basis that production forests are complemented by a reserve system, and incorporate Forest Management Zones (see **Chapter 3**), in which all habitat trees are retained, a lesser number of habitat trees should be acceptable in those Forest Management Zones in which trees are harvested. Further research and modelling specific to river red gum forests would be needed to derive any specific science-based estimates for the minimum number and preferred configuration of habitat trees that should be retained in forests managed for production. On the basis of Forests NSW (2009a) assessment, current prescriptions for retention in each Forest Management Zone would appear appropriate, subject to further research and to increased levels of retention of habitat recruitment trees, as discussed below. Expert opinion emphasises the importance of ensuring that retained trees should be distributed across the forested landscape. • The need to ensure adequate numbers of recruitment trees. Modelling (Gibbons et. al., in review) suggests that the ratio of recruitment to habitat trees should be higher than 1:1, to allow for mortality. Based on the most comparable results reported by Gibbons et al (in review), for *E. fastigata* in NSW, an interim ratio of 1.5:1 might be appropriate. Further modelling specifically for river red gum forests will be required to inform prescriptions, which may vary at different stages of stand development. • The need to retain, as far as possible, individual habitat trees over successive harvesting cycles, so that individual trees are allowed to progress to maturity and eventual senescence. • The need to recognise the value of standing dead trees for habitat, and include their retention in prescriptions, as in other NSW State Forests. Specific management prescriptions for this principle need further development based on expert assessment of the best-available knowledge, and should be codified into the Integrated Forestry Operations Approval.

Coarse woody debris – Bama State Forest

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued
Principle S4: Gap intensity needs to explicitly consider the ecological character of river red gum forests, particularly those which are Ramsar-listed.
Gap intensity is related to the application of AGS in river red gum forests – the size of individual gaps, their spatial distribution and proximity to each other, overall extent, and return intervals. Managing gap intensity has been identified in prior studies (e.g. those cited in National Parks Association, 2008), and by recent reviews of river red gum silviculture (Bacon, 2009; McElhinny, 2009; En Chee, 2009), as critical to sustainable management of river red gum forests. Current prescriptions apply to only some elements of gap intensity; these are summarised in **Appendix 10**. Based on this literature and expert opinion, the NRC suggests that specific prescriptions to manage gap intensity be developed and implemented, based on the following parameters: • Individual gap sizes should generally be in the order of twice the height of surrounding trees – to minimise felling damage and promote regeneration – although occasional gaps of up to three tree heights may be necessary in particular cases. However, individual gaps should not usually exceed 80 metres in width. • Gaps created in any given harvesting operation should be separated by distances at least equal to gap width, preferably more, and the pattern of dispersal of gaps should ensure that regeneration in neighbouring gaps has established successfully before an adjoining gap is created. Regeneration success should be expressed in terms of density or basal area of regeneration, and its height, and thresholds may be related to the stage of stand development sufficient to deliver ecological benefits (e.g. the habitat provided by dense young stands). • The total area of a tract of forest that might be subject to group selection over the production rotation period (nominally 100 years) should be estimated, and the proportion of the stand gapped in a specified intermediate period (say 10 years, to allow some management flexibility) should not exceed the pro rata proportion which that period represents of the rotation period. Exact specification of these prescriptions requires further expert input, including that of operational forest managers. The consequence of implementing these criteria is that return intervals to adjacent areas of forest would depend on the period required to achieve successful regeneration of gapped areas.
Principle S5: Selective harvesting in immature forests between 'gapped' areas should be constrained by timing and intensity, and ecological thinning should be guided by ecological principles.
Selective harvesting includes both thinning and Single Tree Selection. The timing and intensity of selective harvesting in immature river red gum forest, and its interaction with any group selection in the same tract of forest, have the potential to impact on environmental values such as habitat, and on the ecological character of the forests. These impacts should not be significant if Principles S3 and S4 are implemented, where an adequate density of trees is retained, and where the timing of selective harvesting between gaps is scheduled to allow re-establishment of regeneration in any adjacent gapped areas, as discussed in Principle S4 above. Specification of a minimum retained basal area in selective harvesting operations, at not less than 12 square metres per hectare, should ensure retention of an adequate density of trees in selectively harvested forests. Principles guiding the implementation of ecological thinning in river red gum forests were discussed in an earlier section of this chapter.
Principle S6: Coarse woody debris loads should be enhanced to threshold levels where practicable and consistent with other management objectives, such as fire management goals.
Coarse woody debris (logs and branches on the ground) are an important habitat resource for a large number of ground-dwelling species (Mac Nally et al., 2001; Mac Nally, 2006; Lada et al., 2007; Mac Nally and Horrocks, 2008) and foraging resource for various woodland birds (e.g. Antos and Bennett, 2006). Densities and breeding success of some fauna are higher in areas with abundant coarse woody debris. Coarse woody debris may originate from natural tree and branch fall, as a consequence of commercial harvesting, or from ecological thinning. Representation of a range of size classes, including large and hollow logs, is desirable to maximise the biodiversity value of coarse woody debris (Mac Nally, 2006; Mac Nally and Horrocks, 2008). Recent ecological research suggests that a threshold level of 40 tonnes per hectare of coarse woody debris is ecologically desirable in river red gum forests (McNally et al., 2002; Mac Nally, 2006; Mac Nally and Horrocks, 2008). Forest managers have noted that current forest management prescriptions require the retention of all coarse woody debris present prior to any harvesting operation, and have also pointed out that high levels of coarse woody debris pose a fire risk, and may not be compatible with some recreational values. Exact specification of these prescriptions requires further expert input. The NRC therefore suggests that river red gum forest management should seek to progressively develop, and subsequently retain a target load of 40 tonnes per hectare of coarse woody debris, of appropriate size class distribution, in those areas of forest where this can be achieved without detriment to other ecological or operational values, and is compatible with fire risk management and asset protection requirements. It may also be desirable to reduce this level in areas of particular recreational use. These prescriptions could be implemented through Forest Management Zoning and related (e.g. fire and recreation) planning processes.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued

Principle S7: Salvage logging has the potential to be ecologically damaging and should follow recognised best-practice guidelines and adhere to the silviculture principles above.

In some river red gum forests, such as those burnt by wildfire or killed by drought, salvage harvesting of dead trees may provide wood which can be recovered for use such as firewood, although this will last only for a limited period. Since timber quality declines as time progresses after tree death, economic values are maximised by rapid access to dead trees.

Salvage harvesting often has negative effects on natural ecosystems (Lindenmayer et al., 2004; Lindenmayer and Noss, 2006; Lindenmayer et al., 2008a) and a recent global synthesis concluded that "timber salvage is most appropriately viewed as a 'tax' on ecological recovery. The tax can either be very large or relatively small depending on the amount of material removed and the logging techniques used" (Lindenmayer et al., 2008a). Negative effects of salvage harvesting include:

- loss of important forest attributes such as large and hollow-bearing trees, coarse woody debris and other 'biological legacies'
- physical damage to soils, watersheds and other ecosystem attributes (e.g. understorey vegetation)
- cumulative impacts of successive disturbances, for instance where salvage harvesting follows wildfires or cyclones.

The negative impacts of salvage harvesting can be reduced by adopting the following best-practice guidelines (Lindenmayer et al., 2004; Lindenmayer and Noss, 2006; Lindenmayer et al., 2008a):

- Retain variable levels of dead standing timber in different areas of the forest, rather than harvesting all areas to the same minimum level of retained trees and stags.
- Exclude salvage harvesting from conservation reserves and areas containing sensitive environmental attributes.
- Minimise losses of important ecological attributes such as large dead trees, hollow-bearing stags and coarse woody debris.
- Ensure low levels of physical disturbance (e.g. to soils, watercourses and understorey vegetation) in harvested areas.
- Design and implement salvage harvesting to allow its impacts on ecosystem function and composition to be rigorously examined in the future.

These general principles provide a sound basis for managing salvage harvesting in river red gum forests, following disturbances such as fire, or widespread tree death caused by reduced water availability. In some cases, salvage harvesting may be pursued to reduce risk from fire, to firefighters and other forest users.

The potential economic losses associated with the death of merchantable trees in production from river red gum forests production forests can be significant. Where the guidelines and practices outlined above are followed, appropriate salvage harvesting can ameliorate some of the extent of these economic losses with minimal impact to environmental values.

Salvage harvesting should be excluded from conservation reserves, to ensure landscape heterogeneity in standing volumes of dead timber and to maximise biological legacies derived from dying trees. Exceptions may occur in particular limited cases where, for example, fire risk needs to be reduced in asset protection zones. In such cases, the principles noted above and those described for ecological thinning should be applied.

Principle S8: Outcomes of river red gum silviculture, and the assumptions underpinning them, need to be monitored and tested in a structured and systematic manner to generate new knowledge and reduce uncertainty over time.

Possingham (2001) describes adaptive management as 'learning by doing'. It describes a structured, iterative process of management and decision-making that is intended to generate knowledge; gradually reduce uncertainty; and improve performance through monitoring, evaluation and response. It adds transparency and accountability to decision-making and the allocation of resources, while providing a framework for learning and ongoing improvement.

To effectively apply adaptive management principles, an organisation's strategic plans and programs will need to be designed and delivered in ways that facilitate structured learning. Only then can the organisation undertake quantitative monitoring of these actions, and evaluate how successful it was in delivering the expected outcomes. Organisations also need relatively sophisticated management systems to support adaptive management. For example, these systems need to keep track of the changes in landscape expected as a result of the management actions within a project, and provide ready access to this and other necessary information when programs or approaches are being evaluated and decisions on improving its effectiveness are being made. These systems also need to keep track of new knowledge that is derived from the monitoring and evaluation process and other sources, so this can be used in making decisions.

Management agencies could draw on expert assistance, from within and outside the organisations, to further develop and improve their capacity to implement adaptive management systems appropriate to river red gum forest management. Doing so would further support the goals and processes identified in Forests NSW's Ecologically Sustainable Forest Management Plan for the Riverina Region (Forests NSW, 2008b).

Table 11.7: Principles and rationale for firewood collection

Firewood collection principles	
Principle FC1:	**As per Principle S6, coarse woody debris at threshold levels should be retained where practicable and consistent with other (e.g. fire risk) management requirements.**
The ecological importance of dead fallen timber has been described in **Chapter 4** and Principle S7 in **Table 5.7**. Firewood collection can reduce levels of coarse woody debris and reduce densities of standing dead trees in river red gum and other forest types. The NRC has proposed a new threshold level of coarse woody debris (i.e. potential firewood for collection) to be retained in river red gum forests to minimise any potential ecological impacts (Principle S6 in **Table 11.6**). Harvesting of standing dead trees for firewood should be undertaken following the principles described above for general silviculture, thinning and salvage logging of dead trees.	
Principle FC2:	**Firewood collection is generally inappropriate in conservation areas unless undertaken to achieve specific ecological or management goals, or where used for in-park recreational use. In such instances the provisions of Principle FC1 should also be adhered to.**
Given the ecological benefits provided by coarse woody debris, firewood collection is generally inconsistent with management objectives in conservation areas. Where firewood is collected in conservation areas for recreational use, it should be subject to the provisions of Principle FC1 above. Strategic management of fuel loads and fire risk must be considered in managing coarse woody debris levels in all forest areas.	

11.4.5 Firewood collection

Firewood is a significant product derived from river red gum forests on public land. For example, it accounts for 35 per cent of all river red gum products (see **Chapter 5** for more detail on the firewood industry). **Chapter 4** describes some of the potential impacts on environmental values from firewood collection.

Firewood can be collected by individual or on a commercial basis but requires either:

- a '30-I' permit – a short-term permit for domestic use, usually valid from two to three days up to two to three months and for small quantities of timber only
- a timber licence– usually issued on a yearly basis, but may be issued for shorter periods where practicable.

Most 30-I permits (about 95 per cent) are issued for the collection of river red gum firewood from the Deniliquin, Barham, Mathoura, Dareton and Yanco offices of Forests NSW (Forests NSW, 2009a).

Firewood collection for personal use is allowed in some specific zones of Regional Parks. However, this is subject to DECCW policy, including annual licensing and environmental assessments (McDonnell, R., DECCW, pers. comm., 2009).

Table 11.7 describes a set of principles the NRC has developed for firewood in both conservation and production areas.

11.5 Performance review

Adaptive management and regular performance reviews are essential to achieve our goals for future landscapes (Commonwealth of Australia, 2009; NRC 2005). As such, the implementation of the principles outlined in **Table 11.2** will rely on the application of effective adaptive management and reporting frameworks. These principles should be subject to on-going monitoring, review and improvement through the implementation of management plans and agreements.

The NSW Government adopted the *Standard for Quality Natural Resource Management* (NRC 2005) to guide and deliver best practice natural resource management. The NRC considers the Standard provides a useful framework to measure the performance of organisations and plans across all tenures,[3] and can be complemented with other performance criteria specific to the relevant land-use – for example, principles to measure performance of managers implementing the National Reserve System (Commonwealth of Australia, 2009).

River red gum firewood

[3] The NRC has recently used the Standard to audit the effectiveness of catchment management authorities in promoting resilient landscapes.

River red gum with spreading crown – Maude State Forest

Appendices

Appendix 1

Terms of reference

Premier of New South Wales
Australia

Terms Of Reference
Assessment Of Riverina Red Gum Forests

The New South Wales Government intends to make a forest agreement with respect to the river red gum and woodland forests within the NSW Riverina IBRA and the South-Western Cypress State Forests in order to determine conservation outcomes and a sustainable future for the forests, the forestry industry and local communities in the region.

To inform that agreement and in accordance with section *13 (1)(e) & (g) of the Natural Resources Commission Act 2003*, I request that the Commission:

1. Carry out a regional forest assessment of the scientific bioregion:

   a) for the purposes of section 15 of the *Forestry and National Park Estate Act 1998* including an assessment of the following: environment and heritage values (including Indigenous heritage), economic and social values, ecologically sustainable forest management, and timber resources; and

   b) otherwise such that the assessment will also meet the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

2. Recommend conservation, protection, economic and ecological sustainable use of public land in the bioregion.

3. Recommend water management and flooding requirements to sustain the forests and identified values and uses under the range of projected impacts of climate change.

The Commission should have regard to the following as they relate to the bioregion:

- nationally agreed criteria for a comprehensive, adequate and representative reserve system;
- other complementary methodologies for protecting conservation values;
- the impacts of drought and climate change on the forests and communities;
- opportunities for ongoing and future employment within affected local communities;
- appropriate forest management practices in order to promote long term productivity and forest health;
- international or intergovernmental obligations, agreements or arrangements;
- NSW Government policies, programs and Catchment Action Plans;
- opportunities for Indigenous involvement in forest management;
- appropriate access for commercial, recreational and community uses; and
- the existing science and body of knowledge about the region.

The Commission should consult with relevant NSW agencies including the Department of Environment, Climate Change and Water, the Department of Industry and Investment, the Land and Property Management Authority, the Treasury, the Department of Premier and Cabinet. The Commission should also consult with relevant Traditional Owners, Local Aboriginal Land Councils, Elders groups and local government. The Commission should liaise with officers from the Commonwealth Department of the Environment, Water, Heritage and the Arts to inform the design and conduct of the assessment.

The Commission should undertake public consultation to inform the assessment.

The Commission is to deliver the assessment in two phases:

1. The Commission is to deliver in relation to the Riverina IBRA:

   - an assessment under term of reference 1 by 30 September 2009; and
   - a report on terms of reference 2 and 3 by 30 November 2009.

2. The Commission is to deliver in relation to the South-Western Cypress State Forests:

   - an assessment under term of reference 1 by 31 December 2009; and
   - a report on terms of reference 2 and 3 in relation by 28 February 2010.

Appendix 2

Relevant legislation

Chapter 3 explains how forestry in the Riverina bioregion is conducted under a broad framework of Commonwealth and NSW legislation, polices and institutional arrangements. Table A2.1 provides more detail on the *key* relevant Commonwealth and NSW environmental legislation applying to forestry in the NSW Riverina bioregion. It also lists a range of other relevant legislation and conventions, treaties and agreements.

Key legislation for forestry		
Legislation	**Key relevant provisions for forestry**	**Relevance to forestry in Riverina bioregion**
Forestry and National Park Estate Act 1998	• Forest Assessment (Pt 3) • Forest Agreements (s 15) • Integrated Forestry Operations Approval (IFOA) (Pt 4)	• Forestry Assessment on river red gum and woodland forests of the Riverina bioregion currently being undertaken by the NRC • The NSW Government intends to make a Forestry Agreement with respect to the river red gum and woodland forests of the Riverina IBRA (subject to the undertaking of a Forestry Assessment) • Currently no IFOA applies but will be developed subject to the establishment of a Forestry Agreement)
Forestry Act 1916	• Establishes Forestry Commission (Pt 1) • Classification and dedication of forest lands (Pt 2) • Establishes commercial elements such as licensing, royalties, permits and leases (Pt 3)	• Commercial river red gum harvesting (timber, products and forest material) in State Forests of the Riverina bioregion
Environmental Protection and Biodiversity Conservation Act 1999 (Cth)	• Establishes matters of national environmental significance (NES) (Pt 3) • Protection of the environment, especially NES (s 3) • Approval of activities that are likely to have significant impacts on NES (Pt 3)	• NES in Riverina IBRA–Central Murray State Forests (RAMSAR) and listed threatened species and migratory birds • Currently no approvals apply for any activities in the Riverina IBRA
National Parks and Wildlife Act 1974	• Licensing of activities that harm any protected fauna (s 120)	• Section 120 licence for forestry activities in the south-west (including Riverina IBRA)
Environmental Planning and Assessment Act 1979	• Encourage the protection of the environment, including threatened species, populations and communities (s 5(a)(vii)) • Environmental Impact Assessments (s 75f, Pt 5)	• Environmental Impact Statement for forestry activities and associated roadworks (as per Land and Environment order) • Review of Environmental Factors for harvesting operations under Part 5
Protection of the Environment Operations Act 1997	• Licensing of activities that have the potential to pollute waters (Ch 3)	• Currently no environment protection licences for operations in the south-west (including Riverina IBRA) • Guidelines and procedures established with the aim to minimise pollution from roadworks and harvesting operations
Threatened Species Conservation Act 1995	• Protection and conservation of threatened species, populations and communities (s 3) • Threatened species listing (Pt 2) • Requirements for species impact statements (Div 2) • Licences for the protection of threatened (Pt 6)	• Recorded threatened species in river red gum forests in Riverina bioregion

Key legislation for forestry		
Legislation	**Key relevant provisions for forestry**	**Relevance to forestry in Riverina bioregion**
Fisheries Management Act 1994	• Conserve species, populations and ecological communities of fish (s 3(2)(b)) • Threatened species listing (Div 2) • Permits and licences for the protection of threatened species (Div 6) • Requirements for species impact statements (s 221k)	• Currently no permits or licences for operations in the south-west (including Riverina IBRA) • Guidelines and procedures established with the aim to minimise potential impacts on threatened aquatic species and habitats
Native Vegetation Act 2003	• Regulate forestry on private land (Native Vegetation Amendment (Private Native Forestry))	• Not applicable to State Forests

Other relevant legislation, conventions, treaties and agreements

- *Aboriginal Land Rights Act 1983*
- *Catchment Management Authorities Act 2003*
- *Crown Lands Act 1989*
- *Game and Feral Animal Control Act 2002*
- *Local Government Act 1993*
- *Natural Resources Commission Act 2003*
- *Nature Conservation Trust Act 2001*
- *Noxious Weeds Act 1993*
- *Rural Fires Act 1997*
- *Rural Lands Protection Act 1998*
- *Water Management Act 2000*
- *Western Lands Act 1901*
- *Water Act 2007(Cth)*
- China–Australia Migratory Bird Agreement (CAMBA)
- The Convention on Biological Diversity
- The Convention on Wetlands of International Importance (Ramsar Convention)
- Japan–Australia Migratory Bird Agreement (JAMBA)
- Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA)
- United Nations Declaration on the Rights of Indigenous Peoples

Appendix 3

References

ABS (2006), *Census of Population and Housing*, Australian Bureau of Statistics.

ABC (2007), *SunRice job cuts begin this week*, ABC news report, 21 December 2007, available online at http://www.abc.net.au/news/stories/2007/12/21/2124969.htm?site=news.

ABS (2008), *Water and the Murray-Darling Basin – A Statistical Profile, 2000–01 to 2005–06*. Available online at http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.007.

Alexander, JSA, Scotts, DJ and Loyn, RH (2002), 'Impacts of timber harvesting on mammals, reptiles and nocturnal birds in native hardwood forests of East Gippsland, Victoria: A retrospective approach', *Australian Forestry*, Vol. 65, pp. 182–210, available online at http://www.forestry.org.au/pdf/pdf-members/afj/AFJ%202002%20v65/AFJ%20Sept%20 2002%2065-3/07Alexander.pdf.

Allen, CD, Savage, M, Falk, DA, Suckling, KF, Swetnam, TW, Shulke, T, Stacey, PB, Morgan, P, Hoffman, M and Klingel, JT (2002). *Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective*. *Ecological Applications*, Vol.12, pp.1418–1433.

Allen Consulting (2005), *Climate Change: Risk and Vulnerability – Promoting an Efficient Adaptation Response in Australia: Final Report*, Department of Climate Change, available online at http://whitepaper.climatechange.gov.au/impacts/risk-vulnerability.html.

Antos, MJ and Bennett, A (2006), 'Foraging ecology of ground-feeding woodland birds in temperate woodlands of Southern Australia', *Emu: austral ornithology*, Vol. 106, pp. 29–40.

Arcidiacono, P, Bayer, PM, and Hizmo, A (2008), 'Beyond Signalling and Human Capital: Education and the Revelation of Ability', *NBER Working Paper No. 13951*, available online at http://www.nber.org/papers w13951.

Armstrong, JL, Kingsford, RT and Jenkins, KM (2009), *The Effect of Regulating the Lachlan River on the Booligal Wetlands – the Floodplain Red Gum Swamps*, University of NSW.

Atkinson, WR (2005), 'Yorta Yorta occupation and the search for common ground', *Proceedings of the Royal Society of Victoria*, Vol. 117, pp. 1–22.

Attiwill, PM (1994), The disturbance of forest ecosystems: The ecologic basis for conservation management, *Forest Ecology and Management*, Vol. 63, pp. 247–300.

Auditor-General of NSW (2009), *Sustaining Native Forest Operations*, Forests NSW, performance audit conducted by The Audit Office of New South Wales.

Australian Greenhouse Office (AGO) (2002), *Living with Climate Change: An Overview of Potential Climate Change Impacts on Australia*, Australian Greenhouse Office.

ANCA (Australian Nature Conservation Agency) (1996), *A Directory of Important Wetlands in Australia*, 2nd edition, ANCA, Australia.

Ayers, D, Nash, S and Baggett, K (1996), *Threatened Species of Western New South Wales*, NSW NPWS, Hurstville, available online at http://www.threatenedspecies.environment.nsw.gov.au.

Bacon, P (2009), 'Expert Advice, *Environmental Protection and Biodiversity Conservation Act 1999*, for Wetlands of International Importance, NSW Central Murray State Forest', unpublished report to Commonwealth Department of Environment, Heritage, Water and the Arts.

Bacon et al (1992), Proceedings of the Floodplain Wetlands Management Workshop, Albury, 1992.

Barker, RD and Vestjens, WJM (1990), *The Food of Australian Birds: Passerines*, CSIRO Division of Wildlife and Ecology, Canberra.

Barrett, C (1931), 'Wildlife on inland waters', *The Australian Museum Magazine*, 16 April 1931, pp. 211–16.

Baur, G (1983), *Notes on the Silviculture of the Major NSW Forest Types*, Forestry Commission of NSW.

Baur, G (1984), *Notes on the Silviculture of Major NSW Forest Types – 5. Red Gum*, Forestry Commission of NSW.

Baxter, CI, Reid, JRW, and Jaensch, RP (2001), 'First South Australian records of the Black-necked Stork, *Ephippiorhynchus asiaticus* and occurrence of vagrants in South-Western Queensland', *South Australian Ornithologist*, Vol. 33, pp. 164–9.

Beardsell, C (1985), *The Regent Parrot. A report on the nest site survey in south-eastern Australia, September 1983 to January 1984*, Australian National Parks and Wildlife Service Report Ser. 1.

Beare, S and Heaney, A (2002), 'Climate change and water resources in the Murray Darling Basin, Australia: Impacts and possible adaptation', ABARE Conference Paper, 2 November 2002, World Congress of Environmental and Resource Economists, Monterey, California, 24–27 June 2002, available online at http://weber.ucsd.edu/~carsonvs/papers/353.pdf.

Beaumont, L and Hughes, L (2002), 'Potential changes in the distributions of latitudinally restricted Australian butterflies in response to climate change', *Global Change Biology,* Vol. 8, pp. 954–971.

Beckley, T, Nadeau, S, Wall, E, Martz, D (2002), '*Multiple capacities, multiple outcomes: delving deeper into the meaning of community capacity*'. Paper presented at the Annual Meeting of the Rural Sociological Society, August 14–17. Congress Plaza Hotel, Chicago, IL .

Beer, T and Williams, AAJ (1995), 'Estimating Australian forest fire danger under conditions of doubled carbon dioxide concentrations', *Climatic Change*, Vol. 29, pp. 169–88.

Beier, P and Noss, RF (1998), 'Do habitat corridors provide connectivity?' *Conservation Biology*, Vol. 12, pp. 1241–52, available online at http://tongass-fpadjust.net/Documents/Beir_Noss_corridors.pdf.

Bennett, AF (1998), *Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation*, IUCN, Gland, Switzerland and Cambridge, UK.

Bennett, AF, Lumsden, LF and Nicholls, AO (1994), 'Tree hollows as a resource for wildlife in remnant woodlands: Spatial and temporal patterns across the northern plains of Victoria, Australia', *Pacific Conservation Biology*, Vol. 1, pp. 222–35.

Benson, JS (2008), 'New South Wales Vegetation Classification and Assessment: Part 2 Plant communities of the NSW South-Western Slopes Bioregion and Update of NSW Western Plains Plant Communities, Version 2 of the NSWVCA database', *Cunninghamia*, Vol. 10, No. 4, pp. 599–673.

Benson, JS and Redpath, PA (1997), 'The nature of pre-European native vegetation in South-Eastern Australia: A critique of Ryan, DG, Ryan JR and Starr, BJ (1995) *The Australian Landscape – Observations of Explorers and Early Settlers', Cunninghamia*, Vol. 5, pp. 285–328.

Benson, JS, Allen, C, Togher, C and Lemmon, J (2006), 'New South Wales Vegetation Classification and Assessment: Part 1. Plant communities of the NSW Western Plains', *Cunninghamia*, Vol. 9, No. 3, pp. 383–451.

Beveridge, P (1889), *The Aborigines of Victoria and the Riverina*, ML Hutchinson, Melbourne.

Binning, C, Cork, S, Parry, R and Shelton, D (2001), *Natural assets: An inventory of ecosystem goods and services in the Goulburn Broken catchment*, Commonwealth Scientific and Industrial Research Organisation, Canberra.

Biodiversity and Climate Change Expert Advisory Group (2009), *Australia's biodiversity and climate change: A strategic assessment of the vulnerability of Australia's biodiversity to climate change: Summary for policy makers*, a report to the Natural Resource Management Ministerial Council, Australian Government Department of Climate Change.

BIS Shrapnel (2001), *Red gum industry development strategy*, unpublished report prepared for State Forests NSW and the Department of State and Regional Development.

BOM (Bureau of Technology) (2009), *Australian Annual Mean Temperature*, available online at http://www.bom.gov.au/climate/change/amtemp.shtml.

Borschmann and Poynter (2003), *Developing a Plantation-Based Firewood Industry in Low Rainfall Areas of North Eastern Victoria*, report prepared for Australian Forest Growers (NE Branch), Plantations North East Inc. and Department of Primary Industries, Australia.

Bowler, JM and Magee, JW (1978), 'Geomorphology of the Mallee Region in semi-arid northern Victoria and western New South Wales', *Proceedings of the Royal Society of Victoria*, Vol. 90, pp. 5–21.

Bowman, DMJS (1998), 'Tansley Review No. 101, The impact of Aboriginal landscape burning on the Australian biota', *New Phytologist*, Vol. 140, pp. 385–401.

Bradley, R and Gans, JS (1998), 'Growth in Australian Cities', *Economic Record*, Vol. 74, No. 226, pp. 266–78.

Brady, A, Shaikh, M, King, A, Ross, J and Sharma, P (1998), *The Great Cumbung Swamp: Assessment of water requirements*, Department of Land and Water Conservation, CNR 97.043, NRMS Project R-5048.

Bren, L. (1990), *Red gum forests*. In: 'The Murray.' (edited by Mackay, N. and Eastburn, D.). Murray-Darling Basin Commission, Canberra, pp. 231–244.

Brereton, R, Bennett, S and Mansergh, I (1995), 'Enhanced greenhouse climate change and its potential effect on selected fauna of South-Eastern Australia: A trend analysis', *Biology Conservation*, Vol. 72, pp. 339–54.

Brigham, RM, Debus, SJS and Geiser, F (1998), 'Cavity selection for roosting and roosting ecology of forest-dwelling Australian Owlet-nightjars (*Aegotheles cristatus*), *Australian Journal of Ecology*, Vol. 23, pp. 424–9.

Brooks, N and Adger, N (2005), 'Assessing and enhancing adaptive capacity', in Chopra, K, Leemans, R, Kumar, P and Simons, H (eds), *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, Cambridge University Press, Cambridge, UK.

Brown, B (undated), *Some Thoughts on the Socio-Economic Impacts of Climate Change*, Namoi Catchment Management Authority.

Brown, CM and AE Stephenson (1991), 'Geology of the Murray basin, South-Eastern Australia', Bulletin No. 235, Bureau of Mineral Resources, Geology and Geophysics, Australian Government Publishing Service, Canberra.

Burbidge, AA (1985), *The Regent Parrot: A report on the breeding distribution and habitat requirements along the Murray River in south-eastern Australia*, Report Series No. 4., Australian National Parks and Wildlife Service, Canberra.

CARE (Centre for Agricultural and Regional Economics Pty Ltd) (2009), *Assessing the socio-economic impacts of climate change on selected regions of NSW: Final Report to the Department of Environment, Climate Change and Water*, prepared by Roy Powell, David Thompson and Linden Chalmers, October 2009.

Cameron, M (2006), 'Nesting habitat of the Glossy Black-cockatoo in central New South Wales', *Biological Conservation*, Vol. 127, pp. 402–10.

Capon, S, Reid, M, Thoms, M, Parsons, M (2009), *Ecological Character of the Lower Lachlan Floodplain and Wetlands*, Rivers and Wetlands Unit, NSW Department of Environment and Climate Change and Water.

Chambers, LE, Hughes, L and Weston, MA (2005), 'Climate change and its impact on Australia's avifauna', *Emu*, Vol. 105, pp. 1–20.

Chapin, FS, III, Folke, C and Kofinas, G (2009), 'A Framework for Understanding Change', in Chapin, FS, III, Kofinas, GP and Folke, C (eds), '*Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*', Springer Verlag, New York.

Chesterfield, EA, Loyn, RH and MacFarlane, MA (1984), 'Flora and fauna of Barmah State Forest and their management, *Victorian Forests Commission Research Bulletin*, Report No. 240.

Cogger, HG (2000), *Reptiles and Amphibians of Australia*, Reed New Holland.

Commonwealth of Australia (1992), *National Forest Policy Statement A New Focus For Australia's Forests*, Advance Press Pty Ltd, Perth.

Commonwealth of Australia (1997), *Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia,* a report by the Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee.

Commonwealth of Australia (2009), *Australia's Biodiversity and Climate Change. A strategic assessment of the vulnerability of Australia's biodiversity to climate change*, summary for policy makers.

Commonwealth of Australia (2009a), *Australia's Strategy for the National Reserve System 2009–2030*. Available online at http://www.environment.gov.au/parks/publications/nrs/pubs/nrsstrat.pdf

Cork, S (ed) (2009), *Brighter Prospects: Enhancing the Resilience of Australia*, Australia21, Canberra.

Cork, S. (2001) *A framework for applying the concept of ecosystem services to natural resource management in Australia*. in Rutherford, I., Sheldon, F., Brierley, G., and Kenyon, C. (Eds), Third Australian Stream Management Conference August 27-29, 2001. Cooperative Research Centre for Catchment Hydrology: Brisbane. Pp 157-162. Available at http://www.ecosystemservicesproject.org/html/publications/docs/Framework_for_ecosystem_services.pdf.

Cork, S, Shelton, D, Binning, C and Parry, R (2003), 'A framework for applying the concept of ecosystem services to natural resource management in Australia, in Rutherford, I, Sheldon, F, Brierley, G and Kenyon, C (eds), *Proceedings of the Third Australian Stream Management Conference 27–29 August 2001*, Cooperative Research Centre for Catchment Hydrology, Brisbane, pp. 157–62, available at http://www.ecosystemservicesproject.org/html/publications/docs/Framework_for_ecosystem_services.pdf.

Coutts, PJF (1981), *Readings in Victorian Prehistory. Volume 2: The Victorian Aboriginals 1800 to 1860*, Victorian Archaeological Survey Ministry for Conservation, Victoria.

Crosbie, RS, McCallum, JL, Walker, GR and Chiew, FHS (2008), *Diffuse groundwater recharge modelling across the Murray-Darling Basin*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, CSIRO, Australia, p. 108.

CSIRO (1992), *Climate Change Scenarios for the Australian Region*, CSIRO Climate Impact Group, Aspendale, Victoria.

CSIRO (2008), *Implications of Climate Change for the National Reserve System*, report by CSIRO Sustainable Ecosystems to the Australian Greenhouse Office, Canberra.

CSIRO (2008a), *Water Availability in the Murray-Darling Basin*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, Australia.

CSIRO (2008b), *Water Availability in the Murrumbidgee*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, Australia.

CSIRO (2008c), *Water Availability in the Lachlan*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, Australia.

CSIRO (2008d), *Water availability in the Murray*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, Australia.

CSIRO, ANU Forestry, RIRDC, Olsen and Vickery, and Hester Gascoigne and Associates (2001) *The Contribution of Mid to Low Rainfall Forestry and Agroforestry to Greenhouse and Natural Resource Management Outcomes: Overview and Analysis of Opportunities*, Australian Greenhouse Office and MDBC.

Cummergunja (2009), transcribed initial submission from Kevin Atkinson on the River Red Gum Assessment, Monday 24 August, available online at http://nrc.nsw.gov.au/content/documents/Forest%20assessment%20-%20Submission%20-%20Red%20gum%20ToR%20-%20Cummergunja.pdf.

Cunningham, SC and Mac Nally, R (2009), submission to the Natural Resources Commission, available online at http://nrc.nsw.gov.au/content/documents/Forest%20assessment%20-%20Submission%20-%20Red%20gum%20PAR%20-%20Australian%20Centre%20for%20Biodiversity.pdf.

Cunningham, SC, Read, J, Baker, PJ and Mac Nally, R (2007), 'Quantitative assessment of stand condition and its relationship to physiological stress in stands of *Eucalyptus camaldulensis* (*Myrtaceae*) in south-eastern Australia ', *Australian Journal of Botany*, Vol. 55, pp. 692–9.

Cunningham, SC, Mac Nally, R, Read, IJ, Baker, PJ, White, M, Thomson, JR and Griffioen, P (2009), 'A Robust Technique for Mapping Vegetation Condition Across a Major River System', *Ecosystems*, Vol. 12, pp. 207–19.

Cunningham, SC, Thomson, JR, Read, J, Baker, PJ and Mac Nally, R (in press), 'Does stand structure influence susceptibility of eucalypt floodplain forests to dieback?', *Australian Ecology*.

Curr, EM (1883), *Recollections of Squatting in Victoria from 1841 to 1851*. Melbourne University Press, 2nd edition (first published in 1883 by George Roberston).

DAFF (2009), *Illegal logging*, available online at http://www.daff.gov.au/forestry/international/illegal-logging.

Daily, GC, Soderqvist, T, Aniyar, S, Arrow, K, Dasgupta, P, Ehrlich, PR, Folke, C, Jansson, A, Jansson, BO, Kautsky, N, Levin, S, Lubchenco, J, Maler, KG, Simpson, D, Starrett, D, Tilman, D and Walker, B (2000), 'The Value of Nature and the Nature of Value', *Science*, Vol. 289, pp. 359–356.

Daily, GE (1997), *Nature's Services – Societal Dependence on Natural Ecosystems*, Island Press, Washington.

DECC (2007), DECC *Annual Report 2006–07*, Department of Environment and Climate Change, available online at <http://www.environment.nsw.gov.au/resources/whoweare/deccar07235ch4pt1.pdf>.

DECC (2008), *Environmental Watering Plan for the Murrumbidgee Valley 2008/09*. NSW Department of Environment and Climate Change.

DECC (2009b), *Murray Darling Basin*, Department of Environment and Climate Change, available online at http://www.climatechange.gov.au/climate-change/impacts/national-impacts/murray-darling-basin.aspx.

DECCW (2008), *New South Wales National Parks Establishment Plan 2008: Directions for building a diverse and resilient system of parks and reserves under the National Parks and Wildlife Act*, Department of Environment, Climate Change and Water, NSW.

DECCW (2009), 'Internal draft report on water management in the NSW Riverina Bioregion', unpublished, Department of Environment, Climate Change and Water, NSW.

Department of the Environment, Sport and Territories (1996), *National Strategy for the Conservation of Australia's Biological Diversity*, available online at http://www.environment.gov.au/biodiversity/publications/strategy/index.html.

DEWHA (2008), *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands*, Module 2 of the National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia. Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2009), '*Biodiversity assessment – Riverina*'. In: 'Australian Natural Resources Atlas', Department of the Environment, Water, Heritage and the Arts, available online at http://www.anra.gov.au/topics/vegetation/assessment/vic/ibra-riverina.html#intro.

DEWHA (2009a), *Toogimbe fact sheet*, available online at http://www.environment.gov.au/indigenous/ipa/index.html.

Dexter, B and Poynter, M (2005), Submissions to the VEAC river red gum forests investigation. Water, wood and wildlife – opportunities for the riverain red gum forests of the Central Murray, October 2005.

Dexter, BD (1970), *Regeneration of river red gum Eucalyptus camaldulensis Dehn*, Masters Thesis, University of Melbourne.

Dexter, BD (2009), *Regeneration, flooding growth study Barmah State Forest – Red Gum Field Day 27 October 2009*, submission to the Natural Resources Commission, Available online at http://nrc.nsw.gov.au/content/documents/Forest%20assessment%20-%20Submission%20-%20Red%20gum%20PAR%20-%20Barrie%20Dexter.pdf.

Dexter, EM, Chapman, AD and Busby, JR (1995), *The Impact of Global Warming on the Distribution of Threatened Vertebrates*, Australia and New Zealand Environment Conservation Council 1991, Environmental Resources Information Network, Australian Nature Conservation Agency, Canberra.

DHI Water & Environment Pty Ltd (2008), *Koondrook Perricoota MIKE Flood Modelling*.

Di Stefano, J, (2001), *River red gum (Eucalyptus camadulensis): a review of ecosystem processes, seedling regeneration, and silvicultural practice*, available online at http://www.forestry.org.au.

Dobson, A, Ralls, K, Foster, M, Soulé, ME, Simberloff, D, Doak, D, Estes, JA, Mills, LS, Mattson, D, Dirzo, R, Arita, H, Ryan, S, Norse, EA, Noss, RF and Johns, D (1999), 'Corridors: Reconnecting fragmented landscapes', in Soulé, ME and Terborgh, J (eds), *Continental Conservation: Scientific Foundations of Regional Reserve Networks*, The Wildlands Project, Island Press, Washington DC, pp. 129–70.

Doerr, VAJ, Doerr, ED and Davies, MJ, (in review), 'Systematic Review 44 – Does structural connectivity facilitate effective dispersal of native species in Australia's fragmented terrestrial landscapes?', in *Collaboration for Environmental Evidence*, available online at http://www.environmentalevidence.org/SR44.html.

Donovan, P (1997), *A history of the Millewa group of river red gum forests*, State Forests of New South Wales, Beecroft, NSW.

Doody, TM, Benyon, RG and Theiveyanathan, T (2006), 'Quantifying water savings from willow removal in creeks in south central NSW', paper for the 9th International River Symposium, Brisbane, 21–24 September 2006.

Dorrough, J, Yen, A, Turner, V, Clark, SG, Crosswaite, J and Hirth, JR (2004), 'Livestock management and biodiversity conservation in Australian temperate grassy landscapes', *Australian Journal of Agriculture Research*, Vol. 55, pp. 279–95.

Drielsma, M, Manion, G and Ferrier, S (2007), 'The spatial links tool: Automated mapping of habitat linkages in variegated landscapes, *Ecological Modelling*, Vol. 200, pp. 403–11.

Driscoll, D, Milovits, G and Freudenberger, D (2000), *Impact and Use of Firewood in Australia*, CSIRO Sustainable Ecosystems, Canberra.

Driver, P, Chowdhury, S, Wettin, P and Jones, H (2005), 'Models to predict the effects of environmental flow releases on wetland inundation and the success of colonial bird breeding in the Lachlan River, NSW', in *Proceedings of the Fourth Annual Stream Management Conference*, Cooperative Research Centre for Catchment Hydrology, Launceston, Tasmania, 19–22 October 2004.

DSE (2004), *EVC/Bioregion Benchmark for Vegetation Quality Assessment Murray Fans Bioregion – EVC 106: Grassy Riverine Forest*, Department of Sustainability and Environment, April 2004.

DSE (2007), *EVC/Bioregion Benchmark for Vegetation Quality Assessment Murray Fans bioregion– EVC 56: Floodplain Riparian Woodland*, Department of Sustainability and Environment, Victoria.

DSE (2008), *Northern Region Sustainable Water Strategy: Draft for community comment*, Department of Sustainability and Environment, Victoria.

DSE (2009), *Victorian Government response to Victorian Environmental Assessment Council's river red gum forests investigation.* Victorian Government Department of Sustainability and Environment Melbourne, March 2009. Available online at http://www.dse.vic.gov.au

Dudding, M (1992), *Lindsay River Salinity Assessment – Progress Report No. 3*, Rural Water.

Dudding, M (2004), 'Groundwater Trend Reversal in Northern Victoria', presentation to the 9th Murray-Darling Basin Groundwater Workshop, 2004.

Dunlop M and Brown, PR (2008), *Implications of climate change for Australia's National Reserve System: A preliminary assessment*, Department of Climate Change, Canberra, Australia.

Eamus, D, Hatton, T, Cook, PJ and Colvin, C (2006), *Ecohydrology: vegetation function, water and resource management*, CSIRO, Victoria, Australia.

Eardley, KA (1999), 'A Foundation for conservation in the Riverina Bioregion', unpublished report, NSW National Parks and Wildlife Service.

Earl, JM and Jones, CE (1996), 'The need for a new approach to grazing management – Is cell grazing the answer?' *Rangeland Journal*, Vol. 18, No. 2, pp. 327–50.

En Chee, Y (2009), Peer review of Bacon (2009a), Research Fellow, School of Botany, The University of Melbourne, Victoria.

Environment Australia (2001), *A directory of important wetlands in Australia*, 3rd edition, Environment Australia, Canberra, available online at http://www.environment.gov.au/water/publications/environmental/wetlands/pubs/directory.pdf.

Environment Victoria (2001), *GKP Gunbower-Koondrook-Perricoota Storylines; personal stories of an iconic forest wetland on the Murray River*.

Esplin, B, Gill, M and Enright, N (2003), *Report of the Inquiry into the 2002–2003 Victorian Bushfires*, Victorian Government, Melbourne.

Evans, R, Bastiaanssen, W, Molloy, R and Hulbert, S (2009), 'Improving the picture for irrigation using SEBAL in Australia to measure evapotranspiration (ET)', paper presented at the Irrigation and Drainage Conference 2009, Irrigation Australia Ltd, Swan Hill, Victoria, Australia, 18–21 October 2009.

eWater CRC (2007), *River Analysis Package (RAP) version 2.0.4.*, University of Canberra, ACT.

Eyre, TJ, Smith, AP (1997), 'Floristic and structural habitat preferences of Yellow-bellied Gliders (Petaurus Australis) and selective logging impacts in southeast Queensland, Australia', *Forest Ecology and Management*, Vol. 98, pp. 281–95.

Fensham, R. (2003), 'Grasslands', in Attiwill, P. and Wilson, B (eds) in *Ecology: An Australian perspective*', pp.247–262, Oxford University Press, South Melbourne.

Fischer, J, Peterson GD, Gardner, TA, Gordon, LJ, Fazey, I, Elmqvist, T, Felton, A, Folke, C and Dovers, S (2009), 'Integrating resilience thinking and optimisation for conservation', in *Trends in Ecology and Evolution*, Vol. 24, Issue 10, pp. 549–554

Florence, RG (1996), *Ecology and silviculture of eucalypt forest*, CSIRO Publishing, Australia.

Folke, C, Chapin, FS and Olsson, P (2009), 'Transformations in ecosystem stewardship', in Chapin, FS, Kofinas, GP and Folke, C (eds), *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*, Springer, New York.

Forestry Commission of NSW (1984), *Notes on the silviculture of major NSW. Forest types – 5*. River red gum, Forestry Commission NSW, Sydney.

Forestry Commission of NSW (1985), *Management Plan for Murray Management Area – 1985*, Sydney, NSW.

Forests NSW (2000), *Forest Practices Code. Part 4: Forest Roads and Fire Trails*, State Forests of NSW, Sydney.

Forests NSW (2000a), *A grazing strategy for State Forests in the Riverina Region – August 2000*, submitted to Natural Resources Commission.

Forests NSW (2001), *A review of the NSW Red Gum Industry – Part B: A detailed resource analysis State Forest and Western Land Leases*, February 2001 (unpublished).

Forests NSW (2004), *The State Forests of the Riverina*, brochure provided by Forests NSW Information Centre, December 2004.

Forests NSW (2005), *Living, working, playing forests: 2005–2009*, NSW Department of Primary Industries, available online at http://www.dpi.nsw.gov.au/aboutus/resources/corporate-publications/living.

Forests NSW (2006), *Operational Guidelines for Aboriginal Cultural Heritage Management*.

Forests NSW (2008), *Ecologically Sustainable Forestry Management Plan* – Riverina Region NSW, Department of Primary Industries, Sydney, NSW, available online at http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/266194/esfm-riverina.pdf.

Forests NSW (2008a), *State Forests Native Forest Silviculture Manual*, NSW Department of Primary Industries, Sydney.

Forests NSW (2008b), *Koondrook-Perricoota Forest Flood Enhancement Works Investment Proposal*.

Forests NSW (2009a), *Harvesting and associated road work operations in South-Western NSW*, Environmental Impact Statement, available online at http://www.dpi.nsw.gov.au/forests/info/riverinaea.

Forests NSW (2009b), *Koondrook-Perricoota Forest Flood Enhancement Works – Preliminary Environmental Assessment (Part 3A Application)*, Report DC09030 by Forests NSW and NSW Government Department of Water and Energy.

Forests NSW (2009c), *Koondrook-Perricoota Presentation to National Resources Commission (NRC).*

Froend, RH, Bertuch, M (2007), 'A shift in the ecohydrological state of groundwater dependent vegetation due to climate change and groundwater on the swan coastal plain of Western Australia', in *Proceedings of the XXXV Congress of the International Association of Hydrogeologists. Groundwater and Ecosystems*, Lisbon 2007.

Game Council of NSW (2009), 'Frequently asked questions. Conservation hunting on declared public land in NSW', available online at http://www.gamecouncil.nsw.gov.au/portal.asp?p=Aug06DPLfaqs.

Garnaut, R (2008), The Garnaut Climate Change Review – Final report. Chapter 22 – Transforming rural land use, available online at www.garnautreview.org.au

Garnett, ST and Crowley, GM (2000), *The Action Plan for Australian Birds 2000*, Environment Australia, Canberra.

Gelletly, T (2009), 'Todd Gelletly's final submission regarding the Riverina Redgum Forests', submission to the Natural Resources Commission, available online at http://nrc.nsw.gov.au/content/documents/Forest%20assessment%20-%20Submission%20-%20Red%20gum%20PAR%20-%20Todd%20Gelletly.pdf.

GHD (2009), *Draft Ecological Character Description – NSW Central Murray State Forests*, report prepared by GHD for Forests NSW, January 2009.

GHD (2009a), '*The late Holocene origins of the modern Murray River course, South-Eastern Australia*'. School of Earth Sciences, University of Melbourne, Victoria.

Gibbons, P and Lindenmayer, D (2002), *Tree Hollows and Wildlife Conservation in Australia*, CSIRO Publishing, Victoria.

Gibbons, P, Lindenmayer, DB, Barry, SC and Tanton, MT (2002), 'Hollow selection by vertebrate fauna in forests of south-eastern Australia and implications for forest management', *Biological Conservation*, Vol. 103, pp. 1–12.

Gibbons, P, McElhinny, C and Lindenmayer, DB (in review), 'Perpetuating old trees in forests managed for wood production: a case study on hollow-bearing trees in south-eastern Australia'.

Gippel, CJ and Blackham, D (2002), *Review of environmental impacts of flow regulation and other water resource developments in the Murray River and Lower Darling River system*, Final Report by Fluvial Systems Pty Ltd, Stockton, to Murray-Darling Basin Commission, Canberra, ACT.

GISCA Applications, *Accessibility Remoteness Index of Australia*, available online at http://www.gisca.adelaide.edu.au/web_aria/aria/aria.html.

Goode, AM and Barnett, BG (2008), *Southern Riverine Plains Groundwater Model Calibration Report*, a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project, p. 138.

Green, K (2003), 'Impacts of global warming on the Snowy Mountains', in Howden, M. et al. (eds), *Climate Change Impacts on Biodiversity in Australia*, Outcomes of a Workshop Sponsored by the Biological Diversity Advisory Committee, 1–2 October 2002, Department of the Environment and Heritage, pp. 35–6.

Gunningham, N (2007), 'The new collaborative environmental governance', paper for the International Meeting on Law and Society in the 21st Century, Humboldt University, Berlin, 25–28 July 2007.

Hacker, R, Bowman, A, Fairweather, H, Hailstones, D, Hegarty, R, Holzapfel, B, Sinclair, K and Williamson, B (2006), *Climate Change Impacts and Priority Actions in the Agriculture Sector: Background Paper*, available online at <http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/191520/Climate-change-and-agriculture---a-background-paper.pdf>

Hagen, R (1997), *Report to the Yorta Yorta Clans Group on Yorta Yorta Associations with the Claim Area*.

Harden, GJ (ed.) (1993), *Flora of New South Wales Volume 4*, Royal Botanic Gardens and New South Wales University Press, Sydney.

Hardwick, L, Maguire, J and Foreman, M (2001), 'Providing Water to Murrumbidgee Billabongs – Maximising Ecological Value, in *The Value of Healthy Streams*, Vol. 1. Proceedings of The Third Australian Stream Management Conference.

Hatton TJ and R Evans (1998), *Dependence of ecosystems on groundwater and its significance to Australia*, LWRRDC Occasional Paper No. 12/98.

Heinsohn, R, Murphy, S and Legge, S (2003), 'Overlap and competition for nest holes among Eclectus Parrots, Palm Cockatoos and Sulphur-crested Cockatoos', *Australian Journal of Zoology*, Vol. 51, pp. 81–94.

Herron, N, Davis, R and Jones, R (2002), 'The effects of large-scale afforestation and climate change on water allocation in the Macquarie River catchment, NSW, Australia', *Journal of Environmental Management*, Vol. 65, pp. 369–81.

Higgins, PJ (ed.) (1999), *Handbook of Australian, New Zealand and Antarctic Birds*. Parrots to Dollarbird, Oxford University Press, Melbourne, Column 4.

Hillman, T, (2009), Former Director Murray Darling Freshwater Research Centre after O'Connell, 2003.

Hillman, TJ, Koehn, JD, Mitchell, D, Thompson, D, Sobels, JD and Woodside, D (2000), *The Murrumbidgee: Assessing the health of a 'working river',* report to Irrigated Agribusiness Taskforce and the Department of Land and Water Conservation.

HO and DUAP (1996), *Regional Histories: Eegional histories of New South Wales Sydney*.

Holland KL, Tyerman SD, Mensforth LJ and Walker, GR (2006), 'Tree water sources over shallow, saline groundwater in the lower River Murray, south-eastern Australia: Implications for groundwater recharge mechanisms, *Australian Journal of Botany*, Vol. 54, No. 2.

Hope, J (1995), *Aboriginal Burial Conservation in the Murray Darling Basin*, Historic Environment, Vol. 11, No. 2 and Vol. 3, pp. 57–60.

Horner, GJ, Baker, PJ, Mac Nally, R, Cunningham, SC, Thompson, JR and Hamilton, F (in press), 'Forest structure, habitat and carbon benefits from thinning floodplain forests: managing early stand density makes a difference', *Forestry Ecology and Management.*

Horner, G, Baker, P, Mac Nally, R, Cunningham, S, Thomson, J and Hamilton, F (2009), 'Mortality of developing floodplain forests subjected to a drying climate and water extraction', *Global Change Biology*, Vol. 15, pp. 2176–86.

Horton (1996), 'Map of Aboriginal Australia', Aboriginal Studies Press, AIATSIS, available online at http://www.aboriginaleducation.sa.edu.au/pages/Educators/aboriginalaustralia/?reFlag=1.

Howden, SM, Moore, JL, McKeon, GM, Reyenga, PJ, Carter, JO and Scanlan, JC (1999), *Dynamics in the Mulga Woodlands of South-West Queensland: Global Change Impacts and Adaptation*, Working Paper Series No.99/05. CSIRO Wildlife and Ecology, Canberra, available online at http://www.mssanz.org.au/MODSIM99/Vol%203/Howden.pdf.

Hughes, L (2003), 'Climate change and Australia: trends, projections and impacts', *Australian Ecology*, Vol. 28, pp. 423–43.

ID&A (2001), *Scoping Study: Waterway Management Plan Hume to Yarrawonga Reach of the Murray River*, report prepared for the Murray-Darling Basin Commission.

Ife, D and Skelt, K (2004), *Murray-Darling Basin Groundwater Status 1990–2000: Summary Report*, Murray-Darling Basin Commission, Canberra.

Inland Rivers Network (2007), *Wetlands in Crisis*, available online at http://www.irnnsw.org.au/pdf/IRNNews_10_1.pdf.

IPCC (2007), *Climate Change 2007: Synthesis Report*, Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC (2007a), *Climate change 2007: The physical science basis*, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S, Quin, D, Manning, M, Marquis, M, Averyt, K, Tignor, MMB, Miller, HL and Chen, Z (eds), Cambridge University Press, Cambridge, UK.

IMFN (International Model Forests Network) (2009), 'Participatory Governance', available online at http://www.imfn.net/?q=node/14.

Jaakko Poyry (2005), *Overview of illegal logging*, Report prepared for DAFF, Canberra.

Jackson, S (2005), *Australasian Journal of Environmental Management*, Vol 12, No. 3, pp 136–46.

Jacobs, MR (1955), *Growth habits of the eucalypts*, Forestry and Timber Bureau.

Jansen, A and Healey, M (2003), 'Frog communities and wetland condition: Relationships with grazing by domestic livestock along an Australia floodplain river', *Biological Conservation*, Vol. 109, pp. 207–19.

Jansen, A and Robertson, AI (2001), 'Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river', *Journal of Applied Ecology*, Vol. 38, pp. 63–75.

Jansen, A, Robertson, AI (2005), 'Grazing, ecological conditions and biodiversity in riparian river red gum forests in south-eastern Australia', in *Proceedings of the Royal Society of Victoria*, Vol. 117, pp. 85–95.

Johnson B (1998), 'Consequences for the Macquarie Marshes', in *Climate Change Scenarios and Managing the Scarce Water Resources of the Macquarie River*, prepared by Hassall and Associates Pty Ltd for the Australian Greenhouse Office, pp. 61–8.

Jurskis, V (2008), 'Drought as a factor in tree declines and diebacks', in Sanchez, JM (ed.), *Droughts: Causes, Effects and Predictions*, Nova Science Publishers Inc., New York, pp. 331–41.

Jurskis, V. (2009), 'River red gum and white cypress forests in south-western New South Wales, Australia: Ecological history and implications for conservation of grassy woodlands', *Forest Ecology and Management*, Vol. 258, pp. 2593–2601.

Jurskis, V, Selby, M, Leslie, D and Jurskis, D (2005), *Health of river red gum, Eucalyptus camaldulensis, in NSW Central Murray State Forests*, Forests NSW.

Kalcounis-Rüppell, MJ, Pysllakis, JM and Brigham, RM (2006), 'Tree roost selection by bats: An empirical synthesis using metadata-analysis', *Wildlife Society Bulletin*, Vol. 33, pp. 1123–32.

Kavanagh, RP and Bamkin, KL (1995), 'Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in southeastern New South Wales', *Australia. Biol. Conserv*. Vol. 71, pp. 41–53.

Kavanagh, RP and Stanton, MA (1998), Bird population recovery 22 years after intensive logging near Eden, New South Wales, *Emu* Vol. 103, pp. 221-231.

Kavanagh, RP and Stanton, M (2009), 'Conserving Barking Owls in the Pilliga Forests', *Wingspan*, Vol. 19, No. 2, pp. 28–30.

Kavanagh, RP and Wheeler, RJ (2004), 'Home-range of the greater glider Petauroides volans in tall montane forest of south-eastern New South Wales, and changes following logging', in Goldingay, RL and Jackson, SM (eds), *The Biology of Australian Possums and Gliders*, Surrey Beatty and Sons, Sydney, pp. 413–25.

Kavanagh, RP, Debus, SJS, Rose, AB and Turner, RJ (1995), 'Diet and habitat of the Barking Owl Ninox connivens in New South Wales', *Australian Bird Watcher*, Vol. 16, pp.137–44.

Keatley, MR and Hudson, IL (2005), 'Change in flowering dates of Australian plants: 1983–2004', *Proc. Greenhouse 2005: Action on Climate Change*, Melbourne, Australia, CSIRO, p. 81.

Keith, DA (2004), *Ocean shores to desert dunes: The native vegetation of New South Wales and the ACT*, NSW Department of Environment and Conservation, Sydney

Keith, DA, Williams, JE, Woinarski, CZ, Williams, J, and Gill, AM (2002), *Fire management and biodiversity conservation: key approaches and principles*. In: 'Flammable Australia: The Fire Regimes and Biodiversity of a Continent'. (edited by R Bradstock), pp. 401–425, (Cambridge University Press, Cambridge, UK).

Keith, H, Mackey, B and Lindenmayer, D (2009), 'Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests', available online at http://www.pnas.org/content/106/28/11635.short.

Killey, P, McElhinny, C, Rayner, I and Woods, J (in press), 'Modelling fallen branch volumes in a temperate eucalypt woodland: implications for large senescent trees and benchmark loads of coarse woody debris', *Australian Ecology.*

Kingsford, RT and Norman, F I (2002), 'Australian waterbirds – products of the continent's ecology', *Emu*, Vol. 102, pp. 47–69.

Kingsford, RT and Thomas, RF (2001), *Changing water regimes and wetland habitat on the Lower Murrumbidgee floodplain of the Murrumbidgee River in arid Australia*, NSW National Parks and Wildlife Service Report to Environment Australia.

Kingsford, RT and Thomas, RF (2004), 'Destruction of Wetlands and Waterbird Populations by Dams and Irrigation on the Murrumbidgee River in Arid Australia', *Environmental Management*, Vol. 34, pp. 383–96.

Kingsford, RT, Thomas, RF and Wong, PS (1996), *Significant wetlands for waterbirds in the Murray-Darling Basin*, Murray-Darling Basin Commission.

Kirby, KL (1992), 'Accumulation of deadwood – a missing ingredient in coppicing?', in Buckley, GP (ed.), *Ecology and Management of Coppice Woodlands*, Chapman and Hall, Melbourne, pp. 99–112.

Kneebone, E (1992), 'Interpreting Traditional Culture as Land Management', in Birkhead, J, DeLacy, T and Smith, L (eds), *Aboriginal Involvement in Parks and Protection Areas*, Australian Institute of Aboriginal and Torres Straight Islander Studies, Canberra, p. 228.

L&EC (2007), *Land and Environment Court, Short Minutes of Order*, National Parks Association vs. Forest Commission of NSW, case no. 40854 of 2007.

Lada, H and Mac Nally, R (2008), 'Decline and potential recovery of yellow-footed Antechinus in parts of south-eastern Australia: A perspective with implications for management', *Ecological Management and Restoration*, Vol. 9, pp. 120–25.

Lada, H, Thomson, JR, Mac Nally, R, Horrocks, G and Taylor, AC (2007), 'Evaluating simultaneous impacts of three anthropogenic effects on the floodplain-dwelling marsupial Antechinus flavipes', *Biological Conservation*, Vol. 134, pp. 527–36.

Lambeck, RJ and Saunders, DA (1993), 'The role of patchiness in reconstructed wheatbelt landscapes', in Saunders D, Hobbs, R and Ehrlich, P (eds), *Nature Conservation 3: Reconstruction of Fragmented Ecosystems*, pp. 151–61.

Law, BS and Dickman, CR (1998), 'The use of habitat mosaics by terrestrial fauna: Implications for conservation and management', *Biodiversity and Conservation*, Vol. 7, pp. 323–33.

Lawler, IR, Foley, WJ, Woodrow, IE and Cork, SJ (1997), 'The effects of elevated CO^2 atmospheres on the nutritional quality of Eucalyptus foliage and its interaction with soil nutrient and light availability', *Oecologia*, Vol. 109, pp. 59–68.

Lebbink J and Lewin K (2008), *Little River Red Gum Health Investigation*, prepared by Sinclair Knight Merz for Melbourne Water.

Leslie, D (2005), 'Is the Superb Parrot Polytelis swainsonii population in Cuba State Forest limited by hollow or food availability?', *Corella*, Vol. 29, No. 4, pp. 77–87.

Leslie, DJ (2001), 'Effect of river management on colonially-nesting waterbirds in the Barmah-Millewa Forest, south-eastern Australia', *Regulated Rivers: Research and Management*, Vol. 17, pp. 21–36.

Leslie, D and Harris, K (1996), *Water Management Plan for the Millewa Forests*. State Forests of New South Wales, Deniliquin.

Lewis, SE (1995), 'Roost fidelity of bats: A review', *Journal of Mammalogy*, Vol. 76, pp. 481–96.

Lindenmayer, D, Hobbs, RJ et al. (2008), 'A checklist for ecological management of landscapes for conservation', *Ecology Letters*, Vol. 11, pp. 78–91.

Lindenmayer, DB and Franklin, JF (2002), *Conserving Forest Biodiversity: A Comprehensive Multi-scaled Approach*, Island Press, Washington, USA.

Lindenmayer, DB and Nix, HA (1993), 'Ecological principles for the design of wildlife corridors', *Conservation Biology*, Vol. 7, No. 3, pp. 627–30.

Lindenmayer, DB and Noss, RF (2006), 'Salvage logging, ecosystem processes, and biodiversity conservation', *Conservation Biology*, Vol. 20, pp. 949–58.

Lindenmayer, DB, Cunningham, RB, Donnelly, CF, Tanton, MT and Nix, HA (1993), 'The abundance and development of cavities in Eucalyptus trees: A case study in montane forests of Victoria, southeastern Australia', *Forest Ecology and Management*, Vol. 60, pp.77–104.

Lindenmayer, DB, Cunningham, RB, Tanton, MT, Smith, AP and Nix, HA (1991), 'Characteristics of hollow-bearing trees occupied by arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia', *Forest Ecology and Management*, Vol. 40, pp. 289–308.

Lindenmayer, DB, Foster, DR, Franklin, JF, Hunter, ML, Noss, RF, Schmiegelow, FA and Perry, D (2004), 'Salvage harvesting policies after natural disturbance', *Science*, Vol. 303, p. 1303.

Lindenmayer, DB, Franklin, JF and Fischer, J (2006), 'General management principles and a checklist of strategies to guide forest biodiversity conservation', *Biological Conservation*, Vol. 131, pp. 433–45.

Lindenmayer, DB, Margules, CR and Botkin, DB (2000), 'Indicators of biodiversity for ecologically sustainable forest management', *Conservation Biology*, Vol. 14, pp. 941–50.

Lochner, K, Kawachi, I and Kennedy, BP (1999), 'Social Capital: A guide to its measurement', *Health and Place*, Vol. 5, pp. 259–70.

Lockwood, M, Davidson, J, Curtis, A, Stratford, R and Griffith, R. (2008), *Governance principles for natural resource management*, available online at http://lwa.gov.au/files/products/social-and-institutional-research-program/pn30299/governance-principles-natural-resource-management.pdf.

Lumsden, L, Bennett, A and Silins, J (2002), 'Selection of roost sites by the lesser long-eared bat (*Nyctophilus geoffroyi*) and Gould's wattle bat (*Chalinolobus gouldii*) in south eastern Australia', *Journal of Zoology*, Vol. 257, pp. 207–18.

Lumsden, LF and Bennett, AF (2000), *Bats in Rural Landscapes: a significant but largely unknown faunal component*, In: 'T. Barlow and R. Thorburn' (edited by Balancing conservation and production in grassy landscapes), Proceedings of the bushcare grassy landscape conference, Clare SA Environment Australia Canberra, pp.42–50.

Lunt, ID (2005), *Effects of Stock Grazing on Biodiversity Values in Temperate Native Grasslands and Grassy Woodlands in SE Australia: A Literature Review*, Environment ACT, Canberra, Technical Report No.18.

Lunt, ID, Eldridge, DJ, Morgan, JW and Witt, GB (2007), 'Turner Review No. 13. A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia', *Australian Journal of Botany*, Vol. 55, pp. 401–15.

Lunt, ID and Morgan, JW (1999), *Effect of Fire Frequency on Plant Composition at the Laverton North Grassland Reserve, Victoria*, Victorian Naturalist Research Report, Vol. 116, No. 3, pp. 84–90.

Lunt, ID and Morgan, JW (2002), '*The role of fire regimes in temperate lowland grasslands of south-eastern Australia*', In: Bradstock, R, Williams, J and Gill, AM (eds) '*Flammable Australia : the fire regimes and biodiversity of a continent*'. pp.177–196. (Cambridge University Press, Cambridge UK).

Mac Nally, R (2006), 'Longer-term response to experimental manipulation of fallen timber on forest floors of floodplain forest in south-eastern Australia', *Forest Ecology and Management*, Vol. 229, pp. 155–160.

Mac Nally, R And Horrocks, G (2007), 'Inducing whole-assemblage change by experimental manipulation of habitat structure', *J Animal Ecology*, Vol. 76, pp. 463–650.

Mac Nally, R and Horrocks, G (2008), 'Longer-term responses of a floodplain-dwelling marsupial to experimental manipulation of fallen timber loads', *Basic and Applied Ecology*, Vol. 9, pp. 458–465.

Mac Nally, R, Parkinson, A Horrocks, G and Young, M (2002), 'Current Loads of Coarse Woody Debris on South-Eastern Australian Floodplains: Evaluation of Change and Implications for Restoration', *Restoration Ecology*, Vol. 10, No. 4, pp. 627–35.

Mac Nally, R, Parkinson, A, Horrocks, G, Conole, L and Tzaros, C (2001), 'Relationships between Terrestrial Vertebrate Diversity, Abundance and Availability of Coarse Woody Debris on South-Eastern Australian Floodplains', *Biological Conservation*, Vol. 99, pp. 191–205.

Mackowski, CM (1984), 'The ontogeny of hollows in Blackbutt, Eucalyptus pilularis and its relevance to the management of forests for possums, gliders and timber', in Smith, AP and Hume, ID (eds), *Possums and Gliders*, Surrey Beatty and Sons, Sydney, pp. 517–25.

Magrath, MJL (1992), *Waterbird study of the Lower Lachlan and Murrumbidgee Valley Wetlands in 1990/91*, NSW Department of Water Resources, Sydney.

Maher, PN (1990), *Bird survey of the Lachlan/Murrumbidgee confluence wetlands*, report to NSW National Parks and Wildlife Service, p. 153.

Marks, GC, Incoll, WD and Long, IR (1986), *Effects of crown development, branch shed and competition on wood defect in Eucalyptus regnans and E. sieberi*, Australian Forest Research, Vol. 16, pp. 117–29.

Marshall, GR (2008) *Community-based, regional delivery of natural resource management: Building system-wide capacities to motivate voluntary farmer adoption of conservation practices*, RIRDC Publication No. 08/175, Rural Industries Research and Development Corporation, Canberra, available online at https://rirdc.infoservices.com.au/items/08-175.

Mattingley, AHE (1908), 'Wild Life of the Murray Swamps', *Victorian Naturalist*, Vol. 25, pp. 60–8.

Maunsell Pty Ltd (2003), Mike 11 Hydraulic Model – Gulf Water Management Area: *Evaluation of Low Banks to Assist Forest Flooding*, report prepared for Barmah-Milllewa Forum, Sydney, Australia.

Mawdsley, JR, O'Malley, R and Ojima, DS (2009), *A review of climate-change adaptation strategies for wildlife management and biodiversity conservation*, Conservation Biology, Vol. 23, pp.1080–1089

McCosker, R (2008), *Yanga Vegetation Mapping: Historical Community Extent and Condition*, report to DECCW, June 2008.

McDougall, KL (2008), 'Evidence for the natural occurrence of treeless grasslands in the Riverina region of south-eastern Australia', *Australian Journal of Botany*, Vol. 56, pp. 461–8.

McElhinny, C (2009), *Peer review of issues relating to the management of river red gum forests*, report to Director, EPBC Compliance Section, Department Environment Water, Heritage and the Arts, Canberra.

McGregor, H (in press), 'Large forest owls in the river red gum State Forests of south-eastern New South Wales – an account of their 2008 status', *Australian Zoologist*.

McGregor, H (2009), *The Distribution of Six Threatened Fauna Species within the Millewa and Barooga Group of River Red Gum State Forests*, a preliminary report prepared for the NSW National Parks Association, October 2009.

McIlroy, JC (1978), 'The effects of forestry practices on wildlife in Australia: A review', *Australian Forestry*, Vol. 41, pp. 78–94.

MDBA (2009), *Issues Paper: Development of Sustainable Diversion Limits for the Murray-Darling Basin November 2009*, MDBA publication No. 48/09.

MDBA (2009b), *Progress Report on The Living Murray Initiative – First Step*, report prepared by KPMG for Murray Darling Basin Authority, Canberra.

MDBA (2009c), *Socio economic context for the Murray-Darling Basin*, available online at http://www.mdba.gov.au/services/publications/more-information?publicationid=37.

MDBC (2002), *Lake Victoria Cultural Landscape Plan of Management*, Murray-Darling Basin Commission.

MDBC (2003), *Inland Shipping The Navigation of the Murray-Darling River System*, Murray Darling Basin Commission.

MDBC (2006a), *The Barmah-Millewa Forest Icon Site Environmental Management Plan 2006–2007*, Murray-Darling Basin Commission, publication No. 30/06.

MDBC (2006b), *The Gunbower-Koondrook-Perricoota Forest Icon Site Environmental Management Plan 2006–2007*, Murray-Darling Basin Commission, Canberra.

MDBC (2006c), *The Murray River Channel Icon Site Environmental Management Plan 2006–2007*, Murray-Darling Basin Commission, Canberra.

MDBC (2007), *The Living Murray, watering the Wakool*, Fact sheet prepared by the Murray-Darling Basin Commission.

MDBC (2007a), *Draft Gunbower Koondrook-Perricoota Forest Asset Environmental Management Plan 2007–2010*, Murray-Darling Basin Commission, Canberra.

MCMA (Murray Catchment Management Authority) (2006), *Catchment action plan 2006*, available online at http://www.murray.cma.nsw.gov.au.

MDBMC (1995), *An audit of water use in the Murray-Darling Basin*, Murray-Darling Basin Ministerial Council, Canberra.

Menkhorst, P and Knight, F (2004), *A Field Guide to the Mammals of Australia*, 2nd edition, Oxford University Press.

Mensforth, LJ, Thorburn, PJ, Tyerman, SD and Walker, GR (1994), 'Sources of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater', *Oecologia*, Vol. 100, pp. 21–2.

Meredith, CW (1984), 'Possums or poles? – The effects of silvicultural management on the possums of Chiltern State Park, northeast Victoria', in Smith, AP and Hume, ID (eds), *Possums and Gliders*, Surrey Beatty and Sons, Sydney, pp. 575–7.

Migration Heritage Centre (2009), *Statement of Significance, Jindera Timber Jinker c*. 1900, available online at http://www.migrationheritage.nsw.gov.au/exhibition/objectsthroughtime/ timberjinker/.

Miles, L and Kapos, V (2008), 'Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation: Global Land-Use Implications', *Science*, Vol. 320, pp. 1454–5.

Millar, CI, Stephenson, NL and Stephens, SL (2007), 'Climate change and forests of the future: Managing in the face of uncertainty', *Ecological Applications*, Vol. 17, pp. 2145–51.

Montreal Process Implementation Group (2008a), *Criteria and indicators*, available online at www.rinya.maff.go.jp/mpci.

Morton, SR, Stafford-Smith, DM, Friedel, MH, Griffin, GF and Pickup, G (1995), 'The stewardship of arid Australia: Ecology and landscape management', *Journal of Environmental Management*, Vol. 43, pp. 195–217.

Munday, TJ, Overton, I and Fitzpatrick, A (2008), 'Managing and protecting the local ecology and biodiversity of the Lower Murray River floodplains in SE Australia using biophysical data derived from airborne EM survey data', presentation at the 2nd International Salinity Forum, 'Salinity, water and society–global issues, local action', 31 March–3 April 2008, Adelaide, Australia.

Murray Irrigation Limited (2009), *Murray Irrigation Limited Annual Report 2008–09,* available online at http://www.murrayirrigation.com.au/files/3291653.pdf.

Murray, PA (2008), *Murrumbidgee Wetlands Resource Book*, Murrumbidgee Catchment Management Authority.

Murrumbidgee CMA (2008), *Murrumbidgee Catchment Action Plan*, Murrumbidgee Catchment Management Authority and the NSW Government, available at http://www.murrumbidgee.nsw.gov.au.

Murrumbidgee CMA (2009), *Murrumbidgee Catchment Management Authority, Schedule 3, water management*, available online at http://www.murrumbidgee.cma.nsw.gov.au.

National Biodiversity Strategy Review Task Group (2009), *Australia's Biodiversity Conservation Strategy, Consultation Draft, March 2009*.

National Parks Association of NSW (2008), 'The impact of River Red Gum logging and associated activities in NSW on matters of National Environmental Significance', unpublished report to Commonwealth Department of Environment and Heritage, NPA, Sydney.

NWC (National Water Commission) (2007), 'River condition in the Murray-Darling Basin 2001', in: 'Australian Water Resources 2005', available online at http://www.water.gov.au/RiverandWetLandHealth/Assessmentofriverandwetlandhealth/Snapshotofriverand wetlandhealth/RiverconditionintheMurray DarlingBasin/index.aspx?Menu=Level1_5_2_3_2.

Navin Officer, Heritage Consultants Forests NSW Harvesting and Associated Road Work Operations in South-Western NSW (2009), *Environmental Assessment Aboriginal Cultural Heritage Desktop Review*, May 2009.

Newton, I (1994), 'The role of nest sites in limiting the numbers of hole-nesting birds: A review', *Biological Conservation*, Vol. 70, pp. 265–76.

Nias, D (2002), 'Managing Wetlands', in Kent, K, Earl, G, Mullins, B, Lunt, I and Webster, R (eds), *Native Vegetation Guide for the Riverina: Notes for land managers on its management and revegetation*, Charles Sturt University, Wagga Wagga.

Noss, RF, O'Connell, MA and Murphy, DD (1997), *The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act*, Island Press, Washington, DC.

Noss, RK (2001), 'Beyond Kyoto: Forest Management in a Time of Rapid Climate Change', *Conservation Biology*, Vol. 15, No. 3, pp. 578–90.

NPWS (2002), *Thick-billed Grasswren (eastern subspecies) Amytornis textiles modestus (North, 1902) Recovery Plan*, NSW National Parks and Wildlife Service, Sydney.

NRC (2005), *Recommendations – State-wide Standard and targets, September 2005*, Natural Resources Commission, Sydney, available online at http://www.nrc.nsw.gov.au/content/documents/Recommendations%20-%20State-wide%20standard%20and%20targets%20September%202005.pdf.

NRC (2007), *A landscape approach to vegetation management – Final Report, June 2007*, Natural Resources Commission, Sydney, available online at http://www.nrc.nsw.gov.au/content/documents/LVP%20-%20Final%20report%20-%20Landscape%20approach%20to%20vegetation%20management.pdf.

NRC (2008), *Progress report on effective implementation of Catchment Action Plan, November 2008*, Natural Resources Commission, Sydney, available online at http://www.nrc.nsw.gov.au/content/documents/Progress%20report%20on%20effective%20implementation%20of%20CAPs.pdf.

NRMMC (2006), *Framework for future NRM programmes*, endorsed by the Natural Resource Management Ministerial Council on 24 November 2006, available online at <http://www.nrm.gov.au/>.

NSW Department of Commerce (2009), 'Koondrook-Perricoota Forest Flood Enhancement Works Project: Preliminary Operating Plan Draft Version 1, September 2009', unpublished.

NSW Department of Planning (2009), *Draft Murray Regional Strategy*, available online at www.planning.nsw.gov.au.

NSW DLWC (NSW Department of Land and Water Conservation) (2004), *Murrumbidgee Management Plan – Draft*, Murrumbidgee Region, Wagga Wagga, NSW.

NSW DWE (NSW Department of Water and Energy) (2009), *Water sharing in the Murrumbidgee Regulated River. Progress Report 2004 to 2008*, available online at http://www.water.nsw.gov.au/Water-Licensing/About-licences/Which-Act-applies-/act_murrumbidgee/default.aspx.

NSW Government (2008), *A new biodiversity strategy for NSW: Discussion paper*, Department of Environment and Climate Change and the Department of Primary Industries, October 2008, available online at http://www.environment.nsw.gov.au/resources/biodiversity/08398biostr.pdf.

NSW Government (2009), *State Plan 2009*, available online at http://more.nsw.gov.au/stateplan.

NSW MWWG (NSW Murray Wetlands Working Group) (2001), *Newsletter December 2001, Issue No. 2*, available online at http://www.mwwg.org.au/news2.php.

NSW NPWS (National Parks and Wildlife Service) (2003), *The bioregions of New South Wales; their biodiversity, conservation and history*, NSW NPWS, Hurstville.

NSW Office of Water (2009), *Critical water planning for the Lachlan Valley*, Issue 5, 9 November 2009, available online at http://www.water.nsw.gov.au/Water-Management/Water-sharing/plans_commenced/default.aspx.

NSW Scientific Committee (2007), *Loss of hollow-bearing trees – key threatening process determination*, Gazettal date: 5 October 2007, available online at http://www.environment.nsw.gov.au/determinations/LossOfHollowTreesKtp.htm.

NWC (2009), *Australian water reform 2009. Second biennial assessment of progress in implementation of the National Water Initiative*, National Water Commission, Canberra.

O'Connor, P, Ward, K and King, A (2006), *Implementation of the Barmah-Millewa Forest Environmental Water Allocation 2005–2006, a case study of the successful delivery of the largest environmental water allocation in Australia and possibly the world*, paper presented to the 2007 International River Symposium.

Overton IC, Jolly ID, Slavich PG, Lewis MM and Walker, GR (2006a), 'Modelling vegetation health from the interaction of saline groundwater and flooding on the Chowilla floodplain, South Australia', *Australian Journal of Botany*, Vol. 54, No. 2.

Pardoe, C (1998), *Prehistoric Aboriginal cemeteries of the River Murray*, Institute of Aboriginal and Torres Strait Islander Studies, Canberra.

Pardoe, C and Martin, S (2001), *Murrumbidgee Province Aboriginal Cultural Heritage Study: Report to New South Wales National Parks and Wildlife Service and Aboriginal Communities of the Region*.

Parker, DG, Webster, R, Belcher, CA and Leslie, D (2007), 'A survey of large forest owls in State Forests of south-western New South Wales, Australia', *Australian Zoologist*, Vol. 34, pp. 78–84.

Parks Victoria (2009), 'Box-Ironbark Ecological Management Strategy & Ecological Thinning', available online at http://www.parkweb.vic.gov.au/1process_content.cfm?section=76&page=27.

Passfield, GRA, Simmons, CT and Doble, R (2008), 'Do artificial wetting and drying cycles for lower Murray wetlands prevent salt accumulation?', presentation to the 2nd International Salinity Forum, 'Salinity, water and society-global issues, local action'.

Pearce, B (2009), 'Assessment of Riverina Red Gum Forests, August 2009', submission to the Natural Resources Commission, Available online at http://www.nrc.nsw.gov.au.

Pels, S (1964), 'The present and ancestral Murray River system', *Australian Geographical Studies*, Vol. 2.

Pels, S (1966), 'Late Quaternary Chronology of the Riverine Plain of South-Eastern Australia', *Journal of Geological Society Australia*, Vol. 13, No. 1, pp. 27–40.

Pennay, M (2009), *Assessment of River Red Gum and Woodland Forest Health Using Multi-temporal Landsat TM Data Generated from the Statewide Landcover and Trees Study (SLATS) Central Murray Ramsar Site Trial*, Department of Environment Climate Change and Water NSW.

Perault, DR and Lomolino, MV (2000), 'Corridors and mammal community structure across a fragmented, old-growth forest landscape', *Ecological Monographs*, Vol. 70, No. 3, pp. 401–22.

Petheram, RJ, Stephen, P and Gilmour, D (2004), 'Collaborative forest management: A review', *Australian Forestry*, Vol. 67, No. 2, pp. 137–46.

Pizzey, G (1980), *A Field Guide to the Birds of Australia*, Collins, Sydney.

Possingham, HP (2001), *The business of biodiversity: Applying decision theory principles to nature conservation*. Earthwatch, South Melbourne.

Powell (2009), *Fifteen Years of the Joint Venture Agroforestry Program – Foundation research for Australia's tree crop revolution*, Rural Industries and Research Development Corporation, Canberra, Australia.

Price, P and Lovett, S (2002), 'River and riparian management fact sheet 6 – managing stock', Land and Water Australia, Canberra.

Pritchard J, Evans R and Richardson S (2009), *Broad Salt Accessions for the River Reach between Locks 7 and 10*, prepared by REM part of Sinclair Knight Merz for the Mallee Catchment Management Authority.

Purcell, P, Aboriginal Cultural Heritage Audit Riverina Bioregion (2003), *Project for RACD* (Resource and Conservation Division) by NPWS Western Regional Assessment Unit.

Purcell, P (2003), *National Parks and Wildlife Service Aboriginal Cultural Heritage Audit Report, Riverina Bioregion*.

Rhind, S (1998), 'Ecology of the Brush-tailed Phascogale in jarrah forest of south-eastern West Australia', PhD thesis, Murdoch University, Perth, Western Australia.

Richards, GP, Borough, C, Evans, D, Reddin, A, Ximenes, FA and Gardner, WD (2007), Developing a carbon stocks and flows model for Australian wood products. *Australian Forestry*, Vol. 70, No.2, pp. 108-119.

Richardson S, Haworth D, Overton I and Pritchard, J (2007), *Summary of floodplain processes and possible changes to groundwater conditions and salt loads associated with floodplain flow options*, prepared for the Mallee Catchment Management Authority.

Roberts, J (2004), *Floodplain Forest and Woodlands in the Southern Murray-Darling Basin*, a report prepared for the Australia Conservation Foundation.

Roberts, J and Marston, F, (2000), *Water regime of wetland and floodplain plants in the Murray-Darling Basin – a source book of ecological knowledge*, CSIRO Land & Water Technical Report 30/00.

Robertson, AI (1997), 'Land-water linkages in floodplain river systems: The influence of domestic stock', in Klomp, N and Lunt, I (eds), *Frontiers in Ecology: Building the Links*, Elsevier Scientific, Oxford, UK, pp. 207–18.

Robertson, AI (1998), 'The effect of cattle on wetlands', in Williams, WD (ed.), *Wetlands in a Dry Land: Understanding for Management*, Environment Australia and The Land and Water Resources Research and Development Corporation, Canberra, Australia, pp. 195–204.

Rowe, M (2002), 'Current Status of Native Vegetation in the Riverina', in Kent, K, Earl, G, Mullins, B, Lunt, I and Webster, R (eds), *Native Vegetation Guide for the Riverina: notes for land managers on its management and revegetation*, Charles Sturt University, Wagga Wagga.

Rowley, I and Chapman, G (1991), *The breeding biology, food, social organisation, demography and conservation of the Major Mitchell or Pink Cockatoo, Cacatua leadbeateri, on the margin of the Western Australian wheatbelt*, Australian Journal of Zoology, Vol. 39, pp.211–261.

Rutherfurd, ID (1990), '*Ancient river, young nation*', (edited by Mackay, N. and Eastburn, D.), The Murray, MDBC, Canberra, ACT, pp. 17–36.

Salient Solutions (2007), *Assessment of salinity impacts of enhanced flooding in the Koondrook Perricoota Forest on the Wakool and Murray Rivers*, prepared by Salient Solutions for the NSW Department of Natural Resources.

Salient Solutions (2008), *Koondrook Perricoota Forest Shallow Drilling Completion Report*, prepared by Salient Solutions for the NSW Department of Water and Energy.

Saunders, DA, Smith, GT and Rowley, I (1982), *The availability and dimensions of tree hollows that provide nest sites for cockatoos (Psittaciformes) in Western Australia*, Australian Wildlife Research, Vol. 9, pp. 541–556.

Scott, A (1997), *Relationships Between Waterbird Ecology and River Flows in the Murray-Darling Basin*. CSIRO Land and Water, Technical Report No. 5/97, June 1997.

Scott, J (2006), *Murray Riverina Private Forestry (MRPF)*; *Murray Riverina Development Committee (PFDC)*. In: 'Murray Regional Development Board Annual Report 2005–2006'. Murray Regional Development Board, Albury, p.8, available online at http://www.murraynow.com.au/home/_download/annrep2005-06.pdf.

Scotts, D and Drielsma, M (2003), *Developing landscape frameworks for regional conservation planning: an approach integrating fauna spatial distributions and ecological principles*. Pacific Conservation Biology, Vol. 8, No.4, pp. 233–254.

SEACI (2009), *Global warming linked to rainfall decline in south-east Australia* (Media Release). South Eastern Australian Climate Initiative, 1 May 2009.

Simpson, K and Day, N (2004), *Field Guide to the Birds of Australia*, 7th edition, Princeton University Press.

Sinclair Knight Merz (2001), *Environmental Water Requirements of Groundwater Dependent Ecosystems. Environmental Flows Initiative*, Technical Report Number 2, Commonwealth of Australia, Canberra.

Sinclair Knight Merz (2009), *Water Balance Study for Murrumbidgee River*, Draft Report in preparation for NSW State Water.

Smith, AP and Lindenmayer, D (1988), *Tree hollow requirements of leadbeater's possum and other possums and gliders in timber production ash forests of the Victorian central highlands*. *Australian Wildlife Research*, Vol. 15, pp. 347–362.

Smith, AP Andrews, SP and Moore, DM (1994), '*Terrestrial fauna of the Casino and Grafton State Forest Management Areas – descriptions and assessment of forestry impacts Northern Region State Forests of New South Wales, Casino Management Area EIS supporting document no. 6*.', Forestry Commission of New South Wales, Coffs Harbour.

Soderquist, T (1993), *Survey Methods for Tuans in Southeast New South Wales*, Unpublished report to the Forestry Commission of New South Wales.

Soderquist, T (1995), *Brush-tailed Phascogale tapoatafa*, In: 'The Mammals of Australia' (edited by Strahan, R.), Reed Books, Chatswood.

Soderquist, T, Lumsden, L and Bennett, A (1999), Size does matter…Large old trees in box-ironbark forests. *Wildlife in Box-Ironbark Forests Information Kit*, Department of Natural Resources and Environment, Heidelberg.

State Forests of NSW (1999a), *Managing Our Forests Sustainably*, Forest Management Zoning in NSW State Forests Operational Circular 99/10.

State Library of NSW (2008), *Public Libraries in NSW: Directory 2008*, available online at http://www.sl.nsw.gov.au/services/public_libraries/docs/pl_directory_08.pdf.

Stephens, N, Wood, M, Allison, B and Howell, C (2002), 'Farmer and landowner contributions to Australia's commercial plantations', paper to 2002 Fenner Conference on the Environment, Australian Academy of Science, Canberra.

Stern, H, de Hoedt, G and Ernst, J (2000), *Objective Classification of Australian Climates*, Bureau of Meteorology, Melbourne.

Stott, P (1994), *Climate change and its implications for the terrestrial vertebrate fauna*, *Trans. Roy. Soc. SA*, Vol. 118, pp. 59–68.

Strahan, R (1995), *The Mammals of Australia*. Reed Books, Sydney.

Sutherland, L, Lunt, I and Mullins, B (2004), *Regrowth Management for Biodiversity: a Review of the Ecological Effects of Thinning Dense Regrowth Stands in Woodlands and Forests of South East Australia*, State Forests of New South Wales, Riverina Region, Johnstone Centre, Research In Natural Resources and Society, Environmental Consultancy, Report No. 42.

Teese, N and Wright, L (2000), *The Barmah Forest In Our Blood*.

Thackway, R and Cresswell ID (1995), *An Interim Biogeographical Regionalisation for Australia: a Framework for Setting Priorities in the National Reserves System Cooperative Program*. Australian Nature Conservation Agency, Canberra, ACT.

Thorburn PJ, Hatton TJ and Walker, GR (1993), *Combining measurements of transpiration and stable isotopes to determine groundwater discharge from forests*. *Journal of Hydrology*, Vol. 150, pp. 563–587.

Tindale, NB (1974), *Aboriginal Tribes of Australia*. University of California Press, Berkeley, LA. Available online at http://www.aboriginaleducation.sa.edu.au/files/pages/aboriginal_aust/ab_aust_south_east.pdf.

TLM (2008), *The Living Murray – Works and Water Modelling, Stage 2 Draft Report*, Unpublished, 13 October 2008.

Tourism NSW (2009a), *Travel to the Murray (Year Ending March 2009)*, available online at http://corporate.tourism.nsw.gov.au/Sites/SiteID6/objLib18/The%20Murray%20YE%20Mar%2009.pdf.

Tourism NSW (2009b), *Travel to Riverina (Year Ending March 2009)*, available online at http://corporate.tourism.nsw.gov.au/Sites/SiteID6/objLib18/Riverina%20YE%20Mar%2009.pdf.

Tourism NSW (2009c), *Travel to Outback NSW (Year Ending March 2009)*, available online at http://corporate.tourism.nsw.gov.au/Outback_NSW_p919.aspx.

Tourism Research Australia (2008a), *Tourism Profile for Balranald Shire*. Available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/NSW/Balranald%20LGA.pdf.

Tourism Research Australia (2008b), *Tourism Profile for Murray Shire*, available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/NSW/Murray%20LGA.pdf.

Tourism Research Australia (2008c), *Tourism Profile for District of Deniliquin*, available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/NSW/Deniliquin%20LGA.pdf.

Tourism Research Australia (2008d), *Tourism Profile for Wakool Shire*, available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/NSW/Wakool%20LGA.pdf.

Tourism Research Australia (2008e), *Tourism Profile for Gannawarra Shire*, available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/VIC/Gannawarra%20LGA.pdf.

Tourism Research Australia (2008f), *Tourism Profile for Mildura*, available online at http://www.tra.australia.com/content/documents/LGA%20Profiles/VIC/MilduraRural%20LGA.pdf.

Traill, B (1991), *Box-ironbark forests: tree hollows, wildlife and management*. In 'Conservation of Australia's forest fauna' (edited by Lunney, D.), Royal Zoological Society of New South Wales, Sydney, pp.119–124.

Turner, R and Kathuria, A (2008), *Forest health assessment with satellite multi-spectral imagery in the Gunbower-Koondrook-Perricoota Icon Site (GKPIS)*, Forests NSW.

URS (2001) *NSW Red Gum Timber Industry and State Forests Options*, Report prepared for State Forests of NSW, June 2001.

URS (2008), *Groundwater Status Report 2000–2005 – Technical Report*, prepared by URS Australia for the Murray-Darling Basin Commission, Canberra.

VEAC (2006), *River Red Gum Forests Investigation*, Discussion Paper, Victorian Environment Assessment Council.

VEAC (2008), *River Red Gum Forests Investigation*, Final Report, Victorian Environment Assessment Council.

Walker, B and Salt, D (2006), *Resilience Thinking – sustaining ecosystems and people in a changing world*. Island Press, Washington, DC, p. 192.

Walker, BH, Abel, N Anderies, JM and Ryan, P (2009), *Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia*. *Ecology and Society*, Vol. 14, No. 1, p.12.

Wallin, DO, Swanson, FJ, Marks, B, Cissel, JH and Kertis, J (1996), *Comparison of managed and pre-settlement landscape dynamics in forests of the Pacific North-West, USA*. *Forest Ecology and Management*, Vol. 85, pp.291–309.

Ward, N (2008), *Effective Indigenous Involvement in the Living Murray – Introducing A New Methodology*, available online at http://www.riversymposium.com/index.php?element=WARD

Water Technology (2009), *Barmah-Millewa Hydrodynamic Modelling. Model Re-calibration*, report by Water Technology for the Goulburn Broken Catchment Management Authority.

Webb, SG (1984), *Intensification, Population and Social Change in South-Eastern Australia: The skeletal evidence*. Aboriginal History, Vol. 8, pp.154–172.

Webster, R (1988), *The Superb Parrot. A survey of the breeding distribution and habitat requirements*, Australian National Parks and Wildlife Service, Report Series No. 12.

Webster, R (1991), *The Biology and Management of the Regent Parrot (*Polytelis anthopeplus*) in New South Wales*, NSW National Parks & Wildlife Service, Sydney.

Webster, R and Ahern, L (1992), *Management for Conservation of the Superb Parrot (*Polytelis swainsonii*) in NSW and Victoria*, NSW National Parks and Wildlife Service and Victorian Department of Conservation and Natural Resources.

Webster, R, Belcher, C and Leslie, D (2003), *A survey for threatened fauna in south western New South Wales*. *Australia Zoologist*, Vol. 32, No. 2, pp. 214–228.

Wentworth Group of Concerned Scientists (2008), *Senate Submission: The Urgent Provision of Water to the Coorong and Lower Lakes, September 2008*, available online at http://www.wentworthgroup.org/blueprints/441.

Wentworth Group of Concerned Scientists (2009), *Optimising Carbon in the Australian Landscape*, available online at http://www.wentworthgroup.org/docs/1270%20Optimising_Terrestial_Carbon-9bfinal.pdf.

Wilkes, J (1982), *Pattern and process of heartrot in Eucalyptus microcorys*. *Australian Forestry*, Vol. 45, pp.51–56.

Williams, AAJ, Karoly, DJ and Tapper, N (2001), *The sensitivity of Australian fire danger to climate change*, *Climatic Change*, Vol. 49, pp.171–91.

Williams, SE, Bolitho, EE and Fox, S (2003), *Climate change in Australian tropical rainforests: an impending environmental catastrophe*, Proc. R. Soc. Lond. B., Vol. 270, pp.1887–1892.

Wormington, KR, Lamb, D, McCallum, HI and Moloney, DJ (2003), *The characteristics of six species of living hollow-bearing trees and their importance for arboreal marsupials in the dry sclerophyll forests of southeast Queensland, Australia*. *Forest Ecology and Management*, Vol. 182, pp. 75–92.

WSC (2009), *Continuous low Flow in Wakool River System – John Williams Urges Government*, Wakool Shire Council, Moulamein, 13 May 2009.

Ximenes, FA, Gardner, WD and Kathuria, A (2008), Proportion of above-ground biomass in commercial logs and residues following the harvest of five commercial forest species in Australia. *Forest Ecology and Management*, Vol. 256, pp. 335-346.

Yarkuwa Indigenous Knowledge Aboriginal Corporation (2009), Submission to Natural Resources Commission, available online at http://www.nrc.nsw.gov.au/content/documents/Forest%20assessment%20-%20Submission%20-%20Red%20gum%20PAR%20-%20Yarkuwa%20Indigenous%20Knowledge%20Centre%20Aboriginal%20Corporation.pdf.

Yates, CJ and Hobbs, RJ (1997), *Temperate eucalypt woodlands: a review of their status, processes threatening their persistence and techniques for restoration*. *Australian Journal of Botany*, Vol.45, pp. 949–973.

Young, M and McColl, J (2008), *A future-proofed Basin*, The University of Adelaide.

Appendix 4

Tables, figures and boxes

List of tables

List of figures

Appendix 5

Acronyms and glossary

List of acronyms

ABC	Australian Broadcasting Corporation
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AGS	Australian Group Selection
AHIMS	Aboriginal Heritage Information Management System
ANCA	Australian Nature Conservation Agency
BOM	Bureau of Meteorology
CAMBA	China–Australia Migratory Bird Agreement
CAP	Catchment Action Plan
CAR	Comprehensive Adequate and Representative
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Australian Government Department of Agriculture Fisheries and Forestry
DECC	Former NSW Government Department of Environment and Climate Change
DECCW	NSW Department of Environment, Climate Change and Water
DEWHA	Australian Government Department of Environment, Water, Heritage and the Arts
DII	NSW Department of Industry and Investment
DPC	NSW Department of Premier and Cabinet
DLWC	Former NSW Department of Land and Water Conservation
DSE	Victorian Department of Sustainability and Environment (Victoria)
DWE	Former NSW Department of Water and Energy
ECD	Ecological Character Description
EEC	Endangered Ecological Community
EIS	Environment impact statement
EIA	Environment Impact Assessment
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
ENSO	El Niño Southern Oscillation
ESFM	Ecologically Sustainable Forest Management
EVC	Ecological Vegetation Class
EWA	Environmental Water Allowance
EWMP	Environmental Works Measures Program
FAMC	Forests Aboriginal Management Committee
FMZ	Forestry Management Zone
FNPE	*Forestry and National Park Estate Act 1998*
FRAMES	Forest Resource Management Evaluation System
FTE	Full-time equivalent
GDE	Groundwater dependent ecosystem
GL	Gigalitre or 1 billion litres
HQ	High quality
IBRA	Interim Biogeographic Regionalisation of Australia
IFOA	Integrated Forestry Operations Approval
ILUA	Indigenous Land Use Agreement
IPA	Indigenous Protected Area
IPCC	Intergovernmental Panel on Climate Change
IU	Improved Utilisation
IUCN	International Union for the Conservation of Nature
JAMBA	Japan–Australia Migratory Bird Agreement
JANIS	Joint ANZECC National Forest Policy Statement Implementation Sub-Committee
LALC	Local Aboriginal Land Council
LGA	Local Government Area
LPMA	NSW Land and Property Management Authority
MA	Management area
MDB	Murray-Darling Basin
MDBA	Former Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Management Committee
MDBSY	Murray-Darling Basin Sustainable Yields projects
MLDRIN	Murray Lower Darling Rivers Indigenous Nations
NES	National environmental significance
NGO	Non-government organisation
NPA	National Parks Association
NPWS	NSW National Parks and Wildlife Service
NRC	Natural Resources Commission
NRM	Natural resource management
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NSWVCA	NSW Vegetation Classification and Assessment
NWC	National Water Commission
RFA	Regional Forest Agreement between the Australian Government and a State Government
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SEACI	South Eastern Australian Climate Initiative
SLATS	State Landcare and Trees Study
STS	Single Tree Selection
TLM	The Living Murray
TSC	*Threatened Species Conservation Act 1995*
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
VEAC	Victorian Environmental Assessment Council
VCA	Vegetation Classification Assessment
VIC	Victoria
WMA	Water management area
WMU	Water management unit
WSC	Wakool Shire Council
WSP	Water Sharing Plan

Glossary

Term	Description
Adaptive management	A systematic and iterative process for decision-making that focuses on learning-by-doing.
Alluvial fan	A fan-shaped deposit formed where a fast-flowing stream flattens, slows, and spreads onto a flatter plain.
Alluvium	Soil or sediments deposited by a river or other running water.
Anabranch	A secondary channel of a river or stream that leaves the main stream and rejoins it downstream.
Apiary	Beekeeping operations.
Arboreal	An animal which spends most if not all of its life in trees.
Australian Group Selection	A silvicultural practice where specific regeneration gaps are created within forest stands.
Benchmark vegetation condition	A term which commonly refers to the condition of an undisturbed or minimally disturbed patch of vegetation.
Billabong	A small lake or a section of still water adjacent to a river, cut off by a change in the watercourse. Billabongs are usually formed when the path of a creek or river changes, leaving the former branch with a dead end.
Bioclimate	A small-scale climatic condition generated by living organisms.
Biodiversity	The variety of all life forms: different plants, animals and microorganisms, the genes they contain and the ecosystems in which they live.
Bioregion	A broad-scale unit that captures large, geographically distinct areas of land with common characteristics such as geology, landform patterns, climate, ecological features and plant and animal communities. The bioregions are described in the Interim Biogeographic Regionalisation for Australia (IBRA) framework. See http://www.environment.gov.au/parks/nrs/science/bioregion-framework/index.html
Biotic resources	Renewable resources such as plant biomass.
Calcareous	Mostly or partly composed of calcium carbonate, that is, containing lime or being chalky.
Carbon footprint	A measure of the impact activities have on the environment, in particular climate change. Relates to the amount of greenhouse gases produced by an activity through burning fossil fuels for electricity, heating and transportation etc.
Carbon sequestration	Storage of carbon dioxide to prevent its release into the atmosphere where it contributes to global warming.
Climate change	Any change in climate over time (generally considered to be as a result of human activity).
Coarse woody debris	Fallen dead trees and the remains of large branches on the ground in forests.
Comprehensive, Adequate and Representative	Principles for the establishment a national reserve system. Comprehensive: being a network of forest parks protecting the full range of native forest communities found within the state. Adequate: being a reserve system large enough to protect the cast range of forest dwelling plants. Representative: being a reserve system including all natural varieties within each forest type or species.
Coppice	A thicket or dense growth of stems, small trees, or bushes from a stump.
Ecological burning	A form of prescribed burning. Treatment with fire of vegetation in nominated areas to achieve specified ecological objectives.
Ecological community	An assemblage of two or more populations of different species occupying the same geographical area.
Ecologically sustainable development	Development which aims to meet the needs of current populations, while conserving ecosystems for the benefit of future generations.
Ecological thinning	Where the primary aim of forest thinning is to increase growth of selected trees, favouring development of wildlife habitat (such as hollows) rather than focusing on increased timber yields.
Ecosystem	The combined physical and biological components of an environment. An ecosystem is generally an area within the natural environment in which physical (abiotic) factors of the environment, function together along with interdependent (biotic) organisms, within the same habitat. Ecosystems can be permanent or temporary.
Ecosystem productivity	The ability of an ecosystem to produce, grow or yield products – whether trees, shrubs or other organisms.

Term	Description
Ecosystem services	Benefits people obtain from ecosystems, including provisioning services such as food, water, timber, and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling.
Ecotone	A transition area between two adjacent but different plant communities.
El Niño	Extensive warming of the central and eastern tropical Pacific Ocean, which leads to a major shift in weather patterns across the Pacific. Generally this occurs every three to eight years and is associated with drier conditions in eastern Australia.
El Niño Southern Oscillation	The oscillation between the El Niño and La Niña (or opposite) phases.
Environmental water	An amount of water allocated to the environment under an environmental entitlement.
Environmental stewardship	A concept that people have a duty to manage and care for the whole natural environment and are responsible for the continued health of the whole ecosystem. It involves integrating and applying environmental values into a process.
Ephemeral stream	Stream that flows for only short periods and then dries up.
Floodplain	Flat land besides a river that is inundated when the river overflows its banks during a flood.
Forest condition	The capacity of a forest stand to support the key elements of ecosystem function that operate in and underpin a reference stand. Condition takes into account forest health, but also includes structural and floristic changes to the forest arising from human activities such as continuous grazing, inappropriate use of fire and logging.
Forest health	Relates to the vigour of the tree canopy, where poor health is denoted by canopy dieback relating to stress factors such as drought, insects, disease, or soil chemical imbalance.
Forest Management Zone	Identifies significant environmental assets and directs how these should be managed.
Functional corridors	A linkage between resource habitats of a species consisting of landscape structures that are different from the matrix, resulting in a favourable effect on the exchange of propagules (individuals seeds genes) of the species.
Geomorphology	The study of the arrangement and form of the Earth's crust and the relationship between these physical features and the geologic structures beneath.
Geosequestration	The storage of carbon dioxide in underground geological formations.
Groundwater-dependent ecosystems	Ecosystems that use groundwater as part of survival, and can potentially include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps.
Habitat	A place or environment in which an organism naturally occurs.
Habitat connectivity	The provision of habitat islands or micro-refuges across which biota can move across variegated landscapes. It is a key feature of natural environments.
Herbivorous	Herbivory is a form of predation in which an organism consumes principally autotrophs such as plants, algae and photosynthesizing bacteria.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust.
Hydrology	The science that deals with surface and groundwater – their occurrence, circulation and distribution, their chemical and physical properties and their reaction with the environment.
Improved utilisation logging/harvesting	Designed to remove a high proportion of the remaining mature to over-mature trees by logging or ringbarking and also thinning the regrowth.
Integrated Forestry Operations Approval	Describes the forestry operations and area to which a Forest Agreement applies. It may contain the terms of relevant licences under the *Protection of the Environment Operations Act 1997*, the *Threatened Species Conservation Act 1995* and the *Fisheries Management Act 1994*. The approval may also contain other relevant conditions. It is granted by the Ministers for the Environment, for Planning, for Forestry and, where necessary, the Minister for Fisheries.
Inundation	To cover with water, usually by the process of flooding.
JANIS criteria	The criteria for achieving the principles of comprehensiveness, adequacy and representativeness in Australia's reserve system developed by the Commonwealth and state governments.

Term	Description
Lagoon	A body of comparatively shallow salt or brackish water separated from a deeper waterbody by a shallow or exposed sandbank, reef or similar feature.
Landscape	Comprises the visible features of an area of land, including physical elements such as landforms, living elements of flora and fauna, abstract elements like lighting and weather conditions, and human elements like human activity and the built environment.
Lunette	Crescent or semi-circular shaped aeolin deposits of fine sediment located on the eastern (or lee) side of lake beds in semi-arid areas.
National Water Initiative	An initiative of the Council of Australian Governments that aims to achieve a nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use by optimising economic, social and environmental outcomes.
NSW Forest Agreements	Formal agreements between the NSW Minister for Environment and Climate Change, and the Minister for Primary Industries setting out how forests in particular regions will be managed as part of the NSW reserve system or as State Forests.
Overstorey	The upper level of the forest created by the crowns of trees or shrubs.
Phenological	Of or pertaining to phenology the study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate.
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity, and rate of spread required to attain planned resource management objectives.
Quaternary period	The youngest of three periods of the Cenozoic era in the geologic time scale. It follows the Neogene period, spanning from approximately 2.588 million years ago to the present. The Quaternary includes two geologic epochs: the Pleistocene and the Holocene epochs.
Ramsar Convention	The Convention on Wetlands of International Importance is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
Ramsar site	A wetland nominated and listed on the Ramsar List of Wetlands of International Importance.
Regional Forest Agreements	20-year plans for the conservation and sustainable management of Australia's native forests to provide certainty for forest-based industries, forest-dependent communities and conservation.
Remnant vegetation	Vegetation remaining after an area has been cleared or modified.
Resilience	A measure of a system's capacity to cope with shocks and undergo change while retaining essentially the same structure and function.
Ringbarking	A process of completely removing a strip of bark around a tree's outer circumference, causing its death.
River catchment	The area of land drained by a creek or river system, or a place set aside for collecting water which runs off the surface of the land.
Riverina bioregion	The Riverina bioregion lies in south-west NSW, extending into central-north Victoria. It is approximately 9,576,964 hectares and extends from Ivanhoe in the Murray Darling Depression bioregion south to Bendigo, and from Narrandera in the east to Balranald in the west. Within its boundaries lie the towns of Hay, Coleambally, Deniliquin, Leeton, Mossgiel, Hillston, Booligal and Wentworth, while Griffith, Ivanhoe, Narrandera and Albury lie just outside its boundary in neighbouring bioregions.
River red gum	A tree of the genus *Eucalyptus Camaldulensis*. It is one of around 800 in the genus. It is a plantation species in many parts of the world but is native to Australia where it is widespread, especially beside inland water courses.
Refugia	A refugium is a biological community or geographic entity, which, because of its moderating structural characteristics and/or physical isolation, provides a sanctuary to which species or groups of species have retreated or been confined in response to threatening processes, including climatic change.
Semi-arid	A climatic region that receives low annual rainfall (200–500 mm).
Senescence	Biological changes related to aging, with special emphasis on plant, animal, and clinical observations which may apply to humans.

Term	Description
Silviculture	The art and science of controlling the establishment, growth, composition, health, and quality of forests to meet diverse needs and values of the many landowners, societies and cultures.
Stand	A group of trees in a forest that can be distinguished from other groups by their age, species composition and condition.
Tenure	A broad concept that includes ownership, tenancy and other arrangements for the use of forests.
Thinning	Cutting down and removal of a proportion of trees in a forest to provide more growing space for the remaining trees, which leads to an increase in volume of individual trees.
Threatened species	Native plants and animals in danger of becoming extinct.
Understorey	The layer of vegetation that grows below the canopy formed by the tallest trees in the forest.
Vegetation classes	Groupings of vegetation communities based on floristic, structural and ecological features.
Vegetation mosaic	The pattern of different plant communities, or stages of the same community – the term is applied particularly to communities that show cyclical change, with examples of all stages being present together in a typically extensive and well-developed community.
Viticulture	The specific branch of agriculture relating to the raising of grapes and grape vines.
Water management unit	Relatively discrete geographical areas that have varying restrictions on flow delivery and manipulation, and have stands of high-value forest.
Western Lands Lease	A contract for sustainable land management in the Western Division of NSW, under the *Western Lands Act 1901*.

Appendix 6

Communication and consultation

Communication and consultation

The NRC's communication and consultation on the river red gum forest assessment included meetings with a cross-section of interested parties, inviting written and verbal submissions, tours of the Riverina bioregion in the company of stakeholders, media releases, information updates and public forums – three in the bioregion and one in Sydney. The NRC communicated and consulted on the process for assessment as widely as possible, given the timeframe of the assessment.

The NSW Government provided the Terms of Reference for the assessment on 12 August 2009 and two days later we circulated a 'Notice of Assessment' to forestry industry representatives, relevant government agencies and their Ministers, and posted it on the NRC's website.

The Notice of Assessment outlined the timeline, scope and process for the assessment, included the Terms of Reference and invited people to register their interest in the NRC's forest assessment. Individuals and organisations who registered were kept informed of the progress of the assessment through regular updates that were sent electronically and posted on our website. Updates were sent on 4 September, 18 September, 9 October and 6 November 2009.

Table A6.1 shows the timeline for consultation and communication.

We also sent out media releases to announce the receipt of the Terms of Reference from the Premier and to announce the release of the preliminary assessment report.

We invited public submissions through our website – first on the Terms of Reference in August 2009 and then on the preliminary assessment report in September 2009. The NRC received 5,534 submissions, of which 259 were unique and the remainder were form letters or emails.

The NRC reviewed and considered every submission during the preparation of this final assessment report and the recommendations report. Individuals, interest groups and organisations representing a broad cross-section of the community made submissions to the assessment. Several submissions provided detailed information including technical reports to support opinions or proposals.

To better understand the issues facing the river red gum forests in the bioregion and the communities which rely on them, the NRC visited the region nine times and visited 50 State Forests between August and November 2009. **Figure A6.1** shows the areas visited by the NRC.

Table A6.1: Timeline for consultation and communication

12 August 2009	Government provides Terms of Reference
14 August 2009	NRC issues Notice of Assessment
20 – 22 August 2009	Regional tour (Deniliquin)
28 August 2009	Public submissions close on Terms of Reference
4 September 2009	Information Update 1
10 – 15 September 2009	Regional tour (Deniliquin/Balranald)
18 September 2009	Information Update 2
30 September 2009	Preliminary Assessment Report to Government
9 October 2009	Information Update 3
19 – 22 October 2009	Regional tour (Albury/Deniliquin) including workshops
23 October 2009	Public submissions close on Preliminary Assessment Report
26 October 2009	Balranald public forum
27 October 2009	Barham public forum
28 October 2009	Denliquin public forum including workshop
2 November 2009	Sydney public forum
6 November 2009	Information Update 4
21 December 2009	Final Assessment Report to Government

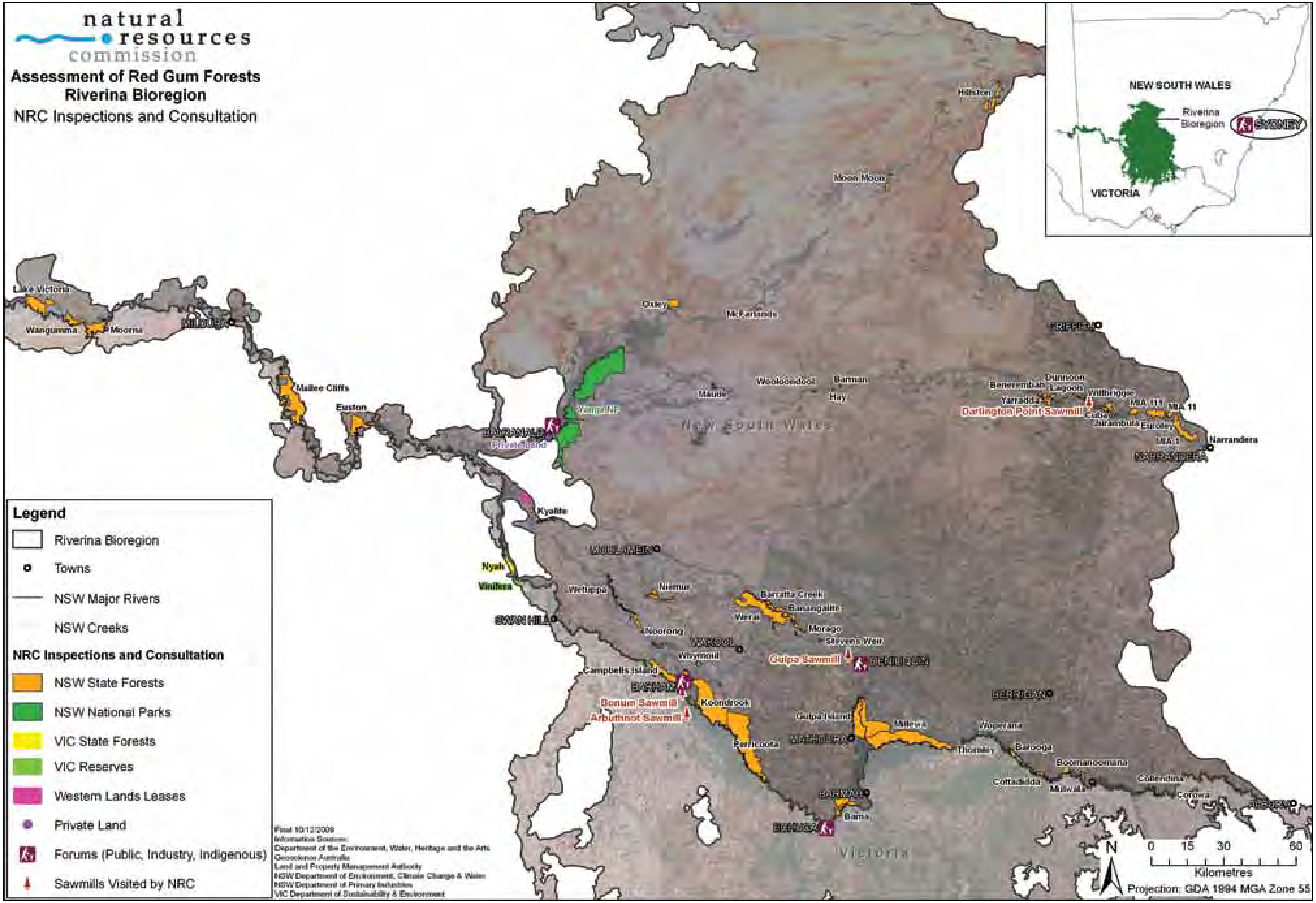


Figure A6.1: NRC inspections and consultation

The local Indigenous communities, forest industries, local government, state agencies and community representatives generously gave their time and expertise to help the NRC understand the issues concerning the river red gum forests. The NRC:

- observed silvicultural practices, and mill operations, including timber processing for high-value timber veneers
- met with Indigenous people, who shared their stories and history
- visited sites of environmental and cultural significance and observed the close connections between the forests and the communities that rely on them
- visited Yanga National Park and saw the contrast of healthy river red gum forests with non-flooded areas of drought-stressed trees
- visited interpretative centres on the history and heritage values of the rivers and their floodplain forests
- visited areas important for tourism and the recreation of locals.

Through these activities we were able to 'view' the forests from a diversity of perspectives. While aspirations for the forests may have differed, it was clear that everyone we consulted was concerned about the condition of the forests and wanted to see them healthy again.

Table A6.2: Organisations consulted

Organisations consulted
Government agencies
Australian Government Department of Environment, Water, Heritage and the Arts
Department of Environment, Climate Change and Water
Land and Property Management Authority
Forests NSW
Forest industry representatives
Campbell Sawmills
Darlington Point Sawmill
Forests Products Association
Merbene Sawmill
O'Brien's Sawmill
Local government
Balranald Shire Council
Berrigan Shire Council
Conargo Shire Council
Deniliquin Council
Jerilderie Shire Council
Murray Shire Council
Murrumbidgee Shire Council
Riverina and Murray Organisation of Regional Councils
Wakool Shire Council

Table A6.3: Regional consultations

Date	Event/Group consulted	Location
19 – 21 August 2009	Regional tour	
10 – 15 September 2009	Regional tour	
19 – 22 October 2009	Regional tour	
19 and 28 October 2009	Forestry Industry	
19 and 28 October 2009	Riverina and Murray Regional Organisation of Councils	
19 October 2009	Environmental groups (National Parks Association and The Wilderness Society)	
21 – 22 October 2009	Murray Lower Darling Indigenous Nations	
26 October 2009	Public forum	Balranald
27 October 2009	Public forum	Barham
28 October 2009	Public forum	Deniliquin

Table A6.4: Submissions received

Submissions on Terms of Reference – from organisations	
Arbuthnot Sawmills Pty Ltd	Murray Shire Council
Balranald Shire Council	Nambucca Valley Conservation Association
Berrigan Shire Council	National Parks Association of NSW
Bird Observation and Conservation Australia	Nature Conservation Council NSW
Bullatale Creek Landholders	North East Forest Alliance
Bullatale Creek Trust	Northern Inland Council for the Environment
Bushwalking Victoria	NSW Forest Products Association
Citizens Wildlife Corridors Armidale Inc.	NSW Red Gum Forest Action Inc.
Combined submission – Farmers, irrigators and landholders	Save Manly Dam Catchment Committee Inc.
Conargo Shire Council	South East Forest Rescue
Culpra Milli Aboriginal Corporation	The Colong Foundation for Wilderness Ltd
Cummergunja	The Friends of Eastern Otways
Ecological Surveys and Planning	The Nationals, Member for Burrinjuck
Falbrook Wildlife Refuge	The Wilderness Society Sydney
Friends of the Earth Australia	Timber Communities Australia
Hunter Community Environment Centre	Total Environment Centre Inc.
J and G Coulter Pty Ltd	Victorian National Parks Association
Lower Murray-Darling CMA	Wiringal

Table A6.4: Submissions received (cont.)

Submissions on preliminary assessment report – from organisations	
ANGAIR Inc.	National Parks Association of NSW
Australian Centre for Biodiversity	National Parks Association – Coffs Harbour and Bellingen
Australian Conservation Foundation	National Parks Association – Reserve Committee
Balranald Shire Council	National Parks Association – Three Valleys
Bird Observation and Conservation Australia	Nature Conservation Council of NSW
Bird Observation and Conservation Australia – Echuca	North Central Catchment Management Authority
Byron Environmental and Conservation Organisation	North Coast Environment Council Inc.
Campi Bulk Transport Pty Ltd	North East Forest Alliance
Canopy Native Forest Committee	Northern Beaches Greens
Central West Environment Council	Northern Inland Environment Council
Clarence Environment Centre	NSW Apiarists Association Inc.
Clarence Valley Conservation Coalition Inc.	NSW Forest Products Association
Conargo Shire Council	NSW Red Gum Forest Action Inc.
Deniliquin Council	Oatley Flora and Fauna Conservation Society Inc.
Department of Agriculture, Fisheries and Forestry	Pikapene and Cherry Tree Environment Centre Inc.
Environment groups	Rainforest Information Centre
Firewood and Log Residue Working Group	Redgum Timber Producers (Australia) Pty Ltd
Friends of the Earth Australia	Riverina and Murray Regional Organisation of Councils
Friends of the Koala Committee	Rivers and Red Gum Environment Alliance
Glen Eira Environment Group	Shire of Wakool
Gulpa Sawmills Pty Ltd	South East Forest Rescue
Hay Shire Council	STEP Inc.
High Country Conservation Alliance Inc.	Terania Native Forests Action Group
Humane Society International	The Colong Foundation for Wilderness
Hunter Environment Lobby Inc.	The Habitat Advocate
Inland Rivers Network	The Institute of Foresters of Australia
Mathoura Chamber of Commerce and Citizens Inc.	The Nationals
Mudgee District Environment Group	The Wilderness Society Sydney
Murray Catchment Management Authority	Victorian Apiarists Association Inc.
Murray-Darling Basin Authority	Wingham Forest Action
Murray Lower Darling Rivers Indigenous Nations	Wombat Forestcare Inc.
Murrumbidgee Field Naturalists	Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation
Nambucca Valley Conservation Association Inc.	

Appendix 7

Technical review panel members

Technical Review Panel member	Title and organisation
Professor Andy Bennett	Head of School, School of Life and Environmental Sciences Deakin University
Ms Di Bentley	Natural Resources Commission
Mr Ian Burns/Mr Michael Jones	Director, Environmental Works and Measures Program Murray-Darling Basin Authority
Associate Professor Leon Bren	Department of Forest and Ecosystem Science University of Melbourne
Dr Matthew Colloff	Project Leader Floodplain Ecosystem Function Commonwealth Scientific and Industrial Research Organisation
Dr Michael Harris	Senior Lecturer and Discipline Leader Faculty of Agriculture Food and Natural Resources The University of Sydney
Emeritus Professor Barry Hart	Water Studies Centre Monash University
Professor Terry Hillman	Adjunct Professor La Trobe University
Professor Peter Kanowski (Chair)	Fenner School of Environment and Society The Australian National University
Dr Glen Kile	Director Plant Health Australia
Dr Ian Lunt	Senior Lecturer School of Environmental Sciences Charles Sturt University
Dr Brian Walker	CSIRO Research Fellow Resilience Alliance Program Director and Chair of Board
Dr David Williams	Senior Lecturer in Vegetation Science Institute for Applied Ecology University of Canberra

Appendix 8

Indigenous Engagement Process Report

Murray Lower Darling Rivers Indigenous Nations

Report for the
Natural Resources Commission of NSW
Riverina Bioregion Regional Forest Assessment
River Red Gums and Woodland Forests

INDIGENOUS ENGAGEMENT PROCESS REPORT

NOVEMBER 2009

Prepared by:

Steven Ross
steven.ross@mldrin.org.au
Phone: 02 6051 9948
Mobile: 0428292506

Contents

Murray and Lower Darling Rivers Indigenous Nations and the Natural Resource Commission of NSW
Riverina Bioregion Regional Forest Assessment
River Redgum and Woodland Forest Assessment
Indigenous Engagement Process

Background

Murray Lower Darling Rivers Indigenous Nations

As a confederation of 10 traditional owner groups along the Murray and Lower Darling Rivers, the Murray Lower Darling Rivers Indigenous Nations (MLDRIN) has the responsibility to facilitate processes that reflect the holistic and cooperative nature of Indigenous relationships along these vital eco-systems including the forests.

The MLDRIN principles of Caring for Country are:

- Healthy, clean and alive;
- Restocked and re-vegetated;
- Free flowing with natural cycles;
- Access rights for Indigenous people so they can move freely to continue cultural practice;
- Traditional fishing/hunting;
- Indigenous people and Nations recognised and respected for what and who we are;
- The rivers and tributaries are respected and cared for;
- Indigenous Nations recognised as sovereign entities in their own country; and
- The Forests must be appropriately watered including water allocations for a cultural purpose.

With these principles in mind a meeting with was held with relevant traditional owners and the NRC on 21 October 2009 at Deniliquin.

Natural Resources Commission of NSW

The Natural Resources Commission of NSW (NRC) has carriage of the assessment into Riverina Redgum and Woodland Forests. As part of its terms of reference:

> *"The Commission should also consult with relevant Traditional Owners, Local Aboriginal Land Councils, Elders groups and local government".*

MLDRIN initially approached the NRC to run an Indigenous engagement similar to that undertaken for the Redgum investigation by the Victorian Environmental Assessment Council (VEAC) in 2006-2008.

MLDRIN's role in the proposal was to:

- Disseminate information on the NRC assessment process;
- Facilitate the relationship between the NRC and the relevant Indigenous parties;
- Organise meetings of and between the parties ;
- Develop templates for responses by the parties and assist in submissions;
- Gather relevant information such as cultural sites mapping and other hard data;
- Source and provide technical and expert knowledge on the bio-region and key issues
- Provide information on different forms of land tenure; and
- Any other tasks deemed necessary by the parties.

It was also offered to extend the engagement process beyond traditional owners to include land councils and other indigenous organisations within the bio-region study area.

Due to limited time and resources the NRC and MLDRIN agreed to a more focused engagement process that would still engage relevant traditional owners and endeavor to capture their history, connections, concerns, issues, interests and aspirations in these significant forest areas.

Facilitator

MLDRIN and the NRC agreed to employ the services of an independent facilitator. It was agreed to engage Tony McAvoy, an Indigenous barrister from Sydney. Tony has experience in Native Title negotiations and the establishment of joint management and agreement making throughout Australia.

Tony has also working extensively with MLDRIN including facilitating joint management workshops, water engagement process and drafting of MLDRIN's *Echuca Declaration on Cultural Flows*.

Themes and messages from the Engagement Meeting

- Ancient relationship and affinity traditional owners have with land and waters and these forests in particular;
- Ongoing and contemporary connection including exploitation by traditional owners within the forests including hunting, collection of native foods and cultural activities;
- A recognition of inherent rights of traditional owners needs to occur;
- Illustration of ecological devastation and associated the effects cultural livelihoods of traditional owners;
- The cultural character, as well as the ecological character of these forests must be understood by non-Indigenous peoples;
- Cultural heritage must be protected, including improved access to and management of cultural sites;
- Emerging environmental issues such as mining and climate change will have further adverse impacts on traditional owners;
- Engagement should use informed consent principles;
- There is a history of lack of engagement with traditional owners for example with Forests NSW;
- Access into these forests, wetlands and the Rivers and waterways is an important issue;
- A change of tenure, protected by legislation is need to protect the forests;
- Water, including cultural flows must be included in the final recommendations;
- Economic development including jobs creation for Indigenous peoples must be considered;
- International obligations such as Ramsar should be adhered to;
- Access and benefit sharing and intellectual property should be considered;
- Strategic alignment between the NRC assessment and other processes such as the Murray Darling Basin Authority Basin Plan, needs to occur; and
- The need for a process beyond the final report to ensure appropriate and legitimate Indigenous involvement in whatever land tenure changes are recommended.

Outputs and Outcomes

The NRC, MLDRIN and most importantly traditional owners have seen the following outputs and outcomes:

- The NRC received 3 submissions from traditional owner groups and/organizations representing traditional owners – Yorta Yorta, Yarkuwa Indigenous Knowledge Centre and MLDRIN;
- The NRC also received individual submissions from Jimmy Ingram, Stewart Taylor and Neville Williams;
- There has been a definite increase in the knowledge of the NRC assessment within traditional owner groups;
- A greater understanding of NRC processes including constraints, limits and expectations;
- A greater awareness of the cultural, social, economic rights of indigenous peoples within these forests;
- A greater understanding of the diversity of opinion and aspirations within traditional owner groups;
- Improved relationships between NRC, MLDRIN and traditional owners.

Appendices

Document 1: Notes from the Indigenous Engagement Meeting 21 October 2009

Participants

Natural Resources Commission of NSW:

John Williams, Felicity Calvert, Di Bentley.

Facilitator:

Tony McAvoy

Indigenous participants:

Fred Egan (Wamba Wamba)
Pat Moore (Wamba Wamba)
Debbie Flower (Wamba Wamba)
Ken Stewart (Wamba Wamba)
Stewart Taylor (Wamba Wamba)
Stephen Charles (Wamba Wamba)
Darren Baxter (Wamba Wamba)
Steven Ross (Wamba Wamba/MLDRIN)
Denise Morgan-Bulled (Yorta Yorta)
Marlene Taylor (Barapa Barapa)
Dawn Smith (Barapa Barapa)
Grace Smith (Barapa Barapa)
Roland Smith (Barapa Barapa)
Neville Whyman (Barapa Barapa)
Ramsay Freeman (Wirdjuri)
Jim Ingram (Wirdjuri)
Neville Williams (Wiradjuri)
Jeannie Charles (Mutthi Mutthi)
Jason Pappin (Mutthi Mutthi)
Mary Pappin (Mutthi Mutthi)
Jeanette Crew (Wamba Wamba)
Laura Ross (Wamba Wamba)
Sharnie Hamilton (Wamba Wamba)
Esther Kirby (Barapa Barapa)
Lillian Smith (Barapa Barapa)

- 30 November is the final report deadline and the NRC need a process forward beyond the final recommendations.
- Should be River Country – not "forests".
- Lachlan River
  - A lot of deforestation has occurred with no River flow.
  - Lake Cowal Gold Mine should never have proceeded.
  - No lining of toxic waste on pool – cyanide leaking pool.
- Water is the key point in the preliminary report.
- Survey areas should be put in – the percentages are really low and need to be included.
- Cultural flows needs be included in the document.
- Human remains and repatriation needs to be included.
- 5 November 2009 is a public meeting in Sydney where all are invited.
- Where are cultural flows going to be acknowledged?
- Preparation on the preliminary report – what indigenous involvement has there been? Engagement in the preliminary report was only limited in Werai and Millewa.
- It will difficult to capture the depth of feeling from the damage to these forests.
- Logging on crown land is occurring in Barham including near the River and including canoe trees.
- Anna Flanagan from NSW Forestry has been contacted about this issue. Barapa Barapa has an incorporated body and should be negotiated with.
- NSW Forestry won't talk to Barapa Barapa.
- Legislation should be changed to fully protect cultural heritage and include Indigenous interests – including rangers from the Traditional Owners.
- Freehold title should be considered for Forestry tenure.
- Photos can be taken but must come with a disclaimer that they are in no way an endorsement of NRC reports or processes.
- Contemporary value and uses – restoration of the river and NRM through CMAs.
- Jobs for young people should included as part of recommendations – more broad jobs than logging jobs.
- Should include rehabilitation work for the forests.
- Some Elders carry the burden of ring barking and destroying the environment.
- Under traditional lore the traditional owners have the inherent right to speak for country.
- Cultural flows – share of environmental allocation.
- 1. Holistic management and 2. International mechanisms including Ramsar and the Declaration on the Rights of Indigenous Peoples.
- Access to and protection of native medicines and foods should be looked at.
- Culture can be respected as a walking track.
- Intellectual property is a major issue and should rest with Traditional Owners.
- Access and Benefit sharing should also be considered.
- Haven't even got access to the Rivers.
- Permit under the *Aboriginal Land Rights Act* (section 47) gives you access to anyone's land for the purposes of cultural activity.

Action: get a copy of the forms for the meeting participants.

- We need licenses to access State Forests to hunt and practice our Traditional practices.
- Section 211 of the Native Title Act states that you do not need a permit to practice culture – claimant or holder?
- Exercising traditional rights – marine agreements.
- Interconnectedness of the marine and submerged aquatic plants and the trees.
- We want to be involved in the zoning process including those under the *Native Vegetation Act*.
- Water should not be privatized and sold overseas.
- You must have water for the trees.
- Trying to align the NRC report with the MDBA Basin-wide plan.
- Water should be allocated to traditional owners for cultural flows.

Document 2: Note from Facilitator

A L MCAVOY
BARRISTER

FREDERICK JORDAN CHAMBERS
Ground Floor, 53 Martin Place
Sydney NSW 2000
DX 450 SYDNEY
Tel: 02 92297395
Fax: 02 9221 6944
mcavoy@fjc.net.au

Re: Indigenous Engagement Session – River Red Gum Assessment – 21 October 2009, Deniliquin, NSW

I confirm that I attended at the Intercentre at Deniliquin on 21st October 2009 as facilitator for the purposes of a meeting between the NSW Natural Resources Commissioner, Mr John Williams, and the Indigenous Nations affected by the River Red Gum assessment.

It appears to me from the discussions which occurred on the day with Mr Williams, and his staff who were in attendance, that he is of the view there are significant opportunities for Indigenous people to either own or participate in management of the Crown Estate in which the remnant River Red Gum presently exists. In order to capitalise on this opportunity, it would seem to me that the Indigenous nations ought to ensure that the final report includes recommendations regarding further Indigenous engagement and development of management options and models in a detailed form.

It would appear the prospects of survival for the River Red Gum are of great concern to the NSW Government. The degree to which it will make use of Indigenous options in the solutions to this problem will, in part, be limited by the Indigenous community's ability to resolve internal disputes.

The difficulty some of the MLDRIN Nations face is that there are no tribunals for resolving boundary disputes, other than the Federal Court which can only do so in respect of competing native title applications. There are some options if the competing interests are prepared to be bound by the decision of a third party. Such solutions only work where the parties are willing to seek a resolution. I am not certain that those circumstances exist in the present disputes.

I am happy to discuss methods of resolution of the existing difficulties with you.

Document 3: Indigenous Engagement Meeting Agenda

Agenda: Wednesday 21 October 2009

9:30am	Welcome and Introduction
10:00am	Background to NRC Riverina Redgum Assessment
10:30am	Broad discussion on rights and interests in Traditional Owners in Forest Management
11:00am	*Morning Tea*
11:30am	Where to from Here?
12:30pm	*Lunch*

Split Session – 1 on 1 with Traditional Owners and NRC (John Williams or Felicity Calvert)

1:30pm	Session 1	Wiradjuri	Mutthi Mutthi
3:00pm	Session 2	Yorta Yorta	Barapa Barapa
4:30pm	Session3	Wamba Wamba	

Document 4: Submission Template

Murray Lower Darling Rivers
Indigenous Nations

Template Submission for Indigenous Nations
NSW Natural Resource Commission
Regional Assessment of River Redgum Forests in the Riverina Bio-Region

Opening Statement from Organisation's Chairperson

Points to include:

- An overall statement about the process;
- An acknowledge of other organisations that have supported your work;
- An acknowledgement of similar submissions;
- The aspirations of your people; and
- Perhaps an invitation to be involved further in the process.

Background

Points to include:

- Profile of your peoples including relevant information such as genealogical information, boundaries, maps and general or specific cultural information [this section depends largely on how much information you want to give – base this on what is already public and what your people want to state about themselves]; and
- History of your Nation's organisation including when you were incorporated, your governance arrangements and how you make decisions, your executive structure and your achievements.

Substantive Argument

Points to include:

- State clearly what land tenure you want to see for the relevant River Regum Forest in your traditional country;
- State the benefits you can see coming to your Nation from the land tenure you have chosen [this may include cultural and socio-economic benefits such as employment and other enterprise developments];
- Outline the disadvantages of not changing or changing to another form of tenure;
- Outline what process you have undertaken to reach this decision; and
- General summary and/or appendix of your submission including contact details and any supporting documents.

Document 5: Allowable Activities Table

Murray Lower Darling Rivers Indigenous Nations

SUMMARY OF MAJOR PUBLIC LAND TENURES IN NSW

Tenure	Allowable Activities	Descriptions
National Park	No logging, grazing, mining, or firewood collection allowed. Camping allowed in designated camp sites only. Fishing allowed. Hunting and gathering by Indigenous people for domestic uses (not commercial) is allowed – except for collection of threatened species or communities.	National parks are relatively large areas of land set aside to identify, protect and conserve areas containing outstanding and representative ecosystems, and natural and cultural features, while providing opportunities for sustainable visitor use and enjoyment. They are permanently reserved for conservation and public appreciation, education and recreation, and apart from essential management and visitor facilities, are preserved in their natural state.
Nature Reserve	No logging, grazing, mining, or firewood collection allowed. Recreation mostly discouraged, often no camping allowed. Hunting and gathering by Indigenous people for domestic uses (not commercial) is allowed – except for collection of threatened species or communities.	Nature reserves are protected and conserved for their unique or representative ecosystems, species, communities or other natural values. They also protect and conserve any cultural values that occur on the site. Management practices aim to maximise the value of nature reserves for appropriate scientific research and monitoring, and to promote understanding of their natural and cultural values. Due to their significant natural and cultural values, visitor use of nature reserves is often limited.
State Conservation Area	No logging, grazing or firewood collection allowed. Mineral exploration and mining are permitted. Camping allowed in designated camp sites only. Fishing allowed. Hunting and gathering by Indigenous people for domestic uses (not commercial) is allowed – except for collection of threatened species or communities.	State conservation areas are permanently reserved areas that contain significant or representative ecosystems, landforms or natural phenomena, or places of cultural significance. Provided these activities are compatible with the conservation of the area's natural and cultural values, state conservation areas can provide opportunities for sustainable visitor use and enjoyment, for the sustainable use of buildings and structures, and for appropriate research and monitoring.#
Aboriginal Area	No logging, grazing, mining or firewood collection. Camping generally allowed in designated camp-sites only. Fishing allowed. Aboriginal people may be provided with special access to Aboriginal areas for cultural purposes.	Aboriginal areas are associated with a person, event or historical theme, or contain a building, place, feature or landscape of cultural significance to Aboriginal people or that is of importance in improving public understanding of Aboriginal culture and its development and transitions. They are reserved to protect and conserve these cultural values, both from before and after European settlement, as well as natural values that are present. Aboriginal areas are also used for the promotion of public understanding and appreciation of the significance of their natural and cultural values, where appropriate.
State Forests	Logging, grazing, mining and firewood collection allowed and encouraged. Camping generally permitted almost anywhere. Fishing allowed. Public access can be restricted when logging is occurring. Access restricted to mine sites and leases. Some protection from logging provided for small areas by Flora Reserves and Special Management Zones within State Forests.	State Forests are for the exploitation of timber and mineral resources with relatively unconstrained recreational use also allowed (subject to extractive activities). There are some conditions on logging but these are generally inadequate to protect environmental or cultural values.

NB. The hunting and gathering rights of Indigenous Australians in National Parks and reserves are set down in the NSW *National Parks and Wildlife Regulation 2002* (Part 6). Regulations are not as secure as an Act of Parliament, and can be changed without opportunity for amendment by the parliament.

All forms of permanent reserve estate gazetted under the *National Parks and Wildlife Act 1974* are available for Aboriginal Ownership and joint management.

Appendix 9

Methodology for economic analysis

This appendix describes the methods that were used to undertake the economic analysis reported in **Chapter 5**.

A9.1 Industry survey

To inform the assessment and the development of the industry impact models, Arche Consulting conducted an industry survey on behalf of the NRC. The survey population was identified with the assistance of Forests NSW. Forests NSW provided a contact list of all businesses that hold base licence allocations (quota, ex-quota, residue) to access timber resources on public land (including Western Lands Leases).

A9.1.1 Survey population

Table A9.1 provides a summary of industry participation in the survey.

Some businesses hold licences for more than one type of base allocation (e.g. quota and ex-quota), more than one licence of the same allocation type, or both. Therefore the total number of businesses in the population is less than the sum of the number of businesses in each category. In total, there are 32 businesses that are licensed by Forests NSW. Of the total number of businesses, 25 (78%) were contacted to participate in the survey. Of the total number of businesses, 19 (59%) were respondents to the survey. **Table A9.2** provides a breakdown of the number of businesses by allocation held.

A9.1.2 Survey questionnaire

Two surveys were designed:

- a detailed face-to-face survey for quota holders
- a less detailed telephone survey for ex-quota and residue holders.

Both surveys collected the following information:

- business background and history
- timber sources and harvest activity
- products and markets
- revenue
- employment.

Table A9.1: Summary of industry participation in survey

	Quota	Ex-quota	Residue
Number of businesses	6	8	23
Number completed	6	6	12
Number contacted, not completed	-	1	5
Number not contacted		1*	6
% total volume completed	100	92	70
% total volume contacted, not completed	-	6	21
% total volume completed/contacted	100	98	91
% volume not contacted	-	2	9

* Contact details provided not current.

Table A9.2: Summary of businesses and survey responses for each allocation type

	All	Respondents
Number of businesses with only quota and ex-quota	4	4
Number of businesses with quota, ex-quota and residue	2	2
Number of businesses with only ex-quota	5	3
Number of businesses with only ex-quota and residue	3	2
Number of businesses with only residue	18	8
TOTAL	32	19

In addition to this data, the detailed survey of quota holders collected information relating to:

- employee age and tenure
- expenditure
- assets.

The Timber Survey Questionnaire is attached at the end of this appendix.

A9.2 Regional input-output analysis

A9.2.1 Methodology

Regional economic impact assessment is primarily concerned with the effect of an impacting agent on an economy in terms of a number of specific indicators, such as gross regional output, value-added, income and employment. These indicators can be defined as follows:

- gross regional output – the gross value of business turnover
- value-added – the difference between the gross value of business turnover and the costs of the inputs of raw materials, components and services bought in to produce the gross regional output
- income – the wages paid to employees including imputed wages for the self employed and business owners
- employment – the number of people employed (including full-time and part-time).

An impacting agent may be an existing activity within an economy or may be a change to a local economy (Jensen and West, 1986). This assessment is concerned with the impact of the existing timber industry along the Murray River reliant on the NSW river red gum timber resource.

A9.2.1.1 Selection of method

Four general methods are available for estimating direct and indirect regional economic impacts of an activity, namely economic base multipliers, regional Keynesian multipliers, econometric models and input-output models.

Input-output analysis is generally considered to be methodologically superior to the simpler techniques such as the economic base approach or the use of regional Keynesian employment multipliers. This superiority is generally considered to be attributable to the following factors (Jensen and West, 1986):

- In terms of the incidence of impact, the economic base and the Keynesian approaches normally provide impact measurement only in aggregate terms, i.e. the total impact felt by all sectors collectively. Input-output multipliers allow the analyst to examine the manner in which the total impact is distributed among the sectors of the economy. This is a reflection of the internal linkages and interdependencies in the economy which are specified in the input-output table.
- Input-output multipliers also allow the identification of the components of the multiplier; the economic base and Keynesian models do not, in their standard form, provide all of these details. The components are:

  – the initial effect, which is the stimulus for the impact analysis – normally assumed to be a dollar change in sales to final demand;

  – the first-round effect, which refers to the purchases of inputs required from other sectors in the economy in order to produce the additional output;

  – the industrial-support effect, which refers to second, third and subsequent-round industrial flow-on effects triggered by the purchases in the first round; and

  – the consumption-induced effects, which stem from the spending of household income received as payments for labour used in producing the additional output.

  – regional econometric models, including models of the general equilibrium family, were not readily available for the region or project in question, and were not considered necessary for the impact assessed in this study.

A9.2.1.2 Definition of region

The economy on which the impact is measured can range from a township to the entire nation. In selecting the appropriate economy, regard needs to be had to capturing the local expenditure and employment associated with the river red gum timber industry but not making the economy so large that the impact of the proposal becomes trivial (Powell and Chalmers, 1995).

Based on the location of mills utilising the NSW river red gum timber resource and the location of employees, the region was defined as comprising:

- Wentworth SLA, NSW;
- Balranald SLA, NSW;
- Wakool SLA, NSW;
- Murray SLA, NSW;
- Deniliquin SLA, NSW;
- Conargo SLA, NSW;
- Murrumbidgee SLA, NSW;
- Griffith SLA, NSW;
- Berrigan SLA, NSW;
- Mildura Rural City Part A – SSD, Victoria; and
- Gannawarra SLA, Victoria.

A9.2.1.3 Development of input-output table

A 2005–06 input-output table of the regional economy was developed using the Generation of Input-Output Tables (GRIT) procedure using a 2005–06 NSW input-output table (developed by Monash University) as the parent table. ABS 2006 employment data was used to develop an equivalent table at the regional level. The regional input-output table was then indexed to 2009 values. The 109 sector input-output table of the regional economy was aggregated to 30 sectors and 6 sectors for the purpose of describing the economy.

The GRIT system was designed to:

- combine the benefits of survey-based tables (accuracy and understanding of the economic structure) with those of non-survey tables (speed and low cost)
- enable the tables to be compiled from other recently compiled tables
- allow tables to be constructed for any region for which certain minimum amounts of data were available
- develop regional tables from national tables using available region-specific data
- produce tables consistent with the national tables in terms of sector classification and accounting conventions
- proceed in a number of clearly defined stages
- provide for the possibility of ready updates of the tables.

The resultant GRIT procedure has a number of well-defined steps. Of particular significance are those that involve the analyst incorporating region-specific data and information specific to the objectives of the study. The analyst has to be satisfied about the accuracy of the information used for the important sectors; in this case the river red gum sawmilling sector. The method allows the analyst to allocate available research resources to improving the data for those sectors of the economy that are most important for the study.

An important characteristic of GRIT-produced tables relates to their accuracy. In the past, survey-based tables involved gathering data for every cell in the table, thereby building up a table with considerable accuracy. A fundamental principle of the GRIT method is that not all cells in the table are equally important. Some are not important because they are of very small value and, therefore, have no possibility of having a significant effect on the estimates of multipliers and economic impacts. Others are not important because of the lack of linkages that relate to the particular sectors that are being studied. Therefore, the GRIT procedure involves determining those sectors and, in some cases, cells that are of particular significance for the analysis. These represent the main targets for the allocation of research resources in data gathering. For the remainder of the table, the aim is for it to be 'holistically' accurate (Jensen, 1980). That means a generally accurate representation of the economy is provided by the table, but does not guarantee the accuracy of any particular cell. A summary of the steps involved in the GRIT process is shown in **Table A9.3**.

Table A9.3 The GRIT Method (Bayne and West, 1988)

Phase/Step	Action
Phase I	Adjustments to national table
1	Selection of national input-output table (106-sector table with direct allocation of all imports, in basic values)
2	Adjustment of national table for updating
3	Adjustment for international trade
Phase II	Adjustments for regional imports
4	Calculation of 'non-existent' sectors
5	Calculation of remaining imports
Phase III	Definition of regional sectors
6	Insertion of disaggregated superior data
7	Aggregation of sectors
8	Insertion of aggregated superior data
Phase IV	Derivation of prototype transactions tables
9	Derivation of transactions values
10	Adjustments to complete the prototype tables
11	Derivation of inverses and multipliers for prototype tables
Phase V	Derivation of final transactions tables
12	Final superior data insertions and other adjustments
13	Derivation of final transactions tables
14	Derivation of inverses and multipliers for final tables

A9.2.1.4 Underlying assumptions and interpretation of input-output multipliers

The basic assumptions in input-output analysis include the following:

- There is a fixed input structure in each industry, described by fixed technological coefficients (evidence from comparisons between input-output tables for the same country over time have indicated that material input requirements tend to be stable and change slowly; however, requirements for primary factors of production, that is labour and capital, are probably less constant).
- All products of an industry are identical or are made in fixed proportions to each other; each industry exhibits constant returns to scale in production.
- Unlimited labour and capital are available at fixed prices; that is, any change in the demand for productive factors will not induce any change in their cost (in reality, constraints such as limited skilled labour or investment

funds lead to competition for resources among industries, which in turn raises the prices of these scarce factors of production and of industry output generally in the face of strong demand).

- There are no other constraints, such as the balance of payments or the actions of government, on the response of each industry to a stimulus.

The multipliers therefore describe average effects, not marginal effects, and thus do not take account of economies of scale, unused capacity or technological change. Generally, average effects are expected to be higher than the marginal effects.

The input-output tables underlying multiplier analysis only take account of one form of interdependence, namely the sales and purchase links between industries. Other interdependence such as collective competition for factors of production, changes in commodity prices (which induce producers and consumers to alter the mix of their purchases) and other constraints which operate on the economy as a whole are generally not taken into account.

The combination of the assumptions used and the excluded interdependence means that input-output multipliers are higher than would realistically be the case. In other words, they tend to overstate the potential impact of final demand stimulus. The overstatement is potentially more serious when large changes in demand and production are considered.

The multipliers also do not account for some important pre-existing conditions. This is especially true of Type 2 multipliers, in which employment generated and income earned induce further increases in demand. The implicit assumption is that those taken into employment were previously unemployed and were previously consuming nothing. In reality, however, not all new employment would be drawn from the ranks of the unemployed; and to the extent that it was, those previously unemployed would presumably have consumed out of income support measures and personal savings. Employment, output and income responses are therefore overstated by the multipliers for these additional reasons.

The most appropriate interpretation of multipliers is that they provide a relative measure (to be compared with other industries) of the interdependence between one industry and the rest of the economy which arises solely from purchases and sales of industry output based on estimates of transactions occurring over a (recent) historical period. Progressive departure from these conditions would progressively reduce the precision of multipliers as predictive devices (ABS, 1995).

A9.2.2 Estimated size of the regional economy

A highly aggregated 2009 input-output table for the regional economy is provided in Table 4. The rows of the table indicate how the gross regional output of an industry is allocated as sales to other industries, to households, to exports and other final demands (OFD - which includes stock changes, capital expenditure and government expenditure). The corresponding column shows the sources of inputs to produce that gross regional output. These include purchases of intermediate inputs from other industries, the use of labour (household income), the returns to capital or other value-added (OVA - which includes gross operating surplus and depreciation and net indirect taxes and subsidies) and goods and services imported from outside the region. The number of people employed in each industry is also indicated in the final row.

Gross regional product (GRP) for the regional economy is estimated at $4,845 million, comprising $2,383 million to households as wages and salaries (including payments to self employed persons and employers) and $2,462 million in other value added (OVA).

The employment total in the region was 47,511 people.

A9.2.3 Estimated contribution of the red gum timber industry reliant on public land

The red gum timber industry (based on the NSW river red gum timber resource from public land) provides a stimulus to the regional economy through the purchase of inputs to the production process and the purchases of the employees of the industry. A financial survey of mills and firewood collectors reliant on the NSW river red gum timber resource was undertaken to identify the revenue, employment and expenditure profile of the sector.

This information was adjusted for the level of reliance of each business on resource sourced from public land. This information was then used to generate a 'public land river red gum' sector that could be inserted into the regional economy input-output table and be used to estimate the direct and indirect impact of the industry. For this sector:

- The estimated annual gross revenue of the timber industry was allocated to the output row.
- Direct employment was allocated to the employment row. It was assumed that all people directly employed live in the region.
- Wages were allocated to the household income row.
- Labour on-costs were allocated to the other value-added row.
- Non-labour expenditure was initially allocated across the appropriate intermediate sectors of the regional economy.
- Intermediate sector expenditure was further allocated between local expenditure and imports based on information from the financial survey and location quotient for each relevant sector.
- Purchase prices for each sector were adjusted to basic values and margins and taxes allocated to appropriate sectors using relationships in the latest (2001–02) National Input-Output Tables.
- The difference between total revenue and total costs was allocated to the other value-added row.

The total and disaggregated annual regional impacts of the existing timber industry reliant on the NSW river red gum resource from public land (in 2009 dollars) are shown in **Table A9.5**.

It should be noted that the direct employment contribution identified in Table A9.5 is an estimate of the employment that is reliant on only that timber sourced from public land. This estimate is derived by multiplying the number of full-time equivalent (FTEs) employees of each business by the reliance on public land of that business, as reported by survey respondents. This accounts for the difference in direct jobs

Table 9.4: Aggregated Transactions Table: Regional Economy 2009 ($'000)

	Agriculture/ Forestry/ Fisheries	Mining	Manufact-uring	Utilities	Building	Services	Total	Household Exp	O.F.D	Exports	Total
Agriculture/ Forestry / Fisheries	132,321	11	197,303	16	321	9,627	339,599	12,732	170,008	1,064,832	1,587,171
Mining	61	951	6,437	49	751	404	8,653	185	-595	44,867	53,110
Manufacturing	73,360	1,817	231,863	4,348	59,484	176,658	547,530	138,049	152,996	2,122,059	2,960,634
Utilities	20,837	427	21,057	91,142	2,829	39,586	175,878	30,922	27,669	145,029	379,498
Building	5,366	503	4,730	4,790	122,429	29,733	167,551	0	426,449	92,873	686,873
Services	139,694	3,419	400,456	14,220	58,153	741,103	1,357,045	849,415	1,075,062	1,705,463	4,986,985
TOTAL	371,639	7,128	861,846	114,565	243,967	997,111	2,596,256	1,031,303	1,851,589	5,175,123	10,654,271
Household Income	289,031	8,637	323,959	36,765	148,848	1,576,168	2,383,408	0	0	0	2,383,408
OVA	432,151	22,594	596,982	112,017	87,946	994,121	2,245,811	141,101	65,469	9,301	2,461,682
Imports	494,384	14,752	1,177,794	116,149	206,112	1,419,604	3,428,795	1,384,876	351,752	366,883	5,532,306
TOTAL	1,587,205	53,111	2,960,581	379,496	686,873	4,987,004	10,654,270	2,557,280	2,268,810	5,551,307	21,031,667
Employment	8,341	148	5,687	744	2,440	30,151	47,511				

reported in this section and the 274 direct jobs identified in Chapter 6 of this report. Chapter 6 reports the confirmed total employment in the river red gum timber industry in businesses that source timber from public land. This includes employment in those businesses that source some timber from private land.

The timber industry reliant on the river red gums sourced from NSW public land contributes the following to the regional economy:

- $86 million in annual direct and indirect regional output or business turnover
- $39 million in annual direct and indirect regional value-added
- $21 million in annual household income
- 450 direct and indirect jobs.

This sector represents 1 per cent or less of the regional economy (**Table A9.6**).

A9.2.4 Indicative financial models of timber industry operations

A9.2.4.1 Methodology

Three models were developed to examine three timber industry operations. The financial models require a number of inputs including:

- sawlog supply to the mill by quality of log (separated into public and private supplies)
- product output mix (essentially furniture timbers, sleepers, landscape timbers and firewood and a range of by-products including sawdust, chips and sawdust which are sold to various markets
- product recovery rates
- product prices
- mill variable and overhead costs
- labour costs and requirements
- finance costs
- payments.

Table A9.5 Annual regional economic impacts of the river red gum timber industry*

	Direct effect	Production-induced indirect effect	Consumption-induced indirect effect	Total indirect effect	Total direct and indirect effect
Output ($'000)	47,664	27,613	10,859	38,472	86,136
Type 11A Ratio	1.00	0.58	0.23	0.81	1.81
Value-added ($'000)	23,167	11,044	5,107	16,151	39,318
Type 11A Ratio	1.00	0.48	0.22	0.70	1.70
Income ($'000)	10,862	6,899	3,158	10,056	20,918
Type 11A Ratio	1.00	0.64	0.29	0.93	1.93
Employment (no)	253	131	66	197	450
Type 11A Ratio	1.00	0.52	0.26	0.78	1.78

* Employment in State Forests, haulage and snigging is located in production-induced flow-ons.

Table A9.6 Relative magnitude of the river red gum timber industry

	Gross O/P ($'000)	Value-added ($'000)	Income ($'000)	Employment (no.)
Direct contribution	47,664	23,167	10,862	2531
Total contribution	86,136	39,318	20,918	450
TOTAL REGION	21,079,464	4,868,258	2,394,266	47,511
% Direct contribution	0.2%	0.5%	0.5%	0.5%
% Total contribution	0.4%	0.8%	0.9%	0.9%

Note: The direct employment contribution does not include contractors or Forests NSW employees. These employees are included in the total contribution.

Model outputs include:

- sawmill gross margin (enterprise revenues less variable costs)
- sawmill cash flow over time; and
- Sawmill net income (gross margin less overhead costs and depreciation allowance).

The key parameters which can be varied to show the impact on business performance include:

- log throughput
- product recovery
- product prices.

A9.2.4.2 Model One – high-quality focus

The first model describes a mill with a focus on quota operations geared towards high-quality logs and value-adding. In general these mills have a lower reliance on sleeper and residue operations.

There is a higher investment in machinery within the mill and many of the bush operations are carried out under contract. Reliance on public lands is high with 95% of current throughput sourced publically. The following table outlines the characteristics of the mill.

A9.2.4.3 Model Two – sleepers and residue

The second model describes a mill with a higher reliance on sleeper and residue operations. Reliance on public lands is less, estimated at 54%. Some of the 46% from other sources is sourced from Western Lands Leases as well as private sources.

Table A9.8 outlines the characteristics of this type of mill.

A9.2.4.4 Model Three – residue/firewood operations

The third model describes an operation geared towards producing firewood from trees felled by quotas operations. The following table outlines the characteristics of this type of operation.

Table A9.7 Model One – financial details

Current estimates and assumptions	
Total volume of throughput (m^3)	8,500
Average annual revenue (AR)	$4,814,625
Annual operating costs (OC)	$3,989,295
Net revenue (NR)	$825,330
NR/AR	17%
NR/Total volume	$97
Estimated assets (not including valuation of licences)	$7,250,000
Return on assets (ROA)	9%

Table A9.8 Model Two – financial details

Current estimates	
Throughput (m^3)	19,500
Average annual revenue (AR)	$3,918,000
Annual operating costs (OC)	$3,322,000
Net revenue (NR)	$557,993
NR/AR	15%
NR/Total volume	$29
Estimated assets (not including valuation of licences)	$4,750,000
Return on assets	16%

Table A9.9 Model Three – financial details

Current estimates	
Throughput (t)	7,350
Average annual revenue (AR)	$771,750
Annual operating costs (OC)	$607,515
Net revenue (NR)	$200,985
NR/AR	17%
NR/Total volume	$17
Estimated assets (not including valuation of licences)	$1,175,000
Return on assets	18%
Reduction to 0% ROA	220 t

Timber survey questionnaire (mill owners) 2009

Arche Consulting Pty Ltd has been contracted by the NSW Natural Resources Commission to prepare a socioeconomic impact assessment to inform the Commission's regional assessment of Riverina red gum forests.

The objective of the study was to provide a social and economic assessment of the River Red Gum and woodland forests on public land within the NSW Riverina bioregion.

The information obtained through this survey is confidential and information will only be provided to the NRC in an aggregated form.

OUTLINE

The survey will cover the following areas:

- Background
- Financials, timber sources and practices
- Linkages and dependence to communities

Survey

Details	
Timber business name	
Owner	
Address	
History	
Nearest service town and area of operations	

Operations	Enterprise	Contract
Harvest and haulage (bush)		
Milling		
Manufacture		
Distribution		
Marketing and allied services		

Quotas and volumes	
Annual Licence quantities (tonne or m^3)	
Timber Volumes (m^3):	
Typical focus of operations	
Private forest timber volumes Sawlogs	
Standard logs	
Residual logs	
Sleepers	
Firewood	
Public forest timber volumes Sawlogs	
Standard logs	
Residual logs	
Sleepers	
Firewood	
Private Forest Timber Source(s):	
Public Forest Timber Source(s):	
Timber security – e.g. annual quota, long term wood supply agreement etc	
Product volumes e.g. m3 of structural timber, m3 of flooring, decking and weatherboards, tonnes of chips, tonnes of sawdust etc.:	
Source and haulage (km) refer map	

Total Volumes				
2004/05	2005/06	2006/07	2007/08	2008/09

Revenue	
Average price per m^3 for each product Timber Manufactured Residue mill Residue log Other	
Annual Gross Revenue	
Percentage from public forest timber volumes	

Markets	
Timber Manufactured Residue mill Residue log Other	
Percentage	
Change over the last 5 years	

Annual Costs – Mill	Estimate	Source/ Supplier
Sawlog Costs		
Royalty		
Harvesting costs		
Fall		
Snig		
Haul		
Total Log Costs		
Labour Costs		
Wages		
Payroll, Tax/Super & Workers Comp Insurance		
Total Labour Costs		
Other Inputs Costs		
Materials		
R&M		
Services		
Freight		
Rates		
Utilities		
Fuel		
Total		

Labour	Positions	EFT	Residential Locations	Tenure
Owner				
Management				
Office				
Field				
Mill				
Other				

Overview of workforce and employment history	
What skills are required in the operation?	
Is there a seasonal aspect to your operations?	

Assets	Desription and age	Value (current valuation)
Property		
Buildings		
Machinery and Processing Equipment		
Mobile Plant		
Do you place a value on your quota?		

Has the operation made any recent investments in assets?

Other information and links to the community

Can you provide an overview of your region?

Can you describe past and key attributes of the town?

Are the health services adequate in this region?

Outline the educational facilities that exist in this region?

What other employment opportunities exist for people in this region?

Are the working conditions changed over the past decade?

How does the operation relate to other major employers in the town?

What community facilities exist as a result of this industry?

Other

Have we missed any important points?

Is there anyone in the town/region we should talk to eg Centrelink or employment agency or local development officer in the council?

Appendix 10

Harvesting and management practices on private and public land

Chapter 11 describes silviculture systems and management practices for river red gum on State Forests. A range of management restrictions on harvesting have been put in place to protect and minimise harm to environmental values. **Table A10.1** summarises and compares some of these restrictions for river red gum forests on both public and private land.

Table A10.1 Comparison between river red gum forest harvesting and management practices for environmental values on private and public land

Management practice	Private land	Public land (State Forests)
Tree retention	**Australian Group Selection** • Sum of canopy openings must at no time exceed 20% of the net harvestable area. • No prescriptions for a minimum retained basal area in between gap areas (i.e. buffer areas). **Single Tree Selection and thinning** • Minimum retained basal area – 12 m^2/ha.	**Australian Group Selection** • No minimum retained basal area across coup or compartment. • Must not exceed 20% of compartment in a single logging event. **Single Tree Selection** • No minimum retained basal area. **Thinning** • Minimum retained basal area = 16–25 m^2/ha. **General Prescription** • Retain all dead standing trees with obvious hollows or large cracks and fissures suitable for occupancy by vertebrate fauna across the net harvest area (s 120 licence). • Trees >100 cm diameter at breast height over bark (DBHOB) generally retained. • Trees >120 cm DBHOB retained.
Canopy openings (gaps)	**Australian Group Selection** • Maximum width of a canopy opening must not exceed twice the stand height. • Minimum distance between canopy openings not be less than twice the stand height. **Single Tree Selection and thinning** • Should aim to space trees according to the formula ¼ DBHOB (cm) x100.	**Australian Group Selection (L&E Court agreement)** • No greater than twice stand height, up to 60 m DBHOB. • Minimum distance between gaps not less than twice height of stand. **Single Tree Selection** • No prescriptions for a minimum retained basal area, potentially allowing clearing back to 4 habitat trees/ha (s 120). **Thinning** • MRBA = 16–25 m^2/ha (as per management plans) = maintains a relatively intact canopy cover.
Logging frequency/timing	**Australian Group Selection, Single Tree Selection and thinning** • Harvesting operations must not occur in a previously harvested area until stocking levels meet the minimum stocked plot requirements (see regeneration below). • No prescriptions to limit application of both AGS and STS across a compartment in a single logging event.	**Australian Group Selection, Single Tree Selection and thinning** • No prescriptions on logging frequency (i.e. return logging events) within compartments or coupes. • No prescription to limit the application of both AGS and STS across a compartment in a single logging event.

Table A10.1 Comparison between river red gum forest harvesting and management practices for environmental values on private and public land continued

Management practice	Private land	Public land (State Forests)
Regeneration	**Australian Group Selection, Single Tree Selection and thinning** • Minimum stand stocking of 60%, within canopy openings and 70% elsewhere in the forest, must be achieved within 36 months of a regeneration event. • Regeneration event is the second period of inundation following a harvesting or thinning operation.	• No prescriptions.
Riparian buffers	• No forestry operations in riparian exclusion zones. • Only 30% of the pre-harvest basal area can be removed in any 10-year period and the minimum basal area limit of 12 m2/ha is maintained within the riparian buffer zone. • A 5 m harvesting for any exclusion zone drainage feature with an incised channel. • Prescribed streams: 20 m exclusion, 25 m buffer.	• Min. 20 m exclusion zone around and adjacent to each large permanent or semi-permanent waterbody or nominated waterway (stream, runnel, swamp and lagoon). • Modified harvesting zone (30m) around each exclusion zone
Wetland areas	• Forest operations must not occur in any wetland other than wetlands that comprise a river red gum broad forest type or within 20 m of any wetland, except that existing roads may be maintained.	• An exclusion zone, a minimum of 20 m wide (as measured from the first line of mature trees outside the depression), must be established around and adjacent to each wetland. [Mature is defined as >30 cm DBHOB.] (s120). • A modified harvesting zone, min. 30 m wide, must be established around and adjacent to each exclusion zone, in which at least 5 habitat trees and 5 recruitment trees must be retained per hectare (s120). • Where insufficient habitat trees (H-trees) exist to achieve this level, all existing habitat trees must be retained and recruitment trees (R-trees) must be retained in sufficient numbers to ensure a level of at least 10 retained habitat/recruitment trees per hectare (s120).

Table A10.1 Comparison between river red gum forest harvesting and management practices for environmental values on private and public land continued

Management practice	Private land	Public land (State Forests)
Habitat trees (hollow-bearing and recruitment trees)	• H-trees should be evenly distributed throughout the area of harvesting operations and within the net logging area. Preference should be given to trees with well-developed spreading crowns and minimal butt damage. • Retained H-trees should represent the range of species in mature and late mature growth stages. • Dead standing trees cannot be counted as hollow-bearing trees (HBTs). • A recruitment tree (R-tree) preference must be given to trees from the next cohort to that of retained HBTs. • 5 HBTs/ha, within 20–50 m of any permanent watercourse, water bodies or major wetlands, must be retained. • 2 HBTs/ha in all other areas must be retained. • One recruitment tree from the next cohort must be retained for every HBT retained. • Where the total number of HBTs is less than 10 trees/ha within 20–50m of any permanent watercourse, water bodies or major wetlands, or 4 trees/ha less than elsewhere, additional recruitment trees must be retained to bring the total number of trees retained up to 10 and 4/ha, respectively. • Additional recruitment trees above the number kept for the HBTs can be kept within the riparian buffer zone. • Clumps of HBTs must be retained in river red gum broad forests where they constitute rookeries for water bird species such as herons, cormorants, spoonbills and egrets. • All HBTs are retained in riparian exclusion and buffer zones.	• Across the net harvest area (except where more stringent s 120 conditions apply), a min. of 2 H-trees and 2 R-trees/ha must be retained. Where there are insufficient numbers of H-trees to achieve this level, all existing H-trees must be retained and R-trees must be retained in sufficient number to ensure at least 4 retained H- and R-trees/ha. • A modified harvesting zone, – min. 30 m wide around and adjacent to each exclusion zone, with 5-H trees and 5 R-trees/ha, must be retained (being 50 m for riparian zones). Where insufficient H-trees exist to achieve this level, all existing H-trees must be retained and R-trees must be retained to ensure a level of at least 10 retained H- and R-trees/ha. • Regeneration openings must be sited to avoid the selected H-trees and R- trees.
Pre-harvest survey	• Not required. • Threatened Species records search completed by DECCW.	• Threatened species record search of the DECCW Atlas and Forests NSW Biodata records. • Pre-harvest surveys are only required for koalas, regent and superb parrots. • Threatened species search done during tree mark up and ongoing monitoring. • Pre-harvest surveys are only required for koalas, regent and superb parrots. • Buffer and exclusion zones implemented if found. • Not applicable to all Forest Management Areas.

Table A10.1 Comparison between river red gum forest harvesting and management practices for environmental values on private and public land continued

Management practice	Private land	Public land (State Forests)
Superb and regent parrot	• No prescriptions.	• Includes prescriptions H-trees • Across the entire net harvest area, a minimum of two trees carrying mistletoe, where present, must be retained per hectare. Retained H- and R-trees may be counted toward this prescription. • Net harvest area and the area within 100 m of the boundary of the net harvest area must be surveyed during the breeding season prior to logging for evidence of nest trees. • A person suitably experienced in the identification of such features must undertake the surveys. • An exclusion zone of a minimum of 100 m radius must be established around each nest tree, whether presently active or not.
Coarse woody debris	• No prescriptions.	• Across the net harvest area, sufficient on-ground residue from the current operation must be retained to resemble that in the photo standards (photo showing minimum density and nature of CWD after harvesting). (s120) • Harvesting must minimise disturbance to logging debris and naturally fallen woody debris existing prior to the current operation. (s120)
Source(s)	• DECC (2007)	• FNSW, (2000); FNSW, (1999); FNSW (2008c): DEC,(2004); L&EC (2007); DLWC, (1993)

Notes

Notes