Scoping study for the Narran Lakes and Lower Balonne floodplain management study (R2011)

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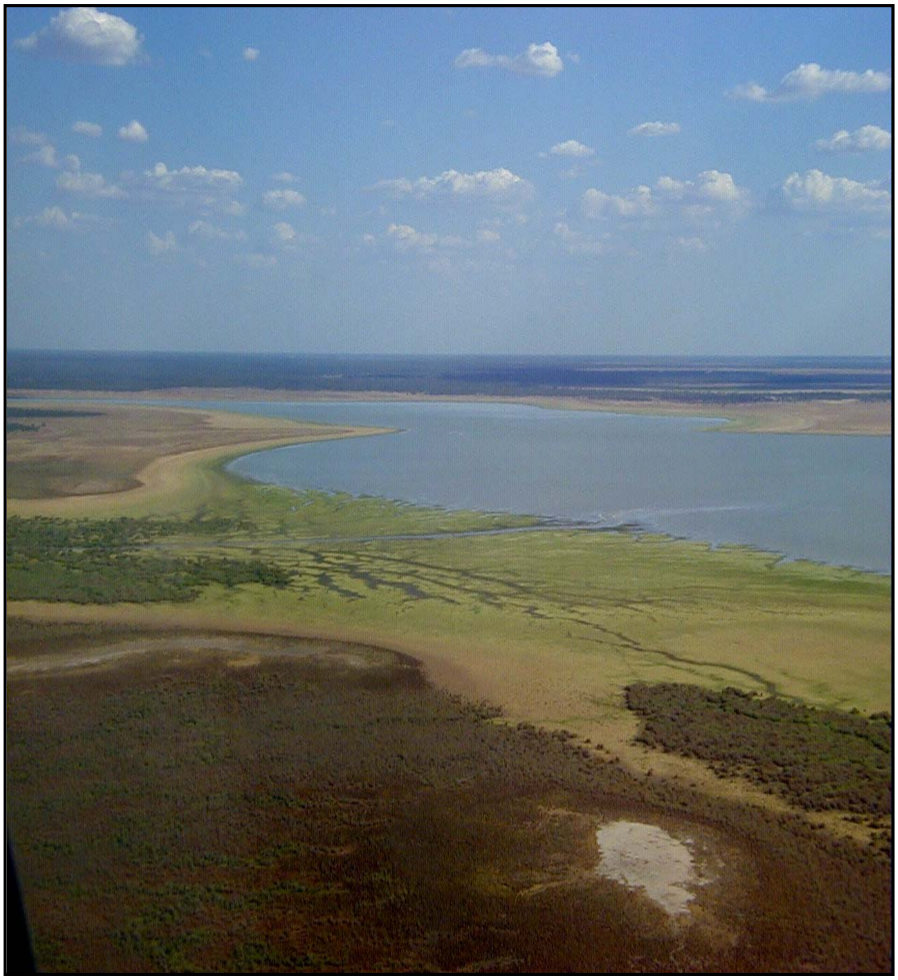

The Narran Lakes

Executive Summary

Large floodplain ecosystems are a feature of Australia's dryland rivers. They are associated with extensive wetlands and numerous lakes and their ecological integrity is maintained by hydrological connections between the floodplain and adjacent river channels. The Lower Balonne floodplain complex straddles the New South Wales (NSW) and Queensland (Queensland) border. The complex contains a series of dryland rivers, two wetlands listed in the directory of important Australian wetlands (the Lower Balonne River floodplain and the Culgoa River floodplain park) and the Narran Lakes, a Ramsar-listed wetland. Hence, this is a region of diverse physical habitats and wetland 'styles', and of potentially high biodiversity.

The Lower Balonne floodplain complex has been subjected to large-scale water resource and floodplain development. As a result, the flow regime of the Lower Balonne complex, and the Narran Lakes system in particular, has been substantially modified. Future developments along the Narran River, which flows into Narran Lakes, can occur in both NSW and Queensland. The Condamine-Balonne Water Allocation Management Plan (WAMP) acknowledges a likely expansion of water abstraction and diversion on the Queensland side. Under WAMP-modelled scenarios of different levels of water resource development, inflows to Narran Lakes would be less than 50% of natural. Without the WAMP in action, inflows could decline to 28% of natural.

This report provides the results of a scoping study into the Lower Balonne floodplain complex, with particular reference to the Narran Lakes ecosystem. The study had four main outputs:

- a review of the hydrology, ecology and cultural issues of the system;
- a discussion of the implications of draft management plans on the system;
- an ecological monitoring framework for the system; and
- identification of the main knowledge requirements for the area.

This study found a surprisingly large amount of information on the Narran River and its terminal lakes. Over 140 documents or reports were sourced. Many other documents exist but were not provided by the relevant agencies. Our review and synthesis of these documents showed that there has been little coordination of work on the Narran River and the Narran Lakes. This is probably not only because several different agencies have responsibilities for the area, but also because the lakes are subject to several different management frameworks. For example, the Narran Lakes Nature Reserve only includes a relatively small part of the whole terminal system and does not include the largest lake, and the Ramsar-listed component overlaps the Nature Reserve boundaries. The whole Narran Lakes terminal wetland complex should be considered as a single ecosystem and should be managed as such, not in bits and parts. Overall, the quality of information and data contained within the cited reports is poor and cannot provide a basis for management of the Narran Lakes.

Little of the available information directly addresses the effects of water resource development in the Condamine-Balonne catchment on the ecological condition or character of the Narran River and its terminal lakes. The only exceptions are recent studies emerging from the CRC for Freshwater Ecology and the Condamine-Balonne WAMP, although raw data backing the latter document have not been formally analysed. In general, studies that collect quantitative information on hydrology, geomorphology, water quality or biota have not been well designed. They generally are location-specific and do not measure spatial or temporal variability.

The most useful data are those on waterbirds. Waterbird records have been collected since 1971, although the sampling has been sporadic and the methods varied. There are also some valuable vegetation data. However, the emphasis has not been on connecting the vegetation communities with flooding regimes, but rather on mapping the terrestrial components. Other biotic data exist, some valuable, some limited, all of which would benefit from collation into a single data base/GIS system that would be available to help target future research and monitoring efforts.

From the studies that have been undertaken in the region it is evident that:

- Water resource development has reduced the frequency of flows downstream of St George in excess of 31% (e.g. Average Recurrence Interval of 1.5 year floods increased by 48%)
- Combined with the impact of large-scale floodplain development, water abstractions have significantly reduced hydrological connections between the river channels and associated floodplains
- Reduced hydrological connections have the potential to significantly alter ecological processes in the region
- Hydrological connections are a key driver in maintaining the ecological integrity of the Lower Balonne floodplain and Narran Lakes
- Rates of sedimentation on the Lower Balonne floodplain have increased by an order of magnitude (1.63 to 11.06 cm year^{-1}) because of increases in sediment supply resulting from upstream land use changes
- The texture and geochemistry of sediments being deposited in the Lower Balonne region have also changed — some of the sediment cores taken from the floodplain have high salinity levels at relatively shallow depths (mean salinity values range from 0.17 to 1.56 mS — plant growth can be inhibited by some of these salinity levels)
- Changes to the flow regime and increased sediment loads in the Narran River will lead to significant alterations to the extent and quality of available habitat, and hence will affect a range of biota and ecological processes in the Narran Lakes ecosystem, and
- Current and proposed development in the region can only lead to a deterioration in the ecological character of this Ramsar-listed wetland.

It is clear that the information available does not provide enough detail to establish the current ecological character of the Narran Lakes nor to reliably predict the effects of increased water resource development. For the Narran Lakes ecosystem and the Lower Balonne floodplain there are four areas of interest under the Commonwealth's Environmental Protection and Biodiversity Conservation (EPBC) Act:

- the part of the catchment listed as a Wetland of International Importance;
- the two nationally, and possibly internationally, important wetlands: Culgoa Floodplain Wetlands and the Lower Balonne River Floodplain wetlands; and
- the presence of several listed migratory waterbird species and the presence of two nationally listed plant species.

Under the Ramsar Convention, Australia has an obligation to ensure that the ecological character of the Narran Lakes is retained — failure to do so will contravene Australia's obligation to the Convention. In the absence of a clear understanding of the ecological character of a listed site, it is recommended that presence, abundance, and activities of certain species and ecological communities, especially waterbirds, act as the expression of the ecological character until such time as it can be adequately described. Under the EPBC Act the expectation is that the Minister would seek to prevent or modify any action deemed likely to cause the loss of these attributes. In so determining, the Act expects the Minister to take the precautionary principle into account.

We recommend a monitoring framework to assess the current ecological character of the Narran Lakes and floodplain and to determine changes in ecological character using on-going monitoring that incorporates appropriate control or reference ecosystems. It is important that a number of comparable systems (e.g. Paroo, Culgoa etc.) be evaluated as possible control or reference sites. Our monitoring framework includes four components.

- First, there needs to be a conceptual model that drives the choice of variables and processes on which monitoring is focused.
- Second, there should be a rigorous and thorough limnological survey that establishes current ecological character. All available data should be used to optimise the design of this survey, although only data on fish and vegetation are likely to be adequate for this purpose. This survey should measure most components of the biota of the Narran Lakes and floodplain, as well as variables such as sedimentation rates and components of water quality. The survey should also build on existing programs, such as the NSW National Parks and Wildlife Service waterbird monitoring.
- Third, the assessment of current ecological character should feed into an on-going ecological monitoring program, and into specific research projects that address important knowledge gaps. The on-going monitoring should use the results of the baseline survey to choose key variables that seem important to ecological character, are sensitive to changes in water regime, are statistically reliable to sample and have power to detect changes. The on-going monitoring needs to have a time component and should compare the Narran system to suitable control or reference systems.
- Fourth, it is also very important that functioning gauges be installed in all three lakes and be linked to a gauge in the Narran River, possibly at Wilby Wilby. The data from these gauges will be a major component of an input response model that links flow, habitat and ecological response.

The Narran Lakes wetlands are regarded as significant within the Murray-Darling Basin, hence the declaration of the Nature Reserve and the Ramsar listing for part of the site. Sixty-five species of waterbirds have been recorded in the Narran Lakes in the past decade, forty-six of which breed in the wetland system. These numbers are comparable to the Macquarie Marshes and suggest that the Narran system is potentially one of the most important breeding and feeding habitats for waterbirds within the Basin. The Narran system may also be important for other taxa (e.g. there are two endangered species of plants at the site), but we have little knowledge about Basin-wide distributions of organisms associated with wetlands in inland Australia. Clearly, a priority for future research would be to determine the role of Narran Lakes relative to other wetlands as a breeding and feeding resource for waterbirds.

The research priorities address knowledge gaps identified specifically for Narran Lakes, but also reflect the relatively poor knowledge base for dryland river floodplains and their wetlands in general. Therefore, the outcomes of these research projects will contribute to the understanding and management of other dryland rivers and wetlands. It is imperative that all research activities that may be undertaken in the Narran system be part of a larger co-ordinated and integrated research program. This would avoid the fragmented approach of past data gathering exercises.

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1 INTRODUCTION

1.1 Scope and method

This scoping study was conducted in response to a project brief prepared by the Murray-Darling Basin Commission (MDBC) Natural Resources Management Strategy, Strategic Investigations and Education program. The major component of the scoping study was the collection and collation of information relevant to the Narran Lakes, Narran River and the Lower Balonne floodplain. All major natural resource agencies in NSW and Queensland were contacted (the major contacts were supplied by the MDBC Project Manager) and additional sources of information were identified and explored where appropriate. This included consultation with local Aboriginal elder Mr Ted Fields Snr, for information on cultural aspects of the floodplain, rivers and lakes.

The scope of this project was limited both in time and in the geographical area that could be covered. For the purposes of this study we focus on the Narran Lakes wetland complex, the Narran River and associated floodplain, and other significant wetlands within the Lower Balonne. Information on other distributary rivers such as the Birrie, Bokhara and Ballandool is not comprehensively covered.

Many of the reports deal with catchment-level management issues and only briefly mention the Narran Lakes. This is particularly evident in material from Queensland where consideration of catchment processes and condition often stops at the NSW border. Likewise the NSW documentation and information predominantly focuses on the portion of the Condamine-Balonne catchment situated in NSW.

The process of information collection and collation continued throughout most of the study and constituted the major task. It quickly became evident that there is a significant amount of information available on the Lower Balonne and Narran systems, but it is widely scattered across the various state agencies. Some material was unable to be sourced from the various agencies, and was excluded from the study because of the restricted time frame. Also, we had to restrict our information search to material supplied by the agencies, and thus the scientific literature is not the dominant feature of the information collected. We acknowledge that there may be scientific literature on general aspects of geomorphology, hydrology, wetland ecology, and waterbird ecology in particular, which was not included in the present study. However, a full literature review was beyond the scope of the study.

1.2 Project objectives

The objectives of this scoping study were to:

- collate and synthesise the best available information regarding the Lower Balonne and Narran Lakes ecosystems, including an assessment of the likely effects of water resource development and land management activities on the ecological value and functioning of the systems;
- review hydrology, ecology, conservation and cultural aspects of Narran Lakes;
- provide an assessment of the Ramsar and EPBC implications for water management in the Narran Lakes;

- use the information to develop an ecological monitoring framework for assessing the impacts of water resource management;
- provide an assessment of draft plans and assessment of the implications of current management frameworks; and,
- identify knowledge gaps found through the review process.

1.3 Background: impacts of water resource development on floodplain wetlands

The impacts of water resource development on floodplain wetlands and their associated biota are well documented for many systems throughout the Murray-Darling Basin, Australia, and also internationally[57,83,85]. The fundamental health of a floodplain wetland is dependent on the natural hydrological regime, which drives most aspects of wetland ecology. The inherent variation and differences between floodplain wetlands on different river systems means that individual wetlands will respond differently to alterations in their hydrological regime. It is difficult to make predictions about specific effects of reductions in flow without having a clear understanding of each wetland's ecology and relationship to its river. However, certain impacts are inevitable and predictable. Take away the water and the wetland dies. Take away the water slowly and incrementally and the wetland still dies, but first undergoes severe degradation and alteration to its ecosystem functioning. Hydrological connections between river channels and their associated floodplain are important for the overall ecological integrity of Australia's inland river systems.

Reductions or alterations to the natural hydrological regime *will* affect the ecological integrity of floodplain wetland systems. In particular, the loss of wetland habitat has occurred at a staggering rate with estimates in the order of 50% globally. Irrigation and agricultural practices have basically ignored the issue of environmental requirements of rivers and floodplains and have continued to put enormous pressure on floodplain wetlands. Most of the degradation of many wetlands of international importance occurred in a period of high public and scientific environmental awareness[85], when we should have known better.

Altering the natural flow regimes in wetlands can result in the following impacts:

- destruction of wetland habitat;
- decrease in local, regional, and in some cases international biodiversity values;
- reduction in abundance and number of waterbird species;
- loss of fish diversity;
- loss of vegetation diversity;
- loss of invertebrate, crustacean, and amphibian diversity;
- increased incidence of blue green algal blooms;
- loss of lateral connectivity between river and floodplain, and disruption of material flows;
- invasion of weedy exotic species;
- increased susceptibility to pest species outbreaks e.g. midges;
- reduced water quality; and,
- increased salinity and associated toxic effects.

1.4 Background: the Lower Balonne region

The Condamine-Balonne River is an allogenic system (Figure 1.1); that is, most of its water and contents are derived from outside sources. It originates in the well-watered highlands of southeast Queensland and flows for most of its length across an essentially dry landscape that contributes little extra runoff. The catchment has an area of 143,900 km^2 (14% of the Murray-Darling Basin) and is a major right-bank tributary of the Barwon-Darling River that contributes 20–35% of long-term (1940–95) median annual flow at Menindee. From its headwaters the Condamine-Balonne River flows due west. Just downstream of Surat, it starts to flow in a south westerly direction. Downstream of St George the river bifurcates or splits into several different channels, namely the Balonne Minor, Culgoa, Briarie, Bokhara, Ballandool and Narran Rivers (Figure 1.1). Each river has a well-developed floodplain and as a result, the Lower Balonne region — that area between St George (Queensland) and the Barwon River (NSW) — is essentially a large floodplain wetland complex. The climate of the region is semi-arid and flooding usually follows heavy rainfall in the upper catchment in Queensland. The Lower Balonne straddles the Queensland and NSW borders and is one of the most productive and intensively irrigated river basins in Queensland. The Lower Balonne region has approximately 357,000 ha of its area in Queensland and 1,631,000 ha in NSW.

The Lower Balonne supports the second largest number of wetlands of 5 ha or more, within the Murray-Darling Basin[43]. Some 3,400 wetlands have been identified in the region, the majority being freshwater wetlands (25.8%) and floodplain areas (24.2%)[43]. The Narran Lakes is a terminal wetland system of the Narran River, a distributary of the Balonne River (Figure 1.1). This 10,000 ha wetland system includes three major wetlands: Back Lake, Clear Lake and Narran Lake[12, 29, 33, 49]. The Narran River and Lakes system represents about 15% of the land area of the Lower Balonne region (including floodplain areas).

The Lower Balonne-Culgoa floodplain has been grazed since the 1840s[64], predominantly by cattle and sheep. A recent change to irrigation agriculture represents a significant shift in land use practice and water resource utilisation. The major irrigated crop is cotton and the cropped area has increased from approximately 4,300 ha in 1988 to some 38,000 ha in 1999[64]. Associated with this expansion in the cotton crop has been an expansion in water storage on the floodplain from 54,750 ML to more than 592,500 ML over the same period[64].

This development of water resources was made possible through the availability of technology that allowed landowners to harvest water from the floodplain and to pump and store large volumes of water from variable river flows. The only regulation of water use was through government-issued irrigation licences, which were not subject to adequate assessment of environmental impacts[83]. In addition, legislation and policies for Australian rivers do not recognise the distinctiveness of dryland rivers[83] and this further exacerbates the problem of inadequate consideration of ecological impacts. There has also been considerable levee bank construction on the floodplain around cotton crops and water storages. This may have a significant impact on the hydrology of the floodplain[64] by effectively reducing the hydrological connectivity between river channels and floodplains.

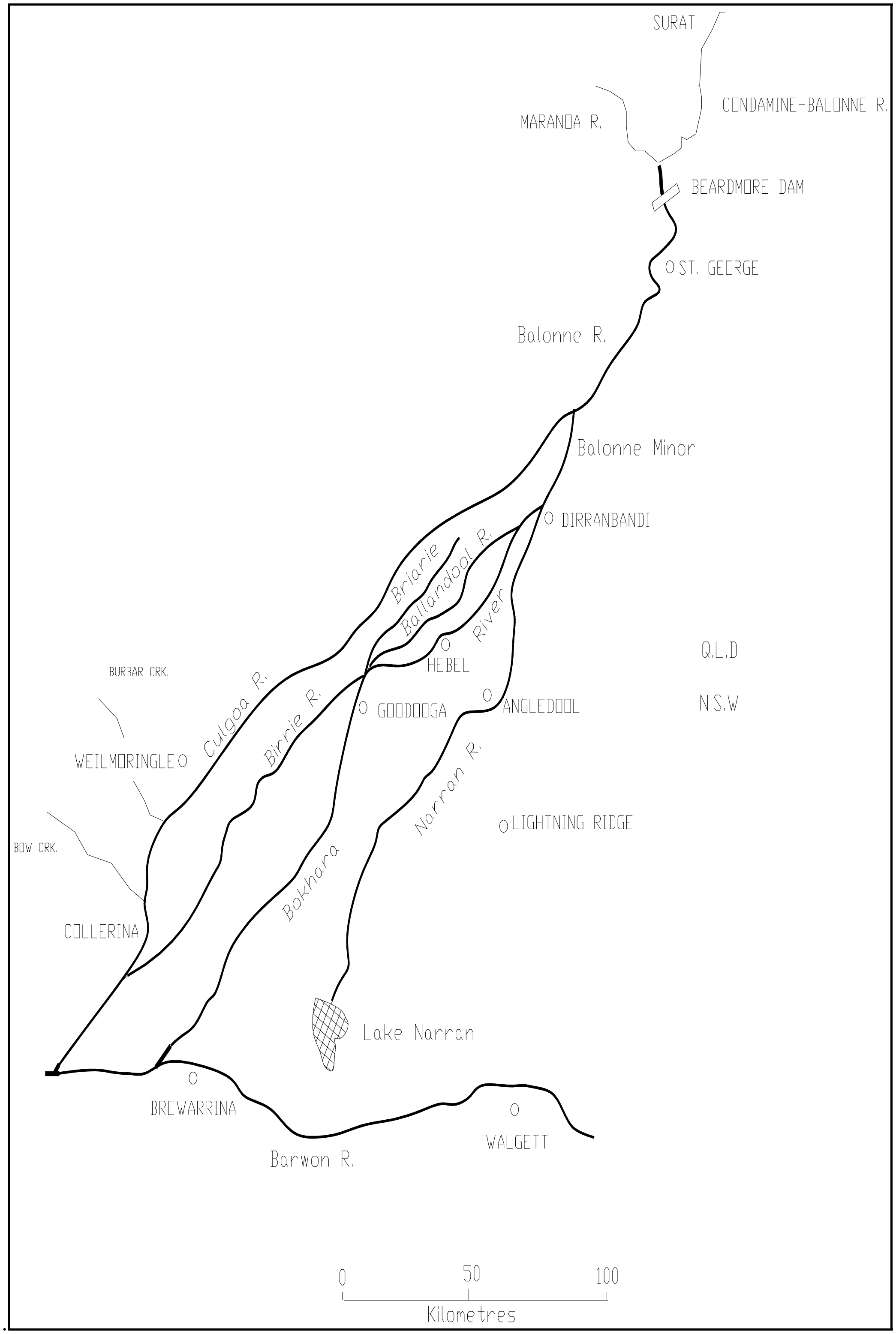

Figure 1.1 The Lower Balonne region.

Kingsford[83] points out that few regulations recognise floodplains and distributaries as watercourses, because of problems with the definition of 'watercourse'. The result of this is a virtual absence of policies for regulating overland flows on the Condamine-Balonne floodplain. Levees built across the floodplain captured overland flows and escaped any regulation or environmental assessment. In addition, floodwaters on such dryland rivers were not controlled by government-built structures, so the water was essentially free[83].

Throughout this study we focus mainly on the Narran River, Narran Floodplain and Narran Lakes portion of the Lower Balonne floodplain, within the Condamine-Balonne catchment. In many instances data for this study are from a restricted number of sites and generally pertain to a component area, such as the Narran River, the Narran Lakes, or the Culgoa floodplain.

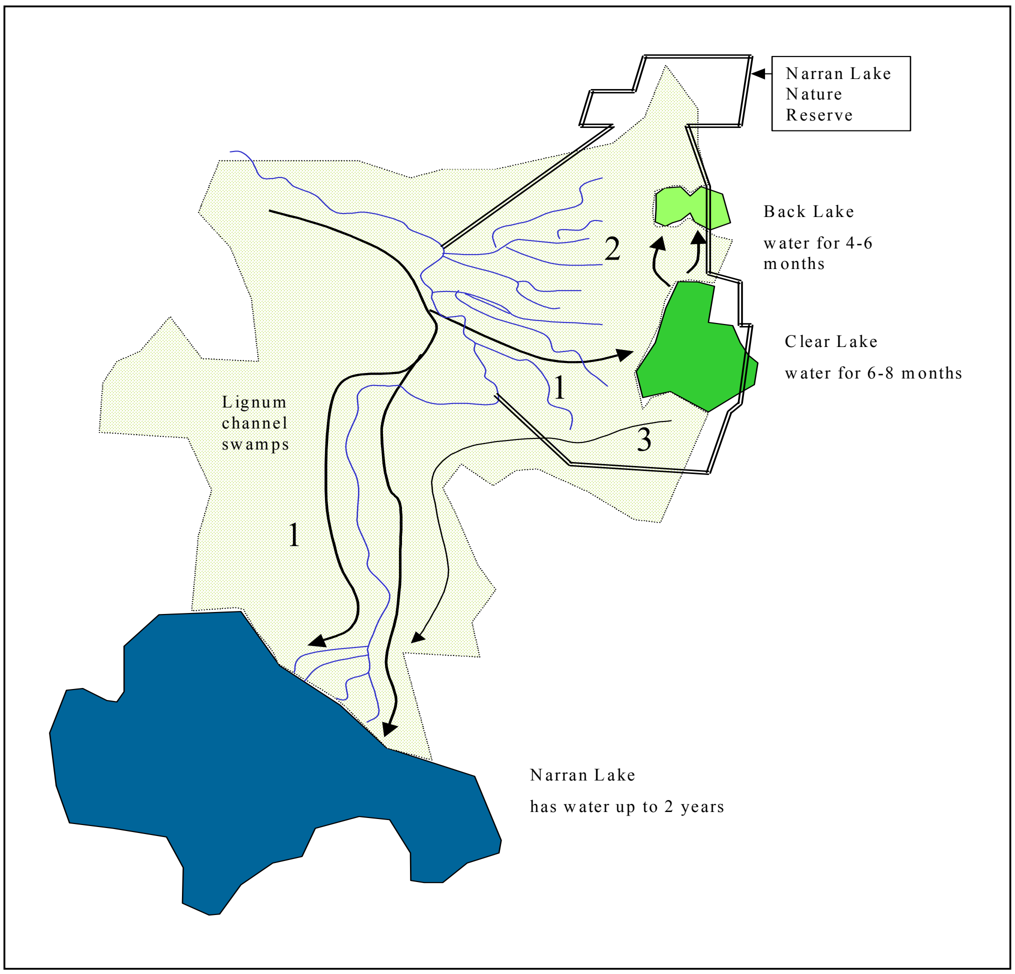

Figure 1.2 Schematic representation of the three major inter-connecting lakes in the Narran Lakes ecosystem, showing the proposed filling and drying patterns. The system fills (on average) once in every 2–5 years.

Flooding of the Narran Lakes occurs one in every two to five years. Clear Lake fills first (Figure 1.2), then overflows into Back Lake and the extensive channelised Lignum swamp (west of Clear Lake). When flows from Narran River fall below a certain level, the water will fall in these two smaller lakes. However, water continues to flow along Narran River and into Narran Lake[4, 5]. Once Narran Lake is full it can retain water for up to two years, and is one of the largest freshwater lakes in NSW[29]. The Narran Lakes have been identified as one of nine refugia for biological diversity in semi-arid and arid NSW[18]. The floodplain of the Narran River, extending west of Clear Lake and south-west to Narran Lake, is made up of extensive areas of channelised wetlands vegetated with Lignum (*Muehlenbeckia florulenta*), river cooba (*Acacia stenophylla*), River Red Gum (*Eucalyptus camaldulensis*) and Coolibah (*E. coolabah*). These form a delta-like terminal swamp area, sometimes referred to as the gilgai overflow swamp[4, 5, 18, 34].

Clear Lake and Back Lake form part of the Narran Lakes Nature Reserve and are surrounded by an extensive channelled floodplain. The Narran Lakes Nature Reserve covers 5,538 ha, and constitutes about one third of the wetland system referred to as Narran Lakes[49]. The area comprises extensive wetlands, associated lunettes and adjacent sandy and rocky ridge country. The Narran Lakes Nature Reserve area was listed as a Ramsar Wetland of International Importance in June 1999 (see Appendix A for the draft Ramsar Information Sheet), eleven years after it was gazetted as a Nature Reserve by the NSW National Parks and Wildlife Service (NSW NPWS)[49]. The reserve does not incorporate Narran Lake, but rather all of Clear Lake and most of Back Lake (Figure 1.2). The Narran Lakes Nature Reserve is also listed on the Register of National Estate as a natural heritage site[19, 12]. At the federal level, 10,000 ha have been listed in the Directory of Important Wetlands in Australia, which includes Narran Lake proper and Clear and Back Lakes [55]. The Nature Reserve adjoins 3,547 ha of land, formerly the Lumeah property, which is managed by NSW NPWS as part of the reserve but has not been gazetted because of objections from the Department of Mineral Resources[49].

The listing of the Narran Lakes Nature Reserve as a Ramsar site was in recognition of it being an excellent example of a relatively undisturbed terminal lake system for NSW, a significant site for waterbirds, both nationally and internationally, and habitat for many species that are recognised as being of conservation concern, either regionally, at the state level, or nationally. Together, these attributes reflect the underlying ‘ecological character’ (incorporates the ideals of health and integrity) of the site, which the Ramsar Convention obliges Australia to retain. In addition the site offers important habitat for several species listed under Australia’s agreements with the Governments of Japan and China for the conservation of migratory birds. Chapter 5 of this report considers these matters in further detail.

The hydrological integrity of a catchment is critically important for maintaining the ‘ecological character’ of terminal wetland systems such as Narran Lakes. The hydrology of Narran Lakes may change considerably because of upstream water resource development. Modelled data suggest that water resource development will reduce the magnitude and frequency of floods reaching the lakes. Floods are believed to be important for the filling of the Narran Lakes. The ecological and conservation value of the site is predominantly focused on the large water bird breeding colonies, which are highly dependent on water levels (Appendix A). Requirements of timing and length of inundation vary for each species and it is believed that the trigger level for the breeding of some species is approximately 86% of capacity[44]. However, the wetlands may need to reach 100% capacity for successful breeding events of some species.

The rivers of the Lower Balonne region are dryland rivers. Many dryland rivers, including the Narran River, are endorheic, flooding terminal wetlands and vast floodplain areas[83]. Endorheic rivers do not flow into the sea but rather, flow into wetlands or dry riverbeds. Extreme flow variability is a feature of the region and has a significant influence on aquatic communities and ecological processes. This, plus the spatial and temporal complexity in habitat availability, heterogeneity, and connectivity across river–floodplainsystems, contributes to a highly dynamic ecosystem capable of supporting exceptionally high levels of biodiversity.

A response to the flow variability of dryland rivers is the ‘boom and bust’ cycles evident in some components of aquatic productivity. The most obvious aspect of this type of ecological cycle is the large breeding events of waterbirds, such as those recorded in Narran Lakes. However, boom and bust cycles are also evident in other biota including algae, higher plants, invertebrates and fish[57,58,83]. Altering or reducing flooding in dryland rivers has predictable consequences for the ecology of these systems. The aquatic components become more terrestrial in nature, and the aquatic plants that are reliant on the ‘natural’ flooding regime can be replaced by species more tolerant of dry periods. The floodplain shrinks and potentially, the biodiversity declines[83].

Although the environmental importance of Narran Lakes has been recognised, this has had little effect on the rapid pace of development. Over a period of 10 years, median flows to Narran Lake have been significantly reduced. Flows in the Lower Balonne River are regulated by Beardmore Dam and through water extractions. Based on the lessons learned from other hydrologically altered Australian and international river systems, the overwhelming consensus among scientists and natural resource managers is that water resource and floodplain development will both have a significant detrimental impact on the ecology of the Lower Balonne floodplain complex and the Narran Lakes[57,83,105].

1.5 Sequence of reports and research programs on the Narran Lakes and Lower Balonne

The largest single study on the Narran Lakes system to date was the Narran River Environmental Management Strategy (NREMS) project (N280) conducted in 1991-1993. The project was funded by the MDBC Natural Resource Management strategy (MDBC NRMS) and was jointly sponsored by the NSW Department of Water Resources and NSW National Parks and Wildlife Service. The aims of the project were to provide an integrated hydrological and ecological model of the Narran system and to formulate a licensing policy for the river in NSW. Specific objectives were to:

- determine the water requirements and management strategies necessary to maintain the ecological values of the Narran River, its floodplain, and specifically the Narran Lakes terminal wetland system;
- develop a NSW water-licensing policy for the Narran River which will balance ecological requirements with agricultural development; and,
- establish a program to monitor the effects of hydrological changes and agricultural development on the ecological values of the Narran River[10].

The focus of the project was to collect water bird data, information on the ecology of the wetlands and hydrological information (including flooding regimes). Six reports were produced, but the final licensing policy was never completed[91]. The reports produced are as follows:

- Narran Lakes mapping and volume calculation[95, 96 ,97 ,98]
- Narran Lake Soil infiltration study
- a report on the vertebrate fauna of the Narran River Floodplain in NSW[82]
- a survey of opinions in the Narran Lakes District[107]
- Narran River Management Strategy – Preliminary Hydrological Investigation[108], and
- Narran Lakes Catchment Management Strategy Hydrological Reconnaissance[10].

There was limited achievement of the objectives of the project. For the assessment of the existing ecological information (Objective 1) it was considered that faunal data were poor and additional data were captured [82]. These data focused on terrestrial vertebrates and no data on aquatic fauna were collected. At the time the available information on flora was considered 'adequate' and no further data were collected[90, 91, 106]. The emphasis of this project was predominantly on terrestrial ecological aspects of the wetland system, and most likely reflected the expertise of the regional agency staff.

Since the completion of this early study a large amount of work has been done in the area. Most have been stand alone projects and there has not been a successful attempt at describing the ecological character of the wetland system in the manner attempted by project N280. Events that have spurred research and survey work have included the listing of Culgoa National Park, the listing of Narran Lakes Nature Reserve as a Wetland of International Importance, and the Water Allocation Management Plan (WAMP) process in Queensland. Table 1.1 lists the reports that deal substantially with the Narran Lakes and the Lower Balonne River, from 1991 through to 2001. While this appears to represent a relatively substantial amount of material much of the information is of little use in determining the ecological character of the Narran Lakes.

Table 1.1 Reports and projects on the Narran Lakes and Lower Balonne River, 1991 to early 2001.

Year	Reference number	Focus of report(s)	Usefulness
1991-1993	10, 82, 90, 91, 92 95-98, 106-108	Vertebrates, hydrology, geology, public opinion, and soils	Fails to achieve all of the objectives set – 6 major reports produced
1991	43	Waterbirds	Baseline referred to by all subsequent studies
1991	34, 35	Waterbirds	Summary only of breeding events over previous 20 years – no detail on methods
1993	87, 88	Vertebrates and vegetation	Significant reports
1994	111, 112	Hydrology	Some useful information but more recent material available
1995	67	Environmental scan	Significant review of existing data
	68	Floodplain resources	Predominantly a survey of landholders opinions
1996	137	All aspects	Background document for the WAMP process – useful review of issues
1997	45	Waterbirds	Provides some habitat mapping of colonies
1998	80, 81	Waterbirds	Useful
	113	Coolibah woodlands	Scoping study
	121	Biodiversity, cultural	Management plan – useful
1999	5	All aspects	Draft Narran Lakes Management Plan
	9	Cultural	Useful
	12	All aspects	Useful (ecology and cultural aspects); however, hydrology calculated using monthly data

Table 1.1 (cont.)

Year	Reference number	Focus of report(s)	Usefulness
1999 (cont.)	66	Water quality, groundwater, pesticides, biodiversity	Limited sites in the Lower Balonne, useful upper-basin data – highlight lack of data in Lower Balonne and alluvial fan
	63,64	Floodplain habitat mapping and vegetation response to inundation	Highly useful but limited in that it only includes the Queensland portion of the Lower Balonne floodplain
	69	Vegetation	Extensive, valuable report
	44	Hydrology	Limited because it is predominantly restricted to the QLD part of the catchment – treatment of Narran Lakes is inadequate
	71	Amphibians	Survey data and results
	76, 77	Waterbirds	Data for 1998/99 monitoring
	116	Floodplain soils, vegetation, nutrients	Useful – but limited to Queensland portion of the Lower Balonne floodplain
2000	1	Hydrology, water resource development	Method review of WAMP
	4	All aspects	Review of available information – based mainly on NSW NPWS data/information – gives a quick synopsis
	11	Water quality monitoring	Discussion paper only
	49	All aspects	Narran Lakes Nature Reserve Management Plan – key document
	52	Ecological condition	Extends knowledge, but limited due to design and analysis issues, not conclusive in determining condition of Lower Balonne rivers
	73	Water requirements for waterbirds	Valuable
	30, 89, 135	Hydrology	WAMP – useful data, some flawed indices, limited data on Narran Lakes
	115	Geomorphology – hydrology	Useful but limited – honours thesis
	117	Geomorphology – hydrology	Useful but limited – honours thesis
2001	118	Zooplankton on floodplain	Baseline study – honours thesis
	122	Ecological indicators of flow	Limited – pilot study – limited coverage of Lower Balonne and Narran River in particular.

2 HYDROLOGY REVIEW

2.1 The Lower Balonne region

To understand the hydrology of the Lower Balonne one must first comprehend its regional geomorphology. The Lower Balonne is a name that has been applied to that section of the Condamine-Balonne catchment downstream of St George (see Figure 1.1). Here, the landscape resembles a large low-angle alluvial fan. Sediments eroded from the catchment upstream have been deposited in a large tectonic depression created over 65 million years ago because of movements in the basement rocks of the upper Barwon-Darling Basin. The depression is approximately 40 km wide. Upstream of St George, the Condamine-Balonne River system is contained within a relatively narrow valley floor trough that is up to 2 km wide. The sudden expansion of the valley floor trough downstream of St George creates a very low energy environment that is conducive to sediment accumulation. Thus, the Lower Balonne is a complex, low gradient landscape that is dissected by a series of river channels. Downstream of St George, the Balonne divides into six channels (the Balonne Minor, Culgoa, Bokhara, Ballandool, Briarie and Narran) and forms an anastomosing river system.

Table 2.1 The channel morphology of rivers in the Lower Balonne region[132].

River	Length (km)	Sinuosity	Meander Wavelength (m)	Bankfull Area Median (m^2)	Classification as per Schumm[131]
Culgoa	245	1.1	611	154	Straight
Narran	201	1.2	568	91	Straight
Briarie	227	1.3	520	70	Transitional
Bokhara	245	1.6	485	40	Transitional
Ballandool	105	1.2	566	55	Straight

The morphological character of a river channel, especially its bankfull channel, is indicative of the hydrology of the surrounding catchment. Thoms and Brunner[132] have investigated the morphology of the individual channels of the Lower Balonne region. This study suggests that these channels are quite different in morphology from the main Condamine-Balonne River upstream of St George.

- The six main river channels of the Lower Balonne have different morphological characters and are different to the main Condamine-Balonne River upstream of St George (Table 2.1). All individual channels are smaller in size than the main channel, especially in terms of their bankfull cross sectional area, or bankfull capacity. Reduced bankfull capacity results in large amounts of water being conveyed across the floodplain of the Lower Balonne;
- Each of the six river channels reduces its bankfull capacity with distance downstream, thus increasing the importance of overbank or floodplain flows. Briarie Creek is the exception with a significant increase in bankfull area with distance downstream;
- Statistical analysis of channel morphology suggests that the outer channels (ie. the Culgoa and Narran) are more similar to each other than they are to the inner channels (Briarie, Bokhara and Ballandool). Hence, flow conveyance along the Culgoa and Narran Rivers may have different character in terms of times of water travel and the nature of individual flood pulses; and,

- In terms of surface area, floodplain areas dominate the Lower Balonne River system. Hence, regular inundation or hydrological connections between the main river channels and their associated floodplains and other aquatic habitats, like terminal lakes, are important for maintaining the ecological integrity of the system.

2.2 The hydrological network of the Lower Balonne

There are 22 gauging stations listed for the Lower Balonne region in Stream Gauging Information, Australia. Nine of these are in Queensland and the rest in New South Wales. Only 17 stations are currently active. The majority of gauging stations provide only a 'fair' quality of data and have a data length less than 35 years. The flow data record for the region varies from 26 to 64 years. Summary discharge statistics for some of the stations are provided in Table 2.2. Given the inherent variability of flows in the wider region[133] and the requirement of a data series that exceeds 35 years in length there are few stations in the region that can provide adequate hydrological information, especially for flood analyses.

Table 2.2 Summary discharge statistics for gauging stations in the Lower Balonne. Discharges are in megalitres per annum.

River	Year	Station	Median	Mean	CV	Skew	Min	Max
Culgoa	1965–1995	422204	298,300	464,523	103	2	9,142	2,260,000
Culgoa	1965–1995	422208	284,600	393,463	94	0.88	7,100	1,455,000
Culgoa	1965–1995	422015	271,700	436,480	103	1.37	2,522	1,621,000
Culgoa	1965–1995	422017	214,700	313,401	96	1.14	2,897	1,125,000
Culgoa	1965–1995	422011	221,600	257,449	85	1.898	6,976	959,300
Culgoa	1965–1995	422006	255,900	437,854	120	1.936	5,034	2,261,000
Narran	1965–1995	422206	119,000	206,802	130	2.35	165	1,237,835
Narran	1965–1995	422012	104,200	171,657	113	1.6	0.1	783,700
Narran	1965–1995	422016	83,115	135,999	102	1.09	0	447,600
Briarie	1965–1995	422211	6,988	79,047	200	3.3	0	781,600
Birrie	1965–1995	422013	26,180	90,816	170	3	0	762,000
Birrie	1965–1995	422010	32,940	88,890	130	1.507	0	384,600
Bokhara	1965–1995	422209	29,950	67,961	135	2.5	589	436,400
Bokhara	1965–1989	422014	15,326	66,454	165	2.676	7	506,846
Bokhara	1965–1989	422005	24,545	68,658	162	2.3	0	460,500
Ballandool	1965–1995	422207	18,390	63,444	181	3.5	127	584,772

There are six Bureau of Meteorology rainfall stations in the region, some of which provide long-term rainfall data. For example, the long-term median annual rainfall for the region ranges from 517 mm at St George (1991–1998) to 410 mm at Hebel (1921–1996). Rainfall generally decreases from east to west across the region and also in a south westerly direction (Table 2.3). Variability is a feature of the annual rainfall of the region. In particular there are periods of 30 to 40 years where rainfall is consistently greater or less than the long-term average. Rainfall is also highly seasonal with the majority occurring in the summer months (December–February). Rates of evaporation are high (ie. >2000 mm y^{-1}) because of high temperatures. Evaporation also increases across the region in a westerly direction.

Examination of the actual flow data available for the region reveals that flows are highly variable in both time and space (Table 2.4). Most of the flow downstream of St George is conveyed through the outer Culgoa and Narran channels. On average, 35% of the annual flow of the Balonne River at St George is conveyed down the Culgoa at the Queensland/NSW border, 28% down the Narran, 6% down the Bokhara, 7% down the Ballandool and between 2–9% down the Briarie. The remainder is lost either through evaporation or transmission. Periods of no flow are common in all channels.

Table 2.3 Rainfall data for the Condamine-Balonne Catchment. na = not available.

Position in catchment	Gauging station	Annual average (mm)	Monthly average (mm)	Maximum (month)	Minimum (month)
East	Warwick	710	59.2	92.5 (Jan)	36.1 (Aug)
	Mitchell	570	47.6	82.1 (Jan)	23.9 (Aug)
	St George	517	43.1	74.7 (Jan)	25.3 (Aug)
West	Hebel	410	na	na	na

Flows are highly seasonal in the region and floods generally occur in late summer (January to February) and also in late autumn/early winter (May to June). Periods of low flow generally occur during spring (September to October). There is a poor relationship between local rainfall and discharge, because rainfall runoff from the floodplain is limited. Hence, flood flows are generally dependent on rainfall and runoff generated in the upper catchment. Floodplain inundation begins to occur when discharge exceeds 30,000 to 40,000 ML/day at St George, and major flooding occurs when flows reach 110,000 ML/day[63]. These floods have average return intervals of 1 in 2 years and 1 in 5–10 years respectively (Table 2.5). During the period 1988 to 1996 floodplain inundation of 30,000–40,000 ML/day occurred on eight occasions. This highlights that floods can occur regularly on the floodplain, although they are not highly predictable.

Daily flow duration curves indicate that periods of low discharge are an important component of the flow regime of the Lower Balonne river system. Low flows occur at least 50% of the time (Table 2.4). During periods of drought, flow in the six main river channels can cease, and the channels are reduced to a series of discontinuous waterholes. The Ballandool and Bokhara Rivers only flow during times of higher discharge, while Briarie Creek flows only in larger events. These channels exhibit similar daily discharges for the majority (90%) of the time. The Culgoa River is the dominant flow path through the Lower Balonne River floodplain, during periods of both low and high flow. During less frequent larger floods other channels become more prevalent. Flow through the Culgoa remains relatively steady during higher discharges. During high flows, large quantities of water are conveyed across the surface of the lower Balonne floodplain (Table 2.4), which facilitates harvesting of floodplain flows.

Table 2.4 Daily flow duration analysis for the Lower Balonne River system ($m^3 s^{-1}$; 1965–1997). Rivers are listed in order of decreasing total annual discharge volume with component gauging stations listed in downstream order.

		% equalled or exceeded										
River	**Station**	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Balonne	422201	2500	60	15	6	3	1	0.5	0.1	0.01	0.00005	0.000001
Balonne-minor	422205	900	35	7	2	0.3	0.0001	0.00006	0.00005	0.00003	0.00002	0.000001
Culgoa	422204	400	30	6	3	2	1	0.4	0.08	0.00001	0.00001	0.00001
Culgoa	422208	200	50	15	5	2	1.5	0.8	0.3	0.0005	0.00001	0.00001
Culgoa	422015	600	43	7	2	1.5	0.8	0.1	0.0001	0.00002	0.00001	0.000001
Culgoa	422017	150	48	7	3	1.5	0.7	0.2	0.00001	0.00001	0.00001	0.00001
Culgoa	422011	200	40	8	3	2	0.9	0.2	0.03	0.00001	0.00001	0.00001
Culgoa	422006	700	75	20	5	3	1	0.5	0.06	0.00001	0.00001	0.00001
Narran	422206	350	20	4	2	0.5	0.02	0.00007	0.00005	0.00003	0.00001	0.000001
Narran	422012	150	15	2.5	0.6	0.03	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001
Narran	422016	100	15	2.5	0.6	0.06	0.000025	0.00002	0.000015	0.00001	0.00001	0.00001
Briarie	422211	200	6	0.1	0.00004	0.000035	0.00003	0.00002	0.000015	0.00001	0.00001	0.00001
Birrie	422013	170	5	1	0.05	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Birrie	422010	95	6	2	0.1	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Bokhara	422209	100	6	2.5	1.5	0.2	0.00004	0.000025	0.00002	0.00001	0.000008	0.000001
Bokhara	422014	200	4	2	0.23	0.00004	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001
Bokhara	422005	200	7	1	0.15	0.02	0.002	0.00001	0.00001	0.00001	0.00001	0.00001
Ballandool	422207	200	4	1.5	0.4	0.1	0.0004	0.00004	0.00003	0.00002	0.00001	0.000001

Table 2.5 Flood frequencies at various stations in the Lower Balonne River system ($m^3 s^{-1}$; 1965–1999). Rivers are listed in order of decreasing total annual discharge volume with component gauging stations listed in downstream order. * = no data.

		Average Return Interval (1:Y)								
River	**Station**	**1.11**	**1.5**	**2**	**2.33**	**5**	**10**	**20**	**50**	**100**
Balonne	422201	53	200	411	508	1113	1697	2000	3066	3627
Balonne-minor	422205	56	150	257	312	644	1014	1450	2167	2797
Culgoa	422204	30	90	202	228	357	414	425	463	469
Culgoa	422208	48	70	111	121	167	200	220	258	278
Culgoa	422015	13	75	130	165	319	434	524	608	651
Culgoa	422017	13	60	80	90	114	120	121	121	123
Culgoa	422011	25	65	88	97	119	126	128	128	128
Culgoa	422006	9	80	98	115	230	306	361	409	431
Narran	422206	21	45	115	140	284	427	510	794	961
Narran	422012	12	40	64	80	95	102	104	104	104
Narran	422016	17	35	47	55	70	80	87	93	96
Briarie	422211	0	0	27	38	86	125	160	212	249
Birrie	422013	10	10	19	25	64	116	187	315	441
Birrie	422010	4	8	17	20	42	65	91	131	165
Bokhara	422209	12	12	23	28	55	85	100	174	221
Bokhara	422014	0.7	*	25	*	46	49	49	50	55
Bokhara	422005	0.3	*	15	*	46	60	68	70	71
Ballandool	422207	15	15	30	39	100	176	290	445	602

There are six historical gauging stations on the Narran River system; one in Narran Lake itself and the rest on the upstream river system between Dirranbandi and Wilby Wilby. The majority have flow data rated as either 'fair' or 'good' and there have been no detailed hydrological analyses of the flow data recorded at any of these sites. In particular the gauging station in Narran Lake only has a continuous or useable data period from 1988–90 with which to investigate the hydrology of the lake.

2.3 Flows and their association with floodplain and lake inundation

There have been few detailed quantitative studies on the inundation character of the floodplains of the region or the hydrology of the Narran Lakes. Those that have been undertaken were done in the Queensland section of the Lower Balonne. Pearce[129] used remotely sensed images of three flood events to investigate the inundation character of the Lower Balonne. This work was extended by Sims *et al.*[63], who used remotely sensed Landsat TM images of 16 different flood events to investigate floodplain inundation. Landsat TM is an earth resources remote sensing satellite that measures the strength of sunlight reflecting off land surfaces. A detailed flooding map was constructed for the Lower Balonne to highlight the main flow paths across the floodplain and the areas most susceptible to inundation (Figure 2.1). There are distinct flooding or flood frequency zones in the Lower Balonne and it appears that flood frequency is not simply related to distance away from the man river channels — an association commonly found in many floodplains. Inundation patterns are complex and appear to follow the courses of palaeo channels present across the region.

The distribution of floodwater strongly influences the distribution of floodplain vegetation communities across the Lower Balonne floodplain. There are five main vegetation communities in the Lower Balonne that vary across the floodplain in response to distance from individual watercourses, and along the floodplain in response to flooding pattern. Coolibah (*Eucalyptus coolabah*) and River Red Gum (*E. camaldulensis*) are located adjacent to watercourses, while Lignum (*Muehlenbeckia cunninghamii*) and nutgrass (*Cyperus bifax*) are found in areas of moderately high inundation frequency. Areas that are not watered as often (ie. that have a low inundation frequency) are dominated by open and dry grassland types, particularly Neverfail (*Eragrostis setifolia*), Lovegrasses (*Eragrostis* spp.), Buffle Grass (*Cenchrus ciliaris*) and chenopods. The distribution of the various vegetation communities resembles a patchwork quilt, with each patch having its own story of watering, supply of nutrients and genesis.

There has not been any detailed investigation of the hydrology of Narran Lakes, although numerous departmental memos do exist. The following provides a summary of information contained in various reports held by the NSW DLWC and NSW NPWS.

- There are limited topographical data for the lakes. Some bathymetry data exist at a resolution of one metre but this is considered to be too coarse for any detailed study of lake hydrology because of the relatively flat terrain of the region.
- There is only one water level recorder for the Narran Lakes system. This is not sufficient to allow a detailed investigation of hydrology of the entire Narran system.
- The estimated combined capacity of the lakes is 185,410 ML. Narran Lake has a capacity of 176,000 ML and Clear/Back Lake has a capacity of 9,350 ML[10]. The NSW NPWS have, however, estimated the capacity of the latter as 28,844 ML, which raises concern over the validity of these figures.
- Other morphological data for the lakes indicate a maximum water depth of 3.5 m and 6 m for Clear/Back Lake and Narran Lake respectively, and surface areas of 1,500 and 9,420 ha.
- During high flows, the Narran River branches to fill Clear Lake. Once Clear Lake fills and exceeds capacity, water backs up and flows via a series of small channels into Back Lake. Filling of Narran Lake, the last in the sequence of the lakes, occurs via flows from the Narran River and overflows from Clear and Back Lakes.
- Clear and Back Lakes may retain water for up to 4–12 months after an infilling event. Narran Lake, being larger, can retain water for over 12 months.

The hydrology of the Narran Lakes is dominated by flows from the Narran River, local rainfall (which can inundate large areas of low-lying Lignum) and evaporation. Crude calculations suggest that Clear/Back Lake and Narran Lake would dry in the absence of rainfall or river flows. Indeed, observations by NSW NPWS staff suggest that after filling, water levels in Back Lake can drop steadily by over 1 cm/day. This highlights the importance of evaporation and other losses in the system. The influence of groundwater in the Narran Lake wetlands is uncertain and has been identified as a knowledge gap requiring further work.

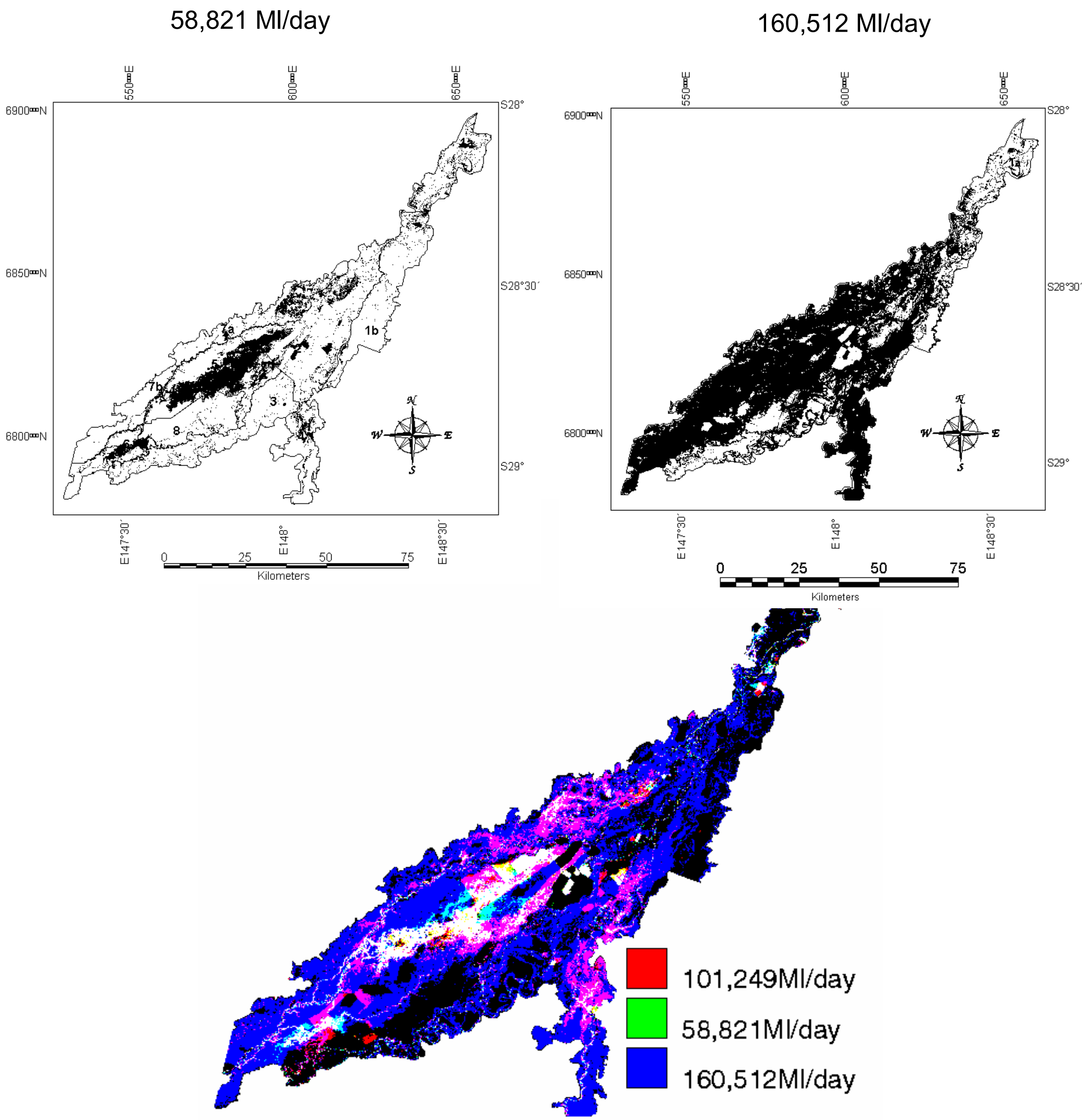

Figure 2.1 The inundation character of the Lower Balonne floodplain between St George and the NSW/Queensland border. The map shows the distribution of floods of different magnitude.

Detailed quantitative relationships of river flow and lake volumes have not been published or reported in government documents. Similarly, studies of the water balance of these systems have not been conducted, although observations by NSW NPWS staff suggest the following:

- the reliability of flow data from the Narran Bridge, New Angledool and Wilby Wilby gauging stations is questionable
- flows of approximately 80 ML/day or greater in the Narran River at Wilby Wilby are required to reach the terminal lakes system
- the average recurrence of floodplain inundation in the terminal lake system is one every two years over a 60 year period (1915–78), and
- discharges in excess of 9,000 ML/day and 5,500 ML/day at Angledool and Wilby Wilby, respectively, may result in a water level of approximately 1 m in Back Lake.

2.4 Simulated flow data

There are limited historical flow data and this makes it difficult to assess the impact of water resource development on the hydrology of the region. Moreover, the rapid rate of water resource development combined with the naturally variable flow also makes it difficult to evaluate the impact of development on the hydrological regime using historical data. Therefore, simulated flow data are relied upon to assess the hydrological impact of water resource development in the Lower Balonne and Narran Lakes system.

Both the Queensland Department of Natural Resources and Mines (Queensland NR&M) and the New South Wales Department of Land and Water Resources (NSW DLWC) use a water resource flow model for water planning purposes in the regions. The Integrated Quantity Quality Model (IQQM) produces simulated flow data for many locations throughout the Condamine-Balonne Catchment. IQQM is a generic, hydrological, river system simulation package that can be used to investigate new water resource management policy options, or refinements to existing policies[139]. The model is a strategic planning tool designed to guide water-sharing at the river basin, inter-state or international level, and among competing groups of users including the environment. IQQM simulates river system behaviour at a daily time step with an option to use smaller time steps for some processes.

IQQM is structured as a modelling shell with component modules linking together to form an integrated package. This shell allows the incorporation of additional component modules as required. The main components of IQQM are:

- user interface shell;
- in-stream water quantity;
- in-stream water quality;
- rainfall-runoff;
- pollutant washoff and export;
- groundwater quantity and quality;
- statistical tools; and,
- climate data generation tools.

IQQM uses two basic units for representing river systems:

- nodes — which represent points on a river system having certain operational or physical processes associated with them; and
- links — which represent river reaches between nodes.

To apply IQQM to a river system it is necessary to configure the model to represent the physical features in the system, and the water management system. Configuring for physical features involves defining locations of storages, demand centres, tributary inflows, effluent outflows and returns, floodplain detention storages and limits of flow routing reaches. Configuring for the water management system involves defining system operating rules such as flow thresholds for unregulated flow licences.

The implementation of IQQM involves calibration and validation of the instream water quantity component in a two-stage process. Stage 1 requires the derivation of values of flow routing coefficients, effluent flow and transmission loss relationships, and relationships describing floodplain storage behaviour. In Stage 1, the model is run with recorded values of water diversions at each irrigation node. In Stage 2 of the calibration, values of parameters relating to irrigation demands are derived and compared with available data.

When interpreting the results obtained from a model such as IQQM, due recognition needs to be given to the purpose of the model, the limitations of the data used to calibrate and validate the model and the limitations of the model itself. In particular it needs to be recognised that:

- IQQM is a planning tool that is intended to provide information on long-term future system performance and behaviour under given scenarios of management rules and physical constraints. It can provide a great deal of valuable information on a daily, monthly, seasonal, annual or longer basis, in a statistical sense. IQQM cannot be used to hindcast, say, the flows that would have occurred on a specific date in the past under a given scenario. For example, the model may not reproduce the timing of a flood precisely although it may simulate the hydrograph volume and shape correctly; this does not matter in a planning model but it may be critical in other applications such as flood forecasting.
- In current modelling practice, the prediction of long-term future performance using models such as IQQM is based on historical hydrologic data (rainfall, streamflow, evaporation). A major limitation of this approach is that it basically assumes that the future will be a repeat of the past, which is clearly unlikely. An interpretation commonly used is that model results show what would have happened in the past had the scenario being modelled been in place then. On this basis the model could be used to hindcast past system performance, but only in a statistical sense and not in terms of comparing modelled and actual behaviour on given dates.
- There are limitations in the accuracy of the input data. In the case of streamflow data the accuracy in the mid-flow range is usually 20% at best. At low flows and high flows the accuracy is generally very much worse and can frequently be no better than +100%/–50%. Accuracy is affected by channel bed stability at low flows and by erratic overland flow behaviour at high flows, both of which are problems in many rivers in the region. There are limitations in the accuracy of other data used in model calibration, such as water use data that are incomplete or contain anomalies as discussed earlier. Metering will largely overcome errors in water use data. There are uncertainties in calibration that are directly related to uncertainties in available data. Hence, great care must be taken during calibration to minimise data uncertainties and impacts on subsequent study results, however, there will still be data-related uncertainties in model results.

There are many stations or nodes in the Lower Balonne where simulated flow data have been generated. The nodes for which data were available for this scoping study were; the Balonne @ St George, Culgoa @ Whyenbah, Culgoa @ Woolerbilla, Ballandool @ Hebel, Bokhara @ Hebel, Narran @ Hebel and Lake Narran. It is pertinent to note that there is only a water resource flow model for the Queensland section of the Lower Balonne region. Hence, knowledge of the potential impact of water resource development on the majority of the region and Narran Lakes is limited. Furthermore, there has been substantial water resource development in the region since 1996–97 when the model was constructed.

2.5 Impact of water resource development and land use change on the Lower Balonne

There are various simulated IQQM data sets available for the Lower Balonne. These data sets have been analysed to examine the impact of water resource development. Simulated 'reference' flows were compared with simulated 'current' flows for the period 1900–98 for several stations in the Lower Balonne region. The 'reference' output is simulated with a zero setting for flow regulating structures, abstractions of water and catchment development, and uses long-term mean climatic conditions. These 'reference' flows are assumed to represent natural flow conditions. The 'current' simulated output uses water and catchment development conditions present in 1996–97 and also uses long-term mean climatic conditions.

Comparisons of simulated outputs have been made for annual and monthly volumes and flood discharges. Annual series flood frequency analyses were performed on the 'reference' and 'current' simulated data sets for each station using a Log Pearson III distribution[130]. Development has not impacted all flood flows equally, therefore discharges were partitioned according to their Average Recurrence Interval (ARI) in years and compared.

Changes in the hydrology of the Lower Balonne system at St George are summarised in Table 2.6. Water resource development has reduced the total volume of water entering the Lower Balonne region as well as the frequency of smaller floods (up to an ARI of 10 years). Hydrological changes have also had an influence on the number of events and the duration of individual flow events in the Lower Balonne (Figure 2.2). A comparison of simulated reference and current data suggests that there has been a reduction in the number of flood events and their duration with water resource development. In the Narran River for example, there has been a reduction in the median number of flow events by up to 31% and the duration of these events have also been reduced.

Table 2.6 Hydrological change in the Condamine-Balonne system at St George, calculated using simulated flow data (IQQM) for 1900–1998.

Parameter	Reference	Current	% Change
MEDIAN ANNUAL (ML)	976,997	688,457	– 29.53 %
1.5 ARI (ML/day)	31,813	16,672	– 47.59 %
2 ARI (ML/day)	56,287	43,879	– 22.04 %
5 ARI (ML/day)	123,663	118,268	– 4.63 %
10 ARI (ML/day)	183,788	166,832	– 9.22 %

Development in the Lower Balonne region has also brought about a loss of active floodplain area. The majority of this development has occurred in the Queensland section of the Lower Balonne and development has been relatively rapid since the late 1980s (Table 2.7).

Water resource development has also had an impact on floodplain sediment character. Sediments deposited on floodplains are indicative of the environment in which they were laid down. They provide historical records of material transported from the upstream catchment and of biota living within the floodplain river system. The physical, chemical and biological character of these sediments can be used to reconstruct the condition of floodplain rivers before and after the advent of human activities. Thus, palaeo-ecological investigations of floodplain areas can establish benchmarks of river condition or health.

Table 2.7 Floodplain development in the Lower Balonne, downstream of St George.

Parameter	1998	1999
Cropped area (ha)	4,300	38,650
Dam storage capacity (ML)	54,750	592,500
Dam surface area (ha)	1,825	19,750
Total area (ha)	6,125	58,400

Sediment cores extracted from the Lower Balonne floodplain system reveal how the floodplain has functioned over the last 1,000 years, and how it has changed in recent years. Figure 2.3 shows a representative sediment core extracted from the Lower Balonne floodplain. The stratigraphy (the study of the order and relative position of layers of sediments) of cores indicates that there was a marked change in the nature of sediments being deposited in the Lower Balonne floodplain approximately 60–80 years ago. Prior to European settlement the Lower Balonne received pulsed inputs of sediment, nutrients and carbon. This pulsing is a characteristic of dryland ecosystems. However, since European settlement the following have occurred[115, 128]:

- Rates of sedimentation have increased by an order of magnitude (0.029 to 6.66 cm year^{-1}). Large quantities of sediment accumulate in floodplain areas because of increases in sediment supply resulting from upstream land use changes.
- The texture and geochemistry of sediments has also changed suggesting a different upstream source of sediments. It is pertinent to note that some of the sediment cores have high salinity levels. Average core salinity ranges from 0.17 to 1.56 mS. Salinity of 0.6 mS can inhibit plant growth while salinities >1.8 mS are detrimental to sensitive crops and salinities >7.7 mS are detrimental to tolerant crops such as cotton. In parts of the Lower Balonne floodplain salinity is high (5.9 mS) at relatively shallow depths (~1m) and is detrimental to plant growth.

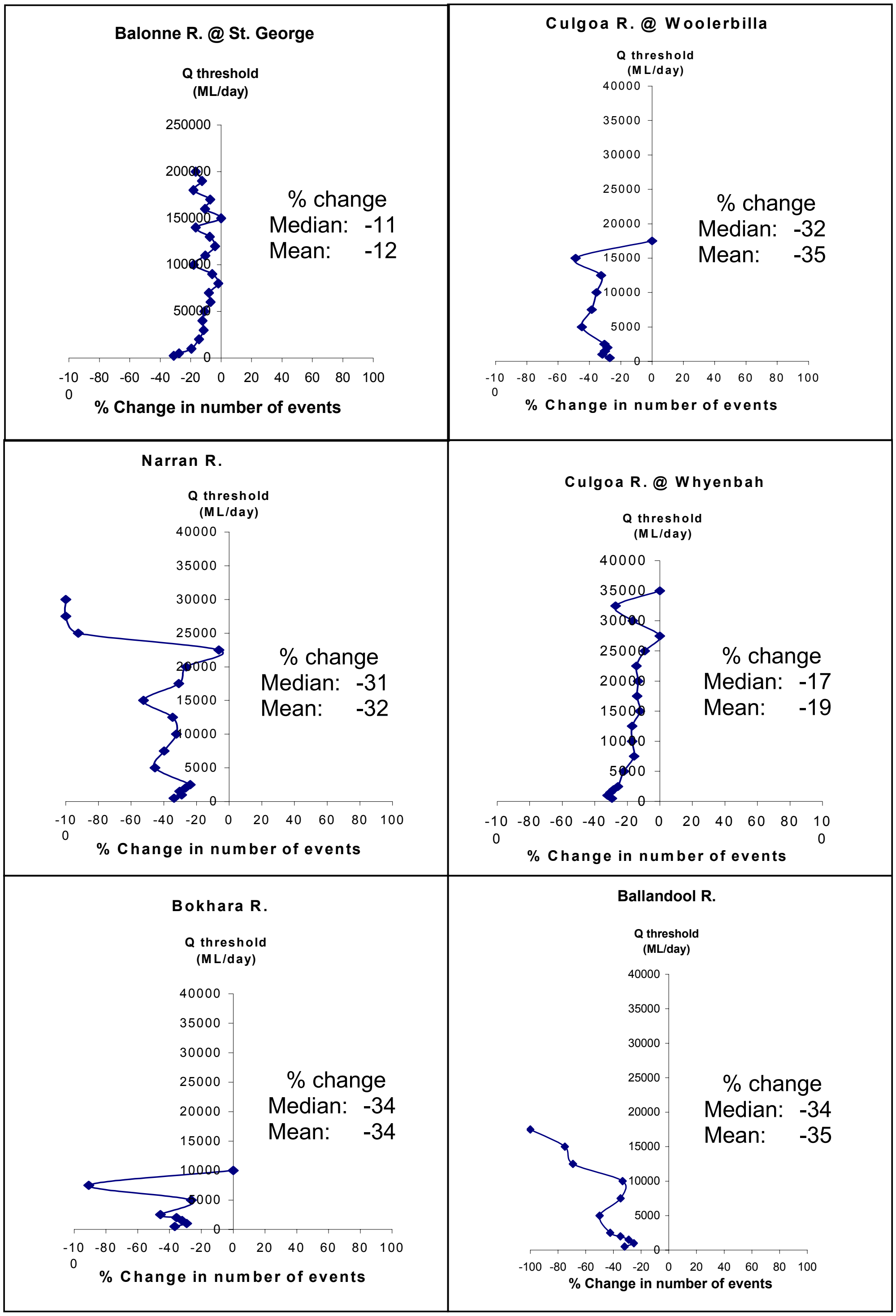

Figure 2.2 The percent change in the number of flow events of different sizes. A comparison of simulated reference and current conditions for the period 1898–1999 was used.

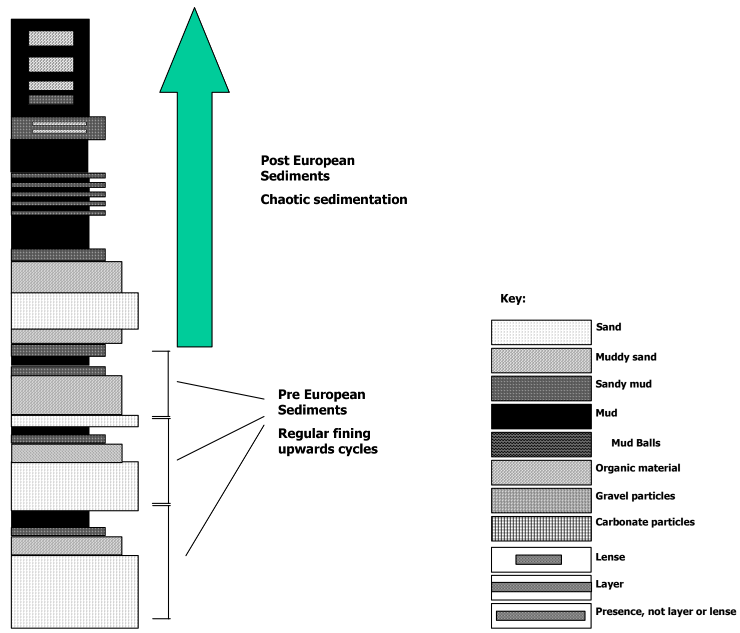

Figure 2.3 Sediment profile from the Lower Balonne floodplain

2.6 Implications of water resource development

The ecological condition of the Lower Balonne system is partly maintained by hydrological connections between the floodplain, river channels, and other water bodies in the region (e.g. Lake Bokhara). Associated with a highly variable flow regime is a dynamic wetting and drying cycle of the adjacent floodplain surface. The wetting and drying regime of floodplains is recognised as an important factor in determining the distribution and structure of plants and animals and for controlling the exchange of nutrients and carbon between river channels and floodplains.

McGinnes and Thoms[127] have demonstrated that the floodplain soil surface of the Lower Balonne is an important potential source of dissolved organic carbon (DOC). Indeed, their experiments noted that 97% of the total organic carbon released from the floodplain soil surface upon wetting was in the dissolved form. In conjunction with data on changes in floodplain hydrology they suggest that water resource development has markedly reduced quantities of DOC being released from the Lower Balonne Floodplain (Figure 2.4). Approximately 33,300 tonnes of DOC would have been made available under ‘reference’ conditions compared to 26,200 tonnes under ‘current’ conditions, for the period 1986–1995. Annual reductions in DOC range from 144 tonnes to 1,326 tonnes for the same period.

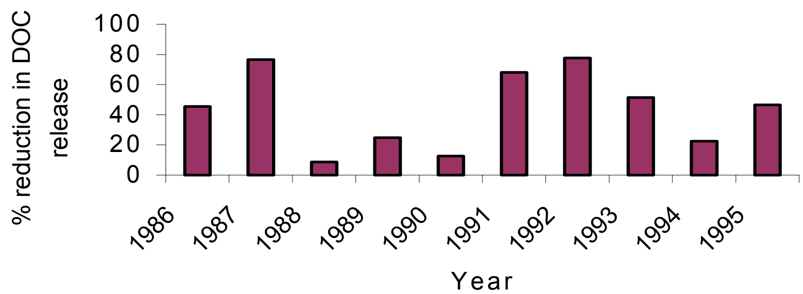

Figure 2.4 Annual reductions (reference to current) in dissolved organic carbon release from the Lower Balonne Floodplain, 1986–1995.

It also appears that water resource and floodplain developments have had a differential impact on DOC dynamics of the Lower Balonne floodplain. For example, McGinness and Thoms[127] calculated that small flood events (e.g. ARI of < 2 years) have suffered the greatest impact, with reductions in flow magnitude between 22 and 48%. To further elicit the impact of development on the release and hence potential supply of DOC from the Lower Balonne Floodplain, the quantity of material available in floods of different magnitudes was calculated. Larger floods release and therefore potentially make available more DOC because they inundate a greater floodplain surface area. For example, a flood with an ARI of 10 years would initiate the release of an average of 520 t of DOC, compared to 90 t from small flood with an ARI of 1.5 years. The impact of water resource development on DOC release from the floodplain surface is presented in Figure 2.5. A change in the hydrological regime alone reduces the potential supply of DOC by 7.6% for floods with an ARI of 10 years, and by up to 50% for smaller floods with an ARI of 1.5 years. Floodplain development further reduces this by 23 to 50%. Indeed, the combined impact of water resource and floodplain development completely eliminates the role of smaller floods (ARI <1.5 years) in triggering a DOC release from the floodplain surface. Under current hydrological and floodplain development conditions the potential supply of DOC from the floodplain would be reduced by 23 to 100%. These figures are likely to be an underestimate of the true impact of regulation on DOC dynamics because the carbon is produced by the floral community whose production is dependent on flooding. Reduced flooding is likely to reduce the DOC stored in the floodplain and which is therefore available for release.

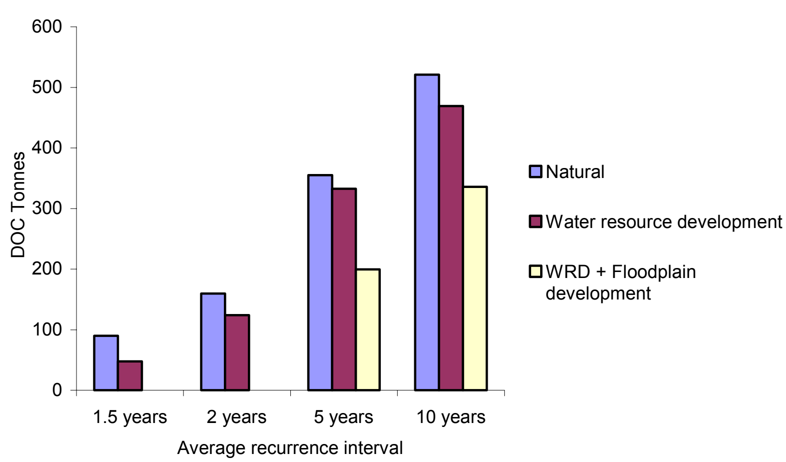

Figure 2.5 The influence of water resource development (WRD) and floodplain development upon the potential release of dissolved organic carbon (DOC) from the Lower Balonne Floodplain during floods of different average recurrence intervals.

Changes in floodplain inundation can also influence soil productivity but this will depend on the nutrient in question. For example, Ogden and Thoms[128] have shown that water resource development should have little impact on the phosphorus (P) fertility of soils because floodplains in the Lower Balonne region are composed of P-rich material. Moreover, a century of grazing by cattle and sheep has not depleted soil P reserves in areas that flood less commonly (once every 2 or more years) or areas that are not flooded. However, reduced flooding will have an impact on N fertility and hence may limit plant growth. Most floods in the Lower Balonne provide an N subsidy and water extractions can thus be expected to decrease regional plant productivity.

2.7 The importance of lag effects

Inland river systems like the Condamine-Balonne respond to three scales of hydrological behaviour: the flow regime, the flow history, and the flow pulse. Thoms and Sheldon[133] suggest that the initial impact of water resources development will always be centred on a change in the nature of the flood pulse, and that continued change will result in a change in flow history leading eventually to change at the scale of the flow regime. Concurrently, the time scale of ecological change, from organism-level responses, through population and community changes and finally ecosystem-level change, will depend on the organism, group of organisms, or ecosystem component in question. This suggests that with any hydrological change there will be a lag time before the ecological response can be detected, and the extent of this lag time will depend on the component in question. For many of the more familiar organisms (large fish, riparian trees) there would be a considerable lag time, with recent hydrological development taking possibly decades to be transferred into detectable environmental impact. Studies undertaken in the Lower River Murray by Thoms and Walker[140] have demonstrated that physical changes brought about through changes to the hydrology of the river and weir construction are still incomplete after 70 years.

3 CONSERVATION AND ECOLOGY REVIEW

3.1 Ecological features

Much of the information used to write this review of the ecology and conservation significance of biota found in the Narran Lakes and Lower Balonne region is from only a few localities. Very little work has been done on Narran Lake and Back Lake. In many cases when data are said to be from the Narran Lakes, most are from Clear Lake only. A clear understanding of the ecology of the terminal wetlands as an interconnected complex is lacking. Similarly the information on riverine and floodplain ecology is also limited to a few sites.

3.1.1 Waterbirds of Narran Lakes

The Narran Lakes Nature Reserve was declared a Ramsar Wetland of International Importance in June 1999, and is recognised as one of the most important waterbird habitats in NSW and Australia. Clearly, changes to flow regimes in the Narran River and wetlands will have an impact on avifauna. The impacts of flow regime changes on characteristics of waterbird habitat should be an important area of future research. Such research will need to be coordinated with on-going investigations conducted by NSW NPWS.

Population movements and abundance of waterbirds are predominantly driven by rainfall, with subsequent flooding of wetland habitat providing food and breeding/nursery refuges[84]. The actual drivers which trigger successful breeding events are unknown for the Narran Lakes system, but are believed to include the size of the area flooded, the rate at which water arrives, the time of the year and the overall period of inundation at both local and regional scales. All of these are linked to rainfall, which is important in successful breeding events[49,73]. Ibis and other waterbirds have been known to abandon nests and young if water levels drop suddenly. This may be related to a problem with food resources or it may be a response to increased risk of predation[49,73].

Data on 10 breeding events for waterbirds in Narran Lakes from 1971 to 1991 showed that the majority of records were from Clear Lake (8 records), then Back Lake (6 records) and Narran Lake (3 records)[34]. Large breeding events were only recorded for all three wetlands in the system in 1983[34]. This bias does not reflect a clear preference of the birds for the two smaller lakes but rather is one of logistics – aerial surveys are required to adequately survey Narran Lake (M. Maher, NSW NPWS, pers. comm.). Narran Lake holds water for longer than the two smaller lakes in the reserve and is important as both an extensive feeding ground and as a breeding area in its own right[49]. Significant breeding events for the Magpie Goose *Anseranas semipalmata* and the Australian Pelican *Pelecanus conspicillatus* have been recorded on Narran Lake only[49, 77]. Results from aerial surveys of waterbirds on Narran Lake over the period December 1998–June 1999 support earlier work that identifies Narran Lake as a significant breeding site in its own right, as well as a feeding ground for the breeding colonies found in the Narran Lakes Nature Reserve wetlands[78]. It is possible that as the two smaller wetlands dry out, the larger Narran Lake becomes more important to waterbirds, with the duration of water inundation and food resources being the most likely critical factors in sustaining large populations of waterbirds.

Sixty-five species of waterbirds have been recorded in the Narran Lakes in the past decade, 46 of which breed in the wetland system[49, 73, Appendix A]. This is slightly more diverse than the Currawinya wetlands to the west on the Paroo River and comparable to the Macquarie Marshes[99], both of which are also Ramsar Wetlands of International Importance. Five species of waterbird are listed under the NSW Threatened Species Act (1995). These are the Brolga *Grus rubicunda*, Blue-billed duck *Oxyura australis*, Freckled Duck *Stictonetta naevosa*, Magpie Goose *Anseranas semipalmata* and the Black-tailed Godwit *Limosa limosa*[49]. At least eight species are of conservation concern in western NSW and eight of the wader species are listed under international agreements for migratory waders[49]. The Narran Lakes are significant waterbird breeding sites with the largest ibis-breeding event in Australia being recorded in the lakes in 1983. The lakes are one of the 12 most significant ibis breeding sites in Australia.

A major concern of the NSW NPWS in the management of Narran Lakes is a lack of understanding as to how the waterbirds utilise the whole wetland complex and floodplains of the region. As stated above it is unclear how important Narran Lake is to waterbirds during breeding events in the other two wetlands to the north, where as many as 200,000 birds can be raising young[78]. The NSW NPWS Narrabri office intends to continue monitoring waterbirds to:

- gather information over the long term on the breeding activity of key colonially nesting species and to relate this information to amounts of water; and,
- record general waterbird information, such as waterbird species, numbers and breeding, to determine utilisation of the nature reserve by waterbirds[73].

The inclusion of Narran Lake proper in the monitoring program is dependent on securing funding to undertake aerial surveys. The ultimate aim of the survey work is to develop a monitoring program that will help determine the relationship between breeding success and hydrology and other environmental variables[49].

3.1.2 Birds of the Narran River Floodplain

Estimated numbers of breeding pairs for 34 species over the period 1988–1991 represents the only information provided on waterbirds associated with the Narran River floodplain[35]. The information supplied gives no indication of methods or why data were collected. However, there are 12 significant floodplain wetlands fed largely by the Narran River, with anecdotal evidence suggesting that large waterbird colonies utilise the wetlands during periods of flooding (L. Benson, pers. comm.).

A total of 105 species of landbirds have been recorded from the Narran area[49]. Other surveys in the region have recorded 85 species from the Narran River floodplain[82] and 113 species (including one introduced) from the Culgoa and Birrie river floodplains[87]. In all surveys it was noted that most species showed a preference for the woodlands associated with the floodplain[49, 82, 87]. Five species from the Narran Lakes Nature Reserve are listed under the NSW Threatened Species Act (1995) with a further two listed species being recorded during 1990–1992 on the Culgoa and Birrie floodplains. (Table 3.1)[87].

In a study of the biodiversity of the NSW NPWS-managed Lumeah property adjacent to the Narran Lakes Nature Reserve, a further three species of conservation significance in western NSW were recorded[121]. In total., 25 species of birds, waterbirds and landbirds have been identified as being of conservation concern in western NSW[70].

Table 3.1 Landbirds of conservation significance recorded from the Narran Lakes Nature Reserve, and the Culgoa, Birrie and Narran River floodplains.

Common name	Scientific name	Year recorded and reference
Pink Cockatoo/Major Mitchell Cockatoo	*Cacatua leadbeateri*	1990–1992[87]
Red–tailed Black Cockatoo	*Calyptorhynchus banksii*	1990–1992[87], year unknown[49]
Painted Honeyeater	*Grantiella picta*	1990–1992[87]
Australian Bustard	*Ardeotis australis*	1990–1992[87], year unknown[49]
Barking Owl	*Ninox connivens*	year unknown[49]
Masked Owl	*Tyto novaehollandiae*	year unknown[49]
Grey Falcon	*Falco hypoleucus*	1990–1992[87], 1993[82], year unknown[49]

3.1.3 Vegetation of the Narran Lakes

The most comprehensive survey of the vegetation of the Narran Lakes Nature Reserve was conducted in 1999[69]. A total of 325 vascular plant species were collected from 50 sites across the Ramsar site. Eleven percent of species were introduced, a low percentage of all species were ferns and gymnosperms and the flora was dominated by arid and semi-arid adapted species[69]. The species richness recorded during the single sampling event was relatively high compared to other western NSW nature reserves.

Six major plant communities have been identified within the Ramsar site. They include chenopod low open shrublands, ephemeral herbfields, mixed low woodlands, riparian open forest, and spinifex grasslands[49, 69, Appendix A]. Associated with the wetlands are several vegetation communities considered to be ecologically significant. These include the following:

- Sedges and ephemeral herbfields occur on the playa lakes and Clear and Back lakes following receding flood waters.
- Lignum (*Muehlenbeckia florulenta*) occupies extensive tracts of land, forming dense shrubland in and around Clear and Back Lakes, and extends southwest down to Narran Lake.
- *Phragmites australis*, the Common Reed, occurs in small patches throughout the Lignum shrublands.
- Riparian open forests, that consist of River Red Gum *Eucalyptus camaldulensis*, Coolibah *Eucalyptus coolabah*, Black Box *Eucalyptus largiflorens* and River Cooba *Acacia stenophylla,* occur along the Narran River and wetlands. Understorey species include Quinine Bush *Alstonia constricta*, Lignum, Boobiallah *Myoporum* spp., Umbrella Mulga *Acacia brachystachya,* and Warrego grass *Paspalidium jubiflorum*[49, 69, Appendix A].

These vegetation communities are vulnerable to alteration in the frequency of flood events that result from water resource development in the upper catchment. As stated by Young *et al.*[104] (p.82): '*Flooding is the single most important natural influence on floodplain vegetation, and determines species distribution, growth of individual trees, reproduction, regeneration and population age structure*.' Appendix A lists other significant vegetation communities and gives more detail on the sandy ridge and dune communities found at the site.

Plant species listed under Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and the *NSW Threatened Species Act 1995* include Winged peppercress *Lepidium monoplocoides* and Macbarrons Goodenia *Goodenia macbarronii*. Winged peppercress has been recorded in Urana Nature Reserve in NSW and in Hattah-Kulkyne and Wyperfield National Parks in Victoria[69]. It has also been recorded from a number of unprotected locations throughout NSW and Victoria. Its range may also extend into South Australia. It was found as isolated individuals in the Narran Lakes Nature Reserve but was not considered to be rare. Hunter[69] does not provide an assessment of the significance of the record compared to other locations. Macbarrons Goodenia is not considered vulnerable in Queensland with its distribution being from the Darling Downs in Queensland, to the Great Dividing Range on the western slopes, to northeastern Victoria. It is believed to be at its western limit in the Nature Reserve and may be sporadic in appearance, being more dependent on favourable conditions. It occurs in five other reserves, but no assessment of the relative significance of the record is given compared to other sites in the state[69].

Hunter[69] lists another 11 plant species that are considered of conservation significance for the region (see Table 3.2). The Narran Lakes Nature Reserve also contains good stands of vegetation communities that have been subject to extensive disturbance throughout their ranges, such as buck spinifex and low woodlands, mulga low woodlands, riparian open forests, Lignum shrublands and cumbungi reedbeds[49].

Table 3.2 Plant species of conservation significance in western NSW[70].

Species	Growth form and associated communities	Conservation status
Actinotus paddisonii	herb — amongst Buck Spinifex	not reserved elsewhere in NSW
Anacampseros australiana	succulent herb — ephemeral herbfields	reserved at Mutawinje NP
Glossostigma diandrum	herb — mulga low woodlands	not reserved elsewhere in NSW
Kennedia procurrens	procumbent scrambler — found with Buck Spinifex and mixed woodlands of White Cypress Pine and Bimble Box	not reserved elsewhere in NSW
Myriophyllum striatum	herb — in and around waterholes	Narran Lakes Nature Reserve is the only reserved locality in western NSW
Nymphoides geminata	annual water plant — usually found in perennial pools	New disjunct distribution record for the species and thus the only known locality where it is reserved in western NSW
Pulchea dentex	herb — found in flooded areas of the open riparian forest	Reserved at Mutawinje and Sturt National Parks
Rorippa eustylis	herb — found in periodically waterlogged semi-arid areas — and the Lignum areas	Reserved at Kinchega National Park
Trachymene ochracea	herb – common in the mulga low woodland communities	Likely to occur in other reserves
Velleia arguta	herb — rocky outcrops in the mulga low woodland communities	Narran Lakes Nature Reserve is the only reserved locality in western NSW
Zaleya galericulata subsp. *Australis*	herb — found opportunistically throughout the reserve	Narran Lakes Nature Reserve is the only reserved locality in western NSW

Vegetation communities of conservation significance include the extensive Lignum shrublands. The stands found within the Narran Lakes wetland complex are some of the largest undisturbed stands in NSW and, as such, are considered to be vulnerable and inadequately conserved. The Silver-leaved Ironbark *Eucalyptus melanophloia*–Kurrajong *Brachychiton populneus* subsp. *trilobus*–Coolibah Apple *Angophora melanoxylon*–Wilga *Geijera parviflora*–Beefwood *Grevillea striata* woodland association occurs in two areas of the sandy ridge section of the Nature Reserve. This woodland association is of conservation significance in western NSW and includes some Spinifex *Triodia mitchellii* and Sandplain Wattle *Acacia murrayana,* both of which are considered to be poorly conserved in the western region of NSW[49, Appendix A].

Three other poorly conserved vegetation communities include Old Man Saltbush *Atriplex nummularia* shrubland, Mitchell Grass *Astrebla* spp. grassland, and Bimble Box *Eucalyptus populnea* woodland. The Western Beefwood *Grevillea striata*–Mulga *Acacia aneura* shrubland, Black Box woodland, Native Fuschia *Eremophila maculata* shrubland, Gidgee *Acacia cambagei* shrubland, and Common Reed sedgeland communities are all considered to be inadequately conserved in NSW[Appendix A]. The River Red Gum woodland, Silver-leaved Ironbark woodland, and Ironwood *Acacia excelsa*–White Cypress Pine *Callitris glaucophylla* shrubland are also all poorly conserved in NSW and are considered vulnerable[Appendix A].

No information was found on vegetation surveys specific to Narran Lake because the majority of work has been focused on the Narran Lakes Nature Reserve.

3.1.4 Floodplain vegetation of the Lower Balonne region

A study of the floodplain vegetation of the Culgoa, Birrie and Narran Rivers was undertaken in 1990[88]. The survey recorded 175 species from 65 plots. Of these, only 8.5% were exotic species, which is one of the lowest records of introduced species in floodplain vegetation in the Murray-Darling Basin[88]. The *Eucalyptus coolabah* woodlands of the alluvial fan are reported to be some of the most extensive and contiguous floodplain communities remaining in northern NSW[12]. The recent declaration of the Culgoa National Park was designed to preserve a significant area of the Coolibah woodlands. The grasslands of the Narran, Birrie and Culgoa floodplains are significant in that they represent one of the largest areas of native grasslands in northern NSW, even though they have been subjected to grazing for approximately 150 years[12].

On the Narran River floodplain there are 12 lakebeds; four of them are >100 ha and are intermittently flooded, and eight of them are mostly dry. All of the intermittently flooded lakebeds and 75% of the predominantly dry lakebeds are intensively cropped, with cultivation being possible after flooding and rainfall[12, 65]. Floodplain wetland vegetation communities rely on the hydrological cycle of the system to stimulate their establishment, and alteration to hydrology can result in isolation of floodplain wetland plant communities. Under an altered hydrological regime, wetlands will dry out more frequently and be subject to invasion by both terrestrial species and also weed species. Species richness could potentially change, and there would almost certainly be a change in community structure[12,102].

Twenty-five species of floodplain vegetation of the Walgett area have been listed as having traditional significance for food, medicinal properties, importance in ceremonies, shelter and implements, and one species, the River Red Gum, is of mythological importance[12].

Preliminary large-scale habitat mapping of the Queensland portion of the Lower Balonne floodplain was undertaken by the CRC for Freshwater Ecology (CRCFE) using Landsat TM satellite remotely sensed imagery and ground truthing[63]. It identified 11 landcover classes and divided the floodplain into 9 regions according to landcover characteristics. To date there has been no assessment of the condition of these broad vegetation landcover classes (refer to section 2.3 for more detail).

Work on riparian and floodplain vegetation of the Narran River below the NSW/Queensland border is generally limited. There is a need for a more comprehensive survey and assessment of the condition of floodplain and riparian vegetation communities. There appears to be significant areas of floodplain vegetation that are of state or regional significance and a comprehensive survey and mapping program should be initiated. The relationship between river hydrology and floodplain vegetation should be investigated in greater detail using methods similar to the CRCFE study in Queensland. A program that assesses both cover and condition in relation to floodplain inundation should be implemented. In particular, the large-scale habitat mapping begun in Queensland[63] should be expanded to include the remainder of the Narran River floodplain and its terminal wetland systems in the NSW portion of the catchment.

3.1.5 Aquatic invertebrate communities in Narran Lakes

No data on aquatic invertebrates of the Narran Lakes were obtained. However, some macroinvertebrate data were collected from Clear Lake as part of a joint Queensland NR&M and Queensland Environmental Protection Agency (Queensland EPA) project. The amount and status of the data are unclear (Paul Clayton, Queensland EPA, pers. comm.).

3.1.6 Aquatic invertebrate communities in the Narran River and associated floodplain

Information on invertebrates in the Narran River and associated floodplain is limited. Queensland NR&M assessed a number of sites on the Narran River using AUSRIVAS, and Sinclair Knight Merz[52] surveyed an additional number of sites using a habitat-based method. However, the number of sites and/or sampling occasions was limited. Direct comparisons of the results are also difficult because of differences in the methods used. Taxa were only identified to family or higher and the overall taxon richness was very low, although this is considered characteristic of dryland rivers and waterholes[52, 100]. However, in the Sinclair Knight Merz (SKM) study a number of predominantly terrestrial invertebrate taxa were included in the data, which raised measurements of taxon richness. Some of the graphical data representation of that study also contained errors. There is some contention from these studies over the ‘condition’ or ‘health’ of the Lower Balonne River. The use of comparable collecting techniques and stratified sampling designs would potentially have made the information much more useful. As it stands, neither of the two studies is adequate to fully describe the aquatic invertebrate fauna or to definitively state that the rivers in the Lower Balonne are healthy or otherwise.

Timms[100] provides a general description of the invertebrate fauna found in river water holes and various types of wetlands in the Currawinya wetland system on the Paroo River. Diversity was lowest in the remnant waterholes and highest in the temporary wetlands with variable flooding regimes. This is most likely to be the case in the Lower Balonne and the Narran River and Lakes. Only one project, that we are aware of, has actually sampled invertebrates on the floodplain. A recent University of Canberra honours project[118] investigated the influence of flooding and geomorphology on the emergence of zooplankton from Birrie River floodplain sediments. The results suggest a highly complex response of zooplankton to the geomorphology of the floodplain, emphasising both spatial and temporal complexity. It also notes the potential impact of altered floodplain hydrology on the abundance and species composition of zooplankton emerging from various floodplain environments.

There have been no comprehensive studies on the aquatic invertebrate fauna of the Narran Lakes. Some anecdotal data may be available on large crustacean species as a by-catch in fish studies, but no other data were located. It is believed that the wetlands within the Narran Lakes system will support a large invertebrate biomass, as evidenced by significant fish and bird populations. Invertebrates would be expected to be an important component of the ecological functioning of the wetland system. The composition and resilience of the invertebrate community is unknown. The range of wetland ‘types’ (freshwater, saline, variable depths and periods of inundation) within the Narran Lakes system and Narran floodplain could potentially support quite high levels of invertebrate diversity, similar to that of the Currawinya wetlands.

No studies have been undertaken on terrestrial invertebrates and their relationship with floodplain ecology in the Lower Balonne region.

3.1.7 Fish communities in Narran Lakes

Despite the inclusion of fish in community claims about aquatic ecological condition, there has been remarkably little effort to understand the fish fauna of the Narran Lakes system. One study from the early 1990s (David Moffat, Queensland NR&M, Toowoomba) surveyed the fish community in several of the Narran Lakes. Five native species were recorded in Clear Lake[49], including high abundances of juvenile golden perch, *Macquaria ambigua*. Although information from this study was not made available, conversations with the principal investigator suggest, but do not confirm, an important nursery role for this lake. Additional sampling over several years will be necessary to ascertain the level of inter-annual variability in recruitment to this system. Nevertheless, the number of golden perch juveniles recorded in 1992 sampling was 10 times that previously recorded from sites throughout NSW[30]. Clearly, the question of fish nursery function should be a priority area for further research.

A concern for fish recruitment in Clear Lake may be that insufficient flow duration is being achieved to allow successful migration back to the Narran River. Sufficient larval/juvenile development within the lake will be required before individuals can competently return to the river system and avoid any subsequent predation pressure. Under artificially short inundation regimes, large densities of larvae or early juveniles may become trapped as the lake dries out.

3.1.8 Fish communities in the Narran River and associated floodplain

Sinclair Knight Merz[52] sampled fish across 16 sites in the Lower Balonne region, including two on the Narran River (NR&M gauging station and Donegri Creek). Fish collected at all sites were golden perch, bony bream (*Nematalosa erebi*), carp (*Cyprinus carpio*), and Hyrtl's catfish (*Neosilurus hyrtlii*). Smelt (*Retropinna semoni*), goldfish (*Carassius auratus*) and spangled perch (*Leiopotherapon unicolor*) were also caught at one or other of the sites. We are unaware of other fish sampling on the Narran River.

The Lower Balonne Floodplain Study in NSW[68] compared surveyed community beliefs on the status of fish species across the Lower Balonne rivers. Fourteen species were thought to exist in the Narran River. Curiously, this list included a species from upland streams, the river blackfish (*Gadopsis marmoratus*), which is only thought to occur in the Condamine-Balonne catchment in the vicinity of Warwick. It also included three exotics: carp, goldfish, and mosquitofish (*Gambusia holbrooki*). Native fish numbers were believed to be declining in all of the Lower Balonne rivers[68]. For the Narran River, 42.3% of respondents felt that loss of instream habitat was the cause of this decline, and 5.2% felt that flow-related factors were the cause. A further 32.1% felt that 'other factors' were to blame, including instream sedimentation and the presence of carp. The declining stocks of a number of native fishes in Lower Balonne streams has also been noted elsewhere[67,68] although one of these, the southern purple-spotted gudgeon (*Mogurnda adspersa*), was believed to be abundant in the Narran River[67,68].

It needs to be remembered that fish communities may be extremely patchy in the Lower Balonne region, with both natural and anthropogenic impacts potentially responsible. For example, assessments of fish community condition across seven Condamine-Balonne sites over two years found consistently poor scores for the Culgoa River at Weimoringle, though noted that some of the best scores were achieved 'immediately upstream' from this site.

No printed information was found on fish assemblages within Narran floodplain waterholes. Brief hand netting in several warrambools (waterholes) along the Walgett–Cumborah Road (G. Wilson, February 2001) indicated an abundance of mosquitofish and juvenile carp. Floodplain-waterhole fish communities hold strong significance for indigenous communities, who believe this habitat functions as an important drought refuge[9,12].

3.1.9 Amphibians and other vertebrates of Narran Lakes, Narran River and Lower Balonne floodplains

Floodplain habitats support a diverse range of vertebrate species. In the woodlands, native grasslands and cleared lands of the Culgoa and Birrie rivers there is a high number of vertebrate species of conservation significance either at the regional, state, or national level[12, 87]. Surveys of the Narran Lakes Nature Reserve and Narran River have identified seven frog species, most of which are considered common[71, 82]. An earlier study on the Culgoa and Birrie river floodplains found an additional four species[55, 87]. Table 3.3 lists the amphibian species recorded from the Narran Lakes and the Culgoa, Birrie and Narran River floodplains. None of the species recorded from the Narran area are listed on the NSW Threatened Species Act, and only the Warty Water-holding frog is of conservation significance in western NSW[55]. However, frogs are reliant on flooding to reproduce, and soil moisture may affect the adult persistence of some species. Changes to flood frequency, extent or duration will therefore pose a significant threat to the amphibian community.

Table 3.3 Amphibians recorded from Narran Lakes, the Culgoa, Birrie, and Narran River floodplains.

Common name	Scientific name	Year recorded and reference
Crucifex toad	*Notaden bennettii*	1990–92[87]
Ornate burrowing frog	*Limnodynastes ornatus*	1990–92[87]
Salmon-striped frog	*Limnodynastes salmini*	1990–92[87], 1993[82], 1999[71]
Spotted grass frog	*Limnodynastes tasmaniensis*	1990–92[87], 1993[82], 1999[71]
Small froglet	*Crinia sloanei*	1990–92[87]
Green tree frog	*Litoria caerulea*	1990–92[87], 1993[82]
Peron's tree frog	*Litoria peronii*	1999[71]
Desert tree frog	*Litoria rubella*	1998[71]
Barking marsh frog	*Limnodynastes fletcheri*	1999[71]
Bibron's toadlet	*Pseudophryne bibronii*	1999[71]
Warty Water-holding frog	*Cyclorana verrucosa*	year unknown[55]

Vertebrate surveys on the floodplains of the rivers of the region and in Narran Lakes Nature Reserve recorded 21 native species of mammals (Table 3.4) and seven introduced species. From the same surveys 30 species of reptiles were recorded (Table 3.5). A large proportion of vertebrate species were thought to be dependent on the woodland associations found on the floodplains[12,87], but the results were described as tentative and require confirmation with further work to establish habitat preferences[87]. However, many species rely on the trees for nesting, foraging, feeding and roosting and most of the bat species are insectivorous and dependent on the trees for foraging[82].

Of the mammal species found in the region (Table 3.4) the Little Pied Bat, Koala, and Stripe-faced Dunnart are listed as vulnerable under the NSW Threatened Species Act. At the regional level the Swamp Wallaby, Brush Tailed Possum, Sugar Glider, Little Red Flying Fox, Gould's Long-eared Bat and the Water Rat are considered to be of conservation significance[87]. The Planigale species are not considered under threat; however, their dependency on cracking soils makes them vulnerable to impacts from grazing and lakebed cropping because these activities affect soil structure[49, 65, 82, 87]. Mammal populations have also reduced significantly in other wetland systems located in dryland regions[49].

Of the reptile species found in the region (Table 3.5) the long-necked tortoise is of conservation significance in western NSW. Dick and Andrew[87] also list the Northern Dtella *Gehyra dubia* as being rare in western NSW. Major habitat types identified as important for reptiles in western NSW are riverine woodland and associated rivers and wetlands, mallee woodland with spinifex understorey and chenopod shrubland[87]. Threats to these habitats include clearing, cropping, fire and grazing.

The Culgoa and Narran regions are significant in that they contain a high number of vertebrates of conservation significance at the international, national, state and regional levels. Dick and Andrew[87] suggest that the proportion of species with conservation significance is 20%. A potential reason for this is the biogeographical position of the Lower Balonne region. The vertebrate fauna is a mix of taxa that have predominantly northern, southern, eastern or western distributions and many species are at the limits of their range[87]. Further, the high percentage of fauna with conservation significance may reflect the fact that the region contains some of the largest intact floodplain vegetation associations in northern NSW.

Table 3.4 Native mammal species recorded from the Culgoa, Birrie, and Narran River floodplains and the Narran Lakes Nature Reserve. Habitat associations reflect where the animal was collected.

Species	Habitat association, where known	Year recorded and reference
Short beaked Echidna, *Tachyglossus aculeatus*	River Red Gum and Coolibah woodlands	1990–1992[87], 1993[82]
Narrow nosed Planigale, *Planigale tenuirostris*	Coolibah, Lignum and grassland, heavy cracking grey soils	1990–1992[87], 1993[82]
Paucident Planigale, *Planigale gilesi*	Coolibah, Lignum and grassland, heavy cracking soils	1990–1992[87], 1993[82]
Fat-tailed Dunnart, *Sminthopsis crassicaudata*	Coolibah woodland and grassland	1990–1992[87], 1993[82]
Stripe-faced Dunnart, *Sminthopsis macroura*	Grassland	1990–1992[87]
Common Brush tail Possum, *Trichosurus vulpecula*	All woodland types	1990–1992[87], 1993[82]
Sugar/Squirrel Glider, *Petaurus* sp.	Coolibah woodland	1990–1992[87]
Koala, *Phascolarctos cinereus*	River Red Gum woodland	1990–1992[87], 1993[82]
Swamp-Wallaby, *Wallabia bicolor*	Coolibah woodland	1990–1992[87], 1993[82]
Eastern Grey Kangaroo, *Macropus giganteus*	All habitats	1990–1992[87], 1993[82]
Red Kangaroo, *Macropus rufus*	Coolibah and cleared lands	1990–1992[87], 1993[82]
Little Red Flying Fox, *Pteropus scapulatus*	River Red Gum and Coolibah	1990–1992[87], 1993[82]
Little Mastiff Bat, *Mormopterus loriae*	Grassland	1990–1992[87], 1993[82]
Goulds Wattle Bat, *Chalinolobus gouldii*	River Red Gum and Coolibah	1990–1992[87], 1993[82]
Little Pied Bat, *Chalinolobus pictus*	River Red Gum and Coolibah	1990–1992[87]
Little Forest Eptesicus, *Eptesicus vulturnus*	Mostly River Red Gum, some Coolibah	1990–1992[87], 1993[82]
Lesser Long-eared Bat, *Nyctohilus geofforyi*	Mostly River Red Gum, some Coolibah	1990–1992[87], 1993[82]
Gould Long-eared Bat, *Nyctohilus gouldii*	River Red Gum and Coolibah	1990–1992[87], 1993[82]
Western Broad-nosed Bat, *Scotorepens balstoni*	Coolibah woodland	1990–1992[87], 1993[82]
Little Broad-nosed Bat, *Scotorepens greyi*	Mostly River Red Gum, some Coolibah	1990–1992[87]
Water Rat, *Hydromys chrysogaster*	River Red Gum — waterholes/river	1990-1992[87], 1993[82]

Table 3.5 Reptiles recorded from floodplains of the Lower Balonne region and Narran Lakes Nature Reserve

Common name	Scientific name	Dependence on trees	Year recorded and reference
Gecko	*Diplodactylus steindachneri*		1990–1992[87], 1993[82]
Tessellated Gecko	*Diplodactylus tessellatus*		1990–1992[87], 1993[82]
Soft-spined Gecko	*Diplodactylus williamsi*		1990–1992[87], 1993[82]
Prickly (Bynoe's) Gecko	*Heteronotia binoei*		1990–1992[87], 1993[82]
Northern Dtella	*Gehyra dubia*	Arboreal	1990–1992[87]
Tree Dtella	*Gehyra variegata*	Arboreal	1990–1992[87], 1993[82]
Marbled Velvet Gecko	*Oeduera marmorata*	Arboreal	1990–1992[87], 1993[82]
Legless lizard	*Delma inornata*		1990–1992[87]
Beaked Gecko	*Rhynchoedura ornata*		1990–1992[87], 1993[82]
Sand Monitor	*Varanus gouldii*		1990–1992[87], 1993[82]
Black headed Monitor	*Varanus tisitis* spp. *trisitis*	Arboreal	1990–1992[87], 1993[82]
Lace Monitor	*Varanus varius*	Arboreal	1990–1992[87]
Eastern Banded Dragon	*Pogona barbata*	Semi arboreal	1990–1992[87]
Gilberts Dragon	*Lophognathus gilberti*	Arboreal	1990–1992[87], 1993[82]
Lined Earless Dragon	*Tympanocryptis lineata*		1990–1992[87], 1993[82]
Skink	*Cryptoblephharus carnabyi*	Arboreal	1990–1992[87], 1993[82]
Skink	*Ctenotus allotropis*		1990–1992[87], 1993[82]
Tree Skink	*Egernia striolata*	Arboreal	1990–1992[87], 1993[82]
Skink	*Lerista muelleri*		1990–1992[87], 1993[82]
Skink	*Lerista punctatovittata*		1990–1992[87], 1993[82]
Skink	*Menetia greyii*		1990–1992[87], 1993[82]
Skink	*Morethis boulengeri*		1990–1992[87], 1993[82]
Skink	*Proablepharus*		1990–1992[87]
Shingleback	*Trachydosaurus rugosus*		1990–1992[87], 1993[82]
De Vis'Banded Snake	*Denisonia devisi*		1990–1992[87]
Brown snake	*Pseudonaja* sp.		1990–1992[87]
Curl snake	*Suta suta*		1990–1992[87]
Snake	*Unechis spectabilis*		1990–1992[87]
Western Brown Snake	*Pseudonaja nuchalis*		1990–1992[87], 1993[82]
Long-necked Tortoise	*Chelodina longicollis*		1990–1992[87], 1993[82]

3.2 Measures of river health in the Lower Balonne

3.2.1 General comments and the Sustainable Rivers Audit

There are numerous measures of river health being used across the Murray-Darling Basin by various state and federal agencies. However, there is little coordination or consistency in the type of method used, the level of detail covered and the frequency of data collection. Because of this it is difficult to make judgements on the health of rivers at the basin scale, or to assess the effectiveness of various management strategies[105]. The Sustainable Rivers Audit (SRA) has been designed to address these issues by undertaking a comprehensive annual and five yearly review of river condition that, in turn, will allow informed debate and decision making[105]. A framework for the SRA has been developed that identifies biota (macroinvertebrates and fish) and biological processes as fundamental measures of river health, but acknowledges that the condition of catchment and landscape features has an influence on the biota. The SRA recommends five indices: macroinvertebrate index, fish index, water quality index, hydrology index, and physical habitat index (see[105] for more details).

As part of the development of the SRA framework, existing major programs that assess river health within the Murray-Darling Basin were identified. Table 3.6 summarises the programs and that have been applied in the Condamine-Balonne catchment. Table 3.6 also lists whether we had access to those data for the present study.

3.2.2 Water quality data

Water quality monitoring has been undertaken since 1990 at six sites in the Intersecting Streams region that includes the NSW portions of the Paroo, Warrego and Culgoa-Narran Rivers[11]. The frequency of sampling, number of sampling sites and parameters measured have all been reduced from the original plan, and no sites were included in the Queensland portion of the catchments. The core parameters that were measured included pH, EC, turbidity, water temperature, suspended solids, total phosphorus and total nitrogen. Sampling was initially intended to be event-based as well as monthly. However, the sampling regime has recently reverted to monthly data collection[11]. Only a single site on the Narran River at Angledool is included in the monitoring. A review of water quality data collected in the NSW portion of the Condamine-Balonne by Stephens (Draft, 1999) may provide useful information, but could not be sourced for this study.

The Salinity Audit of the Murray-Darling Basin (1999, cited in the draft WAMP[135]) estimated that the current salinity of the Condamine-Balonne will rise from 210 EC to 1040 EC by the year 2020, and remain at that level for a further 70 years. The salinity audit also estimated that threshold values of salinity for drinking water and irrigation will be exceeded 58% of the time by 2020, and thresholds for wetland health will be exceeded 40% of the time. The Natural Resources Condition and Trend Report for the Condamine-Balonne Catchment[66] (Queensland portion) did not identify conductivity as a concern, with no discernible trends in the Lower Balonne section of the catchment. Turbidity levels generally increased with increasing distance downstream, and levels in the Lower Balonne section often exceeded 100 NTU. The WAMP Technical Advisory Panel (TAP) assessed the water quality of the Lower Balonne above and below the bifurcation to be in fair to good condition.

Table 3.6 Programs undertaken within the Condamine-Balonne catchment, number of sites, sampling interval and access in this scoping study. Compiled from[105]. * = most likely not relevant to the Condamine-Balonne catchment.

Program	Components measured	Number of sites	Sampling Interval	Accessed
ISC (Index of Stream Condition)	Channel physical form Streamside zone	Queensland 16	Snapshot	Yes
State of the Rivers	Channel habitat diversity Riparian and aquatic vegetation Bank, bed and bar stability Aquatic habitats	Queensland 750	Snapshot	No
WAMP	Streamside zone (as per ISC) Physical form (as per ISC) Fish Macroinvertebrates Hydrology	Queensland 16	Snapshot	Yes
ARC (Assessment of River Condition)	Macroinvertebrate condition Hydrological condition Nutrient status Physical habitat status Catchment disturbance measure	Not specified	Snapshot	No
Wild Rivers*	Catchment disturbance index Flow regime disturbance index River disturbance index	Not specified	Snapshot	No
NRHP (National River Health Program)	AUSRIVAS score SIGNAL score Nutrient data Riparian condition* Geomorphological condition*	20 NSW 56 Queensland	Snapshot — at least 2 samples	In part
Stressed Rivers Assessment	Proportion of water extracted Bank, bed, bar stability Riparian and aquatic vegetation Structures in the channel	NSW 2	Snapshot	No
Others	Hydrology — QNR&M / NSW DLWC	14/86	Irregular	Yes
	Water quality — QNR&M / NSW DLWC	0/13	Monthly	In part
	Fish — QDPI / NSW Fisheries	Under review	Annually	No

3.2.3 Index of Stream Condition

The Index of Stream Condition (ISC) is a river health assessment method developed in 1995 for use in Victorian rivers and streams. The method provides a holistic measure of river health which catchment management groups and community groups can use to benchmark river condition, make management decisions regarding restoration programs and set management priorities[105, 136]. It consists of five subindices that assess aspects of hydrology, physical form of the river, streamside zone (vegetation quantity and quality), water quality and aquatic life.

Stream condition was assessed at 12 sites throughout the Condamine-Balonne catchment, using a version of the ISC that was modified by the TAP[30]. The survey indicated that the Lower Balonne sites generally attained higher ISC scores than elsewhere along the Condamine-Balonne river system[30]. However, data from three of the Lower Balonne sites contained errors of assessment and therefore the assertion that the Lower Balonne sites were in better condition is flawed. In a different study, SKM reported the condition of riparian vegetation to range from low to high levels of disturbance[52], and suggested that this was not surprising in an area that is grazed and used intensively for agriculture. Given that the methods of assessment were different in each study it is difficult to make a judgement about the overall validity of the ISC assessment conducted in the Condamine-Balonne catchment.

3.2.4 Condition of rivers in the Condamine-Balonne Catchment

As part of the recent National Land and Water Resources Audit (NLWRA), the Assessment of River Condition (ARC) evaluated all rivers in the intensive land use zone of Australia. The ARC is based on the premise that ecological integrity, as assessed by the aquatic biota, is the fundamental measure of river condition. Impacts to biota are usually the final point of environmental degradation and pollution, and hence, biota are a good indicator of river and catchment disturbance. The biota are also components of, or are critical to, the goods and services provided by rivers that are valued by society. Thus, the biota are important both as critical elements of river systems, and as indicators of degradation.

Any comprehensive assessment of river condition that can guide management decisions requires information about the extent of impact and the causes of degradation. Consequently the ARC was based on a hierarchical model of river function in which broad-scale catchment characteristics affect local hydrology, habitat features and water quality. In turn, these factors influence the aquatic biota, our ultimate indicator of river health. This approach is a refinement of the models that underpin river assessments made in the Snowy Water Inquiry and that were adopted in the Index of Stream Condition[136, 138]. There are three levels of assessment that indicate causal relationships between human activities and the ecological condition of rivers: catchment condition, habitat condition and biological condition. The ARC comprises indices representing each of these three levels, and together they provide an assessment of the extent of impact, and information on potential causes of degradation.

While the biota are considered the most important indicator of river condition, there are two reasons why other elements need to be assessed. First, unless monitoring is continuous and includes all types of biota, certain types of disturbance may go undetected because the chosen group of organisms may be insensitive, or there may be a lag between environmental disturbance and biotic response. Second, monitoring only the biota may reveal a change, but not the reasons why that change occurred. Thus, a comprehensive assessment that provides information about the causes of degradation, and which can guide management decisions, will assess habitat and catchment condition alongside the biota.

The ARC reports two types of information on streams: status or condition as measured by the biota (ARC_B), and processes that drive or have an impact, as assessed by habitat and catchment measures (ARC_E). Five basic indices go into this reporting: one for biotic condition (Aquatic Biota Index), one for catchment condition (Catchment Disturbance Index) and three for habitat condition (Nutrient and Sediment Load Index, Hydrological Disturbance Index and Habitat Index). The calculation of these indices and the method of integration are explained in Norris *et al*.[138].

Data from the ARC for the Condamine-Balonne show that 51% of the total river length displays a degree of impairment. Indeed, 28% of the total river length is severely impaired and the majority of these river reaches are located downstream of St George. Moreover, this severe impairment rating is associated with a high degree of hydrological and habitat alteration.

3.3 Other wetlands of significance in the Lower Balonne region: Culgoa National Park and the Lower Balonne River Floodplain

In addition to the Ramsar Convention-listed site at Narran Lakes, two floodplain wetland areas of national significance have been recognised via a listing in the 3rd edition of the Directory of Important Wetlands in Australia[55] by the NSW and Queensland State Governments. These are the Culgoa River Floodplain wetlands within the Culgoa National Park and an aggregate of wetlands on the Lower Balonne River Floodplain in Queensland (see section 5.2.3).

The ecological features of the two wetland areas are quite different, and different criteria were used to list each as a wetland of national importance. The Culgoa floodplain was listed predominantly because of the significance of its terrestrial floodplain vegetation, in particular the large area of undisturbed Coolibah woodlands. The Coolibah woodlands were also the reason for its gazettal as a National Park in 1996 and extension in 1998 to a total of 22,430 ha. The Culgoa floodplain has very high plant diversity and a low percentage of exotics compared to other floodplain communities throughout the Murray-Darling Basin[55, 88]. Two hundred and thirty seven species of native animals, 37 of which are of conservation significance at the state and regional level, have been recorded from the Culgoa region[55]. Wetland dependent species include the Freckled Duck *Stictonetta naevosa*, Brolga *Grus rubicunda*, the Long-necked Tortoise *Chelodina longicollis*, the Broad-shelled River Turtle *Chelodina expansa*, and the Warty Water-holding Frog *Cyclorana verrucosa*. At least four of the regionally threatened species depend on the wetland areas of the floodplain. A further three depend more on the floodplain vegetation communities than on wetlands[55]. Water development scenarios under consideration in Queensland are believed to threaten these floodplain vegetation communities and a number of research programs are being developed as part of the Culgoa National Park management plan to investigate the relationship between floodplain vegetation and flooding regimes[55].

The nationally significant Lower Balonne River Floodplain wetlands include a number of wetlands totalling several hundred hectares within a floodplain area of approximately 24,000 ha. Major wetlands within the system include Lake Munya, Parachute Lagoons, Birch Lagoon, Mooramanna Lake and the swamp at Brookdale. The wetlands range from ephemeral systems to permanent billabongs and retain significant riparian and aquatic plant communities. Recreational use is high with most of the wetlands occurring on freehold land. Damming of, and water harvesting from, the wetlands on the floodplain, cotton farming with the implied threat of chemical pollution, and grazing of the sedge communities all contribute to an uncertain long term sustainability of these floodplain wetlands[55].

3.4 An ecological model of Narran Lakes

There are four major conceptual models of riverine ecosystem function: The River Continuum Concept, The Flood Pulse Model, The Riverine Productivity Model and the Serial Discontinuity Model. Each of these makes different predictions about the importance of different river system elements. The key aspects of these models range from emphasis on in-channel processes and longitudinal gradients along a river (River Continuum Concept, RCC), lateral connectivity between rivers and floodplains (Flood Pulse Concept, FPC), and a belief that floods are not the sole source of organic material and that riparian influences and algal productivity play important roles in structuring the animal communities (Riverine Productivity Model, RPM), to the importance of habitat and the hierarchical view that large-scale catchment characteristics determine the smaller-scale aspects of river system structure and function[105, 141].

The common elements of the various models are[103, 105]:

- **Habitat Heterogeneity —** All the models implicitly acknowledge that the biotic community is structured by the availability of habitat and that at a broad level there is a relationship between biodiversity and habitat heterogeneity;
- **Connectivity —** Each recognises one or more gradients associated with longitudinal connectivity, lateral connectivity and the linkage between riparian vegetation and in-stream ecology; and,
- **Metabolic Functioning —** Three of the models are based on a 'bottom-up' template, where the source and amount of organic matter production will have a significant effect on the food web.

A major criticism of these models is their lack of applicability to Australian inland rivers. Characteristic features of Australian inland systems such as flow variability, habitat complexity and the presence of large floodplains and ephemeral and terminal wetlands are not adequately addressed by these models[133, 141]. However, the models do recognise that the flow regime, which influences all features listed above, is a critical determinant of riverine ecosystem functioning. Activities in the catchment affect the flow regime, which in turn influences or determines habitat heterogeneity, connectivity and metabolic functioning in the river, floodplain and wetlands. A natural flow regime is crucial for maintaining the ecological integrity of the river and associated floodplain[105]. The flow regime of the incoming river is also the critical determinant of wetland ecology. Frequency, depth and period of inundation, and the high degree of spatial and temporal variability of these factors are all important to the Narran Lake wetland ecosystem. At any one time, numerous aquatic and terrestrial communities will be present and reflect the different watering conditions of various parts of the terminal wetland complex.

At present there are no ecological models that explicitly deal with terminal wetlands. Many terminal wetlands throughout inland Australia are formed around a network of distributary channels that dissipate flow across areas with very low slope[104]. Hence, river flows entering terminal wetland systems spread out and form a range of large shallow wetlands that have various inundation characteristics. In the case of the Narran Lakes terminal wetland system, flows are spread across a large delta vegetated with Lignum. Flows in this area are towards Clear and Back Lakes and with continued high flows water is delivered to Narran Lake proper. It is suggested that during base flow condition the water remaining in the terminal wetland systems is lost through evaporation or is transpired by plants[104].

Healthy riverine ecosystems provide templates for the development of ecological conceptual models. The Narran River is an example of a bifurcating river that does not rejoin the other major channels in the region. This results in the formation of a terminal wetland system. The typical geomorphic features of the Narran River and lakes are bifurcating channels, with secondary channels that persist relatively independently from the main channel. An important feature of the system is that the bankfull cross sectional area decreases downstream, and most of the habitat occurs in the secondary channels. The dominant functional unit of this type of geomorphic zone is the secondary channels and the extensive floodplain surface through which they flow. The secondary channels are no less complex and contain flat bench surfaces, flood runners, anabranches and other floodplain features.

A conceptual ecosystem model is proposed for the Narran River and Narran Lake system (Figure 3.1). The main components of this model are:

- Water, nutrients, carbon and living organisms are transported from upstream via the river and floodplain and enter the lake system.
- The amount and type of transported material is transformed during interactions with the floodplain.
- Because the wetland system is predominantly ephemeral, much of the biota colonises the wetlands from the river (e.g. fish) or elsewhere (e.g. waterbirds) soon after water arrives.

- A major component of the biota will be permanently associated with the wetlands and include animals and plants that are adapted to the natural flooding regime and survive periods of drying in the egg and seed banks of the wetlands. Also adapted to a flooding regime are several critical vegetation communities that are important habitat for colonial nesting waterbirds, such as Lignum, Coolibah and Black Box.
- The major export of carbon from the system during the aquatic phase is through waterbirds feeding on fish, invertebrates and plants.
- The major export of carbon from the system during the terrestrial phase is through grazing on vegetation by native and introduced vertebrates and invertebrates. The importance of this trophic linkage will be determined by the effect of water regime on the vegetation.
- A key characteristic of the wetland system is spatial and temporal variability, where biotic and abiotic features will be in a constant state of flux.

Figure 3.2 is an attempt to visually represent the spatial and temporal variability likely to occur in the Narran Lake ecosystem. It shows that the flooding regime is different for each component wetland, and that at any one time each will have different biotic communities. Unfortunately, at this point in time we do not have the knowledge required to determine which habitats, connections or metabolic processes are essential and which ones could withstand alteration, or how these factors are affected by water resource development and land use changes. A major component of this project is therefore to propose an ecological monitoring framework to determine the ecological character of the wetland system and also establish indicators that can be used in a monitoring program aimed at determining response to water resource development (see Chapter 6).

The important habitats suggested by the model (Figure 3.3) are:

- deep holes in the river, which provide a refuge for animals in dry times and a source of colonists for the terminal wetland system;
- woody debris from fallen riparian vegetation, which is a major habitat within the river channels;
- the lake bed, which provides a refuge for seeds and eggs of plants and invertebrates;
- riparian vegetation, which provides nesting and roosting habitat for birds and habitat complexity for aquatic organisms;
- open forests and woodlands on the floodplain, which provide important habitat for reptiles and birds; and,
- cracking soils, which are important for small mammals, planigales in particular, frogs and reptiles.

Our model also suggests that the important connections within the Narran Lakes system will include:

- riverine–lake connections which facilitate persistence of aquatic organisms and the delivery of carbon and nutrients to the Narran Lakes system;
- river–floodplain connections which facilitate access to breeding and feeding habitats for aquatic species and for the transfer of organic matter, nutrients and sediment;
- river–floodplain connections for the maintenance of the terrestrial vegetation complexes which support high levels of terrestrial biodiversity; and,
- wetland/lake–riparian connections that facilitate the export of carbon and nutrients from the terminal lake through predation and grazing.

The important ecological and metabolical processes of the system will include:

- algal production;
- organic matter decomposition;
- avian predation; and,
- grazing.

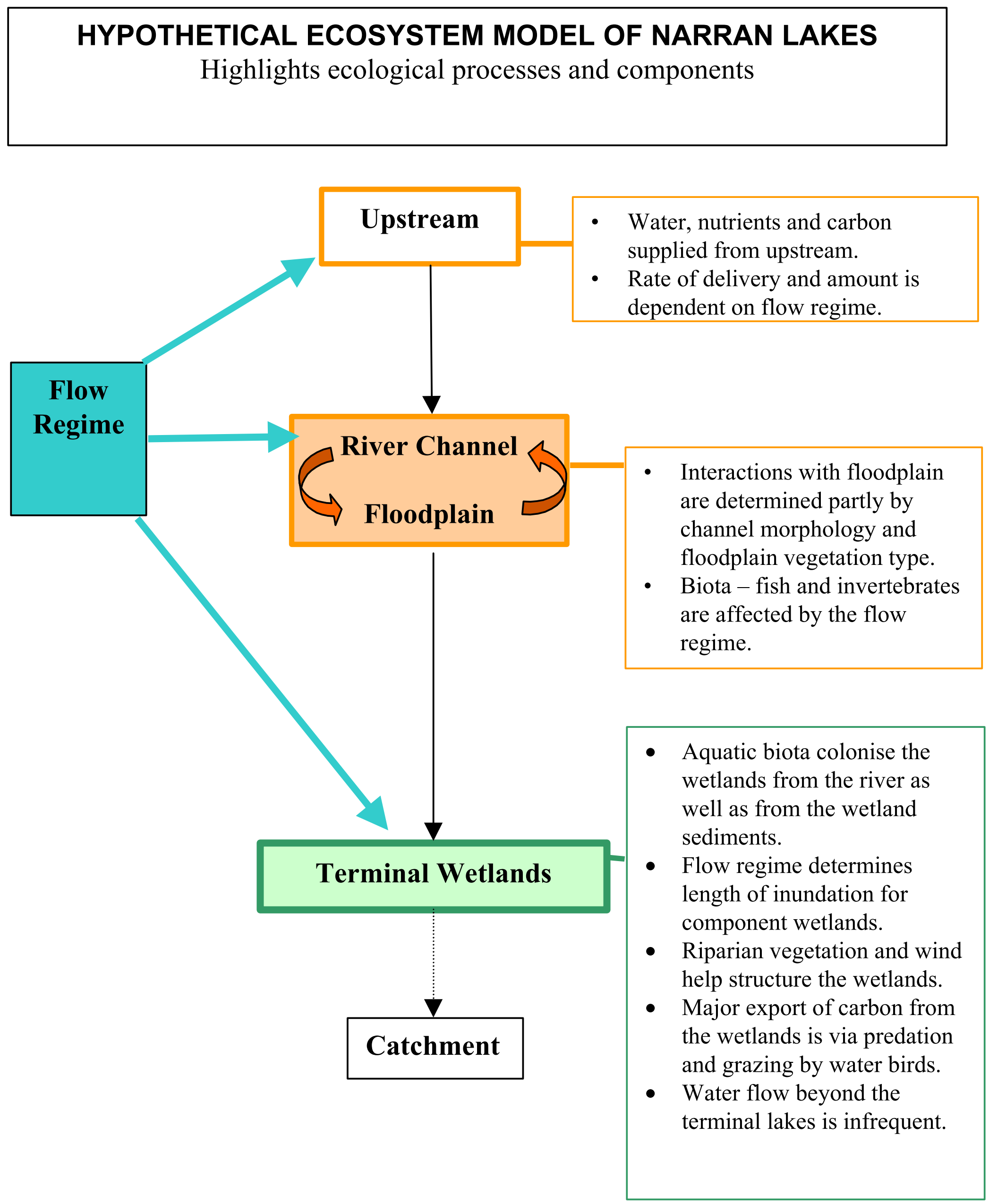

Figure 3.1 Hypothetical ecosystem model of the Lower Balonne River and Narran Lakes terminal wetland system. Flow regime is the major determinant of the 'character' of the wetland system.

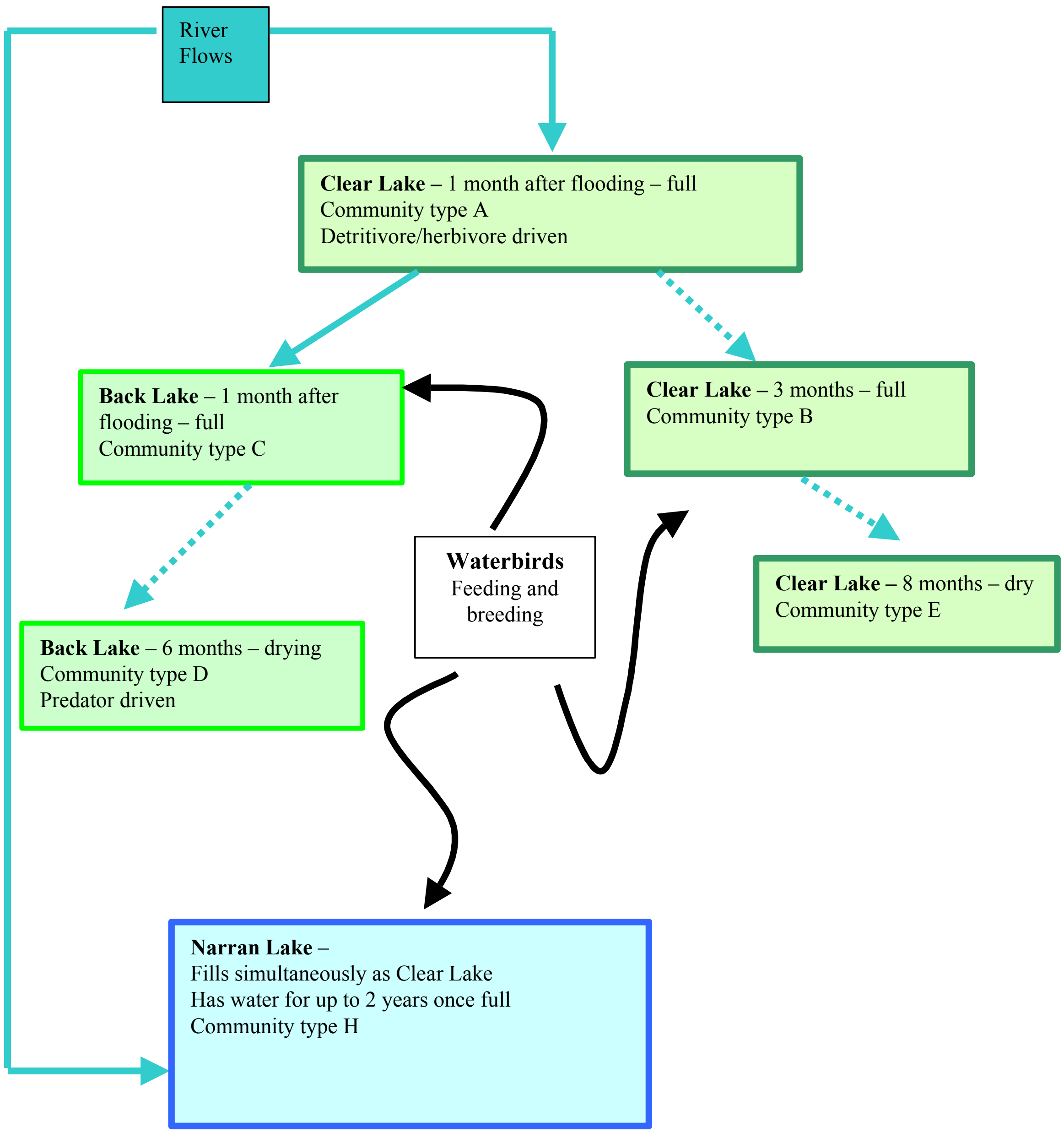

Figure 3.2 Schematic representation of temporal and spatial variability in the Narran Lakes wetland ecosystem. Community composition will change over time with seasonal influences, and in response to inundation stage. Biotic communities in each wetland are likely to be different to each other at any one time.

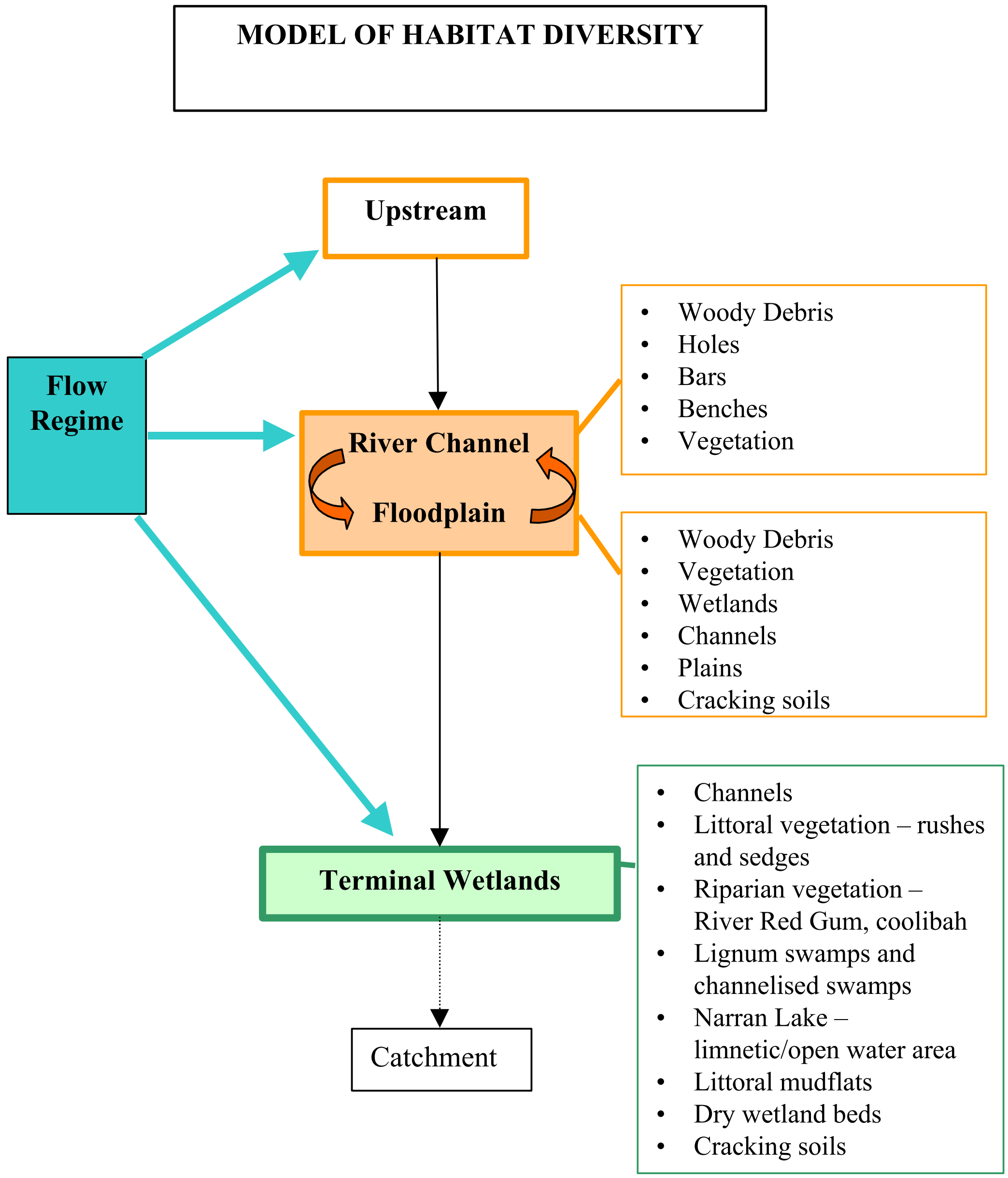

Figure 3.3 Habitat diversity of each component of the Lower Balonne and Narran Lake terminal wetland system. The amount, availability (when), and persistence of aquatic habitat are dependent on the hydrological regime.

3.5 Ecological impacts of water resource development on the Lower Balonne floodplain and Narran Lakes

The Narran Lake wetland system and the floodplain environments of the Lower Balonne are a highly dynamic ecosystem. This is reflected in part by the diversity of vegetation across the Lower Balonne region and the variability in its character over time, which in turn, is a reflection of the overall hydrology and geomorphology of the ecosystem. The long-term maintenance of ecological function and character is inextricably linked to the natural cycles of flooding and drying. Hence, any alteration to the flow regime because of water resource development throughout the catchment will affect the ecological character and processes of the wetland system.

The degree of the impact of water resource development is uncertain. Data collected in existing studies are insufficient to determine the impact of water resource development on the ecological condition of the Narran River and the terminal wetland system. The weight of international and national scientific evidence regarding the ecological impacts of over development of water resources is indisputable. While there may not be enough data to clearly state that current levels of development are having an impact, an ecological impact will eventually occur.

The predicted ecological impacts of continued water resource development on the Narran Lakes are:

- Loss of water bird breeding habitat and associated decline in waterbird numbers recorded at the wetlands. Less frequent breeding events of national importance. Regional and potentially national impact on water bird populations. Lag effects are likely to occur with impacts on breeding events potentially not evident for several years;
- Reduced spatial and temporal variability within the terminal wetland system reducing biodiversity value of the wetland system. Potential simplification of ecological communities, depending on the frequency and extent of altered flooding regime into the Narran Lakes system;
- Loss of resilience in egg and seed banks on the floodplain and in wetland sediments;
- Continued loss and isolation of floodplain;
- Critical disruption to the energy flow pathways of the Lower Balonne floodplain. Disruption of the lateral connections between the river, floodplain and wetlands will affect the delivery of carbon and nutrients into the wetlands; and,
- Altered cycles of wetting and drying could disrupt energy pathways, affecting rates of decomposition and availability of nutrients by affecting bacterial communities in wetland sediments.

4 CULTURAL REVIEW — INDIGENOUS COMMUNITIES

4.1 Introduction

The Lower Balonne floodplain has an extensive and long history of indigenous cultural use. There are currently more than 648 known sites of Aboriginal significance on the Lower Balonne floodplain[124]. Cultural resources are numerous in this area, including an abundance of bush food, medicine, and shelter items, and ceremonial sites and materials[9,68]. The Narran Lakes and their surrounds have been a key focal point for indigenous people for around 40,000 years, both as a meeting place for ceremonial and economic purposes, and as a rich source of food and other materials[69]. Indeed, the high indigenous cultural value of the area continues to be one of the main reasons for NSW NPWS maintaining restricted access to the nature reserve[49]. There is currently a Native Title claim over the Narran Lakes area, by Mr Michael Anderson.

This review examines impacts to indigenous cultural values in the Narran Lakes area that might result from upstream flow diversion. It has been written with both an indigenous and a non-indigenous readership in mind. Some of the information was gained from discussions with key indigenous community members from the region, Mr Ted Fields Snr, his son Mr Ted Fields Jnr (both of Walgett) and Mr Bruce Wilson (of Brewarrina). Mr Ted Fields Snr is an elder with strong on-going participation in efforts to document indigenous culture across the Narran region. Mr Ted Fields Jnr is an Aboriginal Liaison Officer with NSW DLWC. Mr Bruce Wilson is not of Aboriginal descent, although he has maintained a strong association with the Brewarrina indigenous community for 25 years. He is currently on the Barwon-Darling River Management Committee and has been involved with past community conservation campaigns for the Narran Lakes. All three were also on the NSW Indigenous Working Party that responded to the Condamine-Balonne draft WAMP (August 2000). Other information was gleaned from a number of reports (principally state agency) on the Narran region. It needs to be recognised, however, that time limits did not allow for an exhaustive search for past documentation, and some key material may not have been consulted.

The review first examines the historic and current use of the Narran Lakes area by indigenous people. Second, it presents views on perceived impacts from past flow alteration on cultural values of the lakes, and any potential exacerbation should rates of upstream abstraction be increased. Third, it briefly details the implications of this information for natural resource management in the Narran region.

4.2 Historic use of the Narran Lakes by indigenous people

A number of indigenous groups made traditional use of the Narran Lakes. This focal point provided a venue for trading of stone and other materials, and also served ceremonial and food-gathering purposes. An Aboriginal Dreaming Track was recognised by all groups, extending from above the Queensland border along the Narran River to Narran Lake[12,49,68]. Use of the wider Lower Balonne floodplain area by Aboriginal people was summarised in 2000 as:

'… the lower Condamine-Balonne catchment was a focus for large-scale human activity. … the area was fertile enough to allow the development of widespread social networks, was capable of supporting large gatherings and special enough to platform ceremonial events.' [124].

The explorer Mitchell (1848, cited in Hunter[69]) noted that indigenous people made extensive use of grass seed, quandong fruit and mussels for food along the Narran River. Seeds were pounded into flour and subsequently used to make bread. These resources would all depend heavily on overbank flood conditions for their local replenishment. The prevalence of mussels in the local Aboriginal diet is evidenced by the extent of shell middens along the banks of Clear Lake. At least 26 other floodplain plant species were also used for medicines and constructing implements and shelters throughout the Narran region[12]. All of these species are restricted to areas subject to flooding.

Recent work through the NSW NPWS has identified a shift in the faunal composition of middens within the Narran Lakes Reserve, from principally riverine/lacustrine species (e.g. mussels) to a greater contribution by terrestrial items (Allan Hutchins, pers. comm.). Mussel middens contain two separate species that require very different flow conditions. Moreover, the location of some mussel-dominated middens is well away from areas subject to the necessary (modern-day) flow conditions for at least one of these species.

Smaller anabranch and flood-runner channels off the Narran River were used to trap fish during flood conditions (Ted Fields Snr, pers. comm.). Stick barriers would be placed across these channels and any trapped fish retrieved after the waters had receded sufficiently. This method clearly depended on the delivery of flood pulses along the river channel, though was not restricted to larger overbank floods.

Only three of the 648 sites of Aboriginal significance recorded on the Lower Balonne floodplain[124] are within the current nature reserve boundary. Clearly, the broader floodplain environment has significant cultural value to local indigenous communities. Professor Iain Davidson (Department of Archaeology and Palaeoanthropology, University of New England) recently received a Commonwealth SPIRT grant to further investigate historical use of the Narran Lakes in this context.

4.3 Current use of the Narran Lakes by indigenous people

Indigenous visits continue to represent one of the main human uses of the Narran Lakes Nature Reserve, on a controlled basis through the NSW NPWS District Office (Narrabri). However, this appears to be primarily from the townships of Walgett and Lightning Ridge. Few Brewarrina people appear to have visited the lakes, possibly on account of restricted access through private property. Some contact with the lakes by these people has occurred in the past through employment on properties such as Narran Station (Bruce Wilson, pers. comm.).

Current direct users of the lakes include the Euahlay-I, Ngempa and Moorawanni people from Brewarrina (Bruce Wilson, pers. comm.) as well as clans from Walgett and Lightning Ridge (Ted Fields Snr, pers. comm.). In general terms, the reserve continues to be a vital education setting for the intergenerational transfer of traditional knowledge[5,12]. For example, indigenous people from Walgett continue to use the Nature Reserve area for brief camps to teach traditional ways of gathering foods from the area, particularly freshwater crayfish and mussels (Ted Fields Snr, pers. comm.). The Lightning Ridge community takes a group of approximately 20 people to the Narran Lakes around 10 times each year for the purposes of visiting sacred sites and retracing dreamtime stories[12].

Indigenous people from both Lightning Ridge and Goodooga regularly fish in the Narran River[12]. Deeper floodplain waterholes along the Narran River continue to hold significance as sources of fish during drought times, and concern has been raised over these being fished out during such times[9]. These sites would all depend on flood inundation for their replenishment (Ted Fields Snr, cited in[12]).

4.4 Indigenous community views — perceived impacts of upstream flow abstraction on Narran cultural values

Indigenous concern for the impacts of flow diversion is broader than merely a concern for the natural environment[124]. While maintaining a focus on river health, flora and fauna, indigenous people also recognise connected aspects of their own health as well as a spiritual significance of the landscape.

A past review of this question[68] noted that attitudes to Queensland–New South Wales water sharing differed between communities in the Narran region. Nevertheless, all communities expressed a strong and consistent view that the Narran and adjacent rivers had degraded to an unacceptable level under existing rates of irrigator abstraction. Moreover, they felt that this was having social and economic impacts. While archaeological sites (e.g. middens) may not be directly affected by increased abstraction rates along the Narran River and lakes, their cultural significance will be severely diminished by any associated reductions in food resources (e.g. fish, crayfish)[12].

In volumetric terms, Aboriginal communities consider a secure access to water supply as an undeniable right based on the same principles as the 1992 High Court Mabo decision. This is of particular concern in relation to housing. For example, in Weilmoringle (Culgoa River) and Goodooga (Bokhara River), Aboriginal people have expressed a belief that Queensland irrigation development had reduced their access to safe domestic water[68]. Declines in the health of Narran wetlands due to reductions in flow levels are widely regarded as serious desecration of a highly significant area (Ted Fields Snr, cited in[5]). Indeed, the NSW Indigenous Working Party encouraged a comprehensive and integrated study into the Narran Lakes to gain an appropriate understanding of any ecological, hydrological and geomorphological impacts from upstream flow diversion[124].

Aboriginal people continue to recognise direct links between their health and a regular supply of quality water[68]. They see this supply as providing recreation opportunities, food, local employment and a connection with a past life that has been disrupted by irrigation development. Aboriginal people have expressed concern for declining water quality in rivers on the Lower Balonne floodplain[9,68,124], and also felt that water quality in the Narran River was generally higher than in the other intersecting streams[68].

Aboriginal views on the region’s flow management have reflected strongly negative views in the past[68]. Managers (‘administrators’) have been seen as focusing solely on economic values, with no regard for maintaining environmental health, nor any interest in engaging Aboriginal views through management committees. Aboriginal people have felt disempowered in the flow management process, despite their strong desire to make constructive input[68,124].

In economic terms, Aboriginal communities have noted declining employment opportunities on grazing properties, in line with reductions in the incidence and frequency of beneficial overbank flooding of pastures[68]. Flow reductions downstream have also been seen as limiting Aboriginal employment in other ways, such as the potential to develop aquaculture, hydroponic or market garden ventures[68].

Flow diversions into warrambools (waterholes) on the Narran floodplain for stock watering may also compromise other significant sites through inevitable trampling. Warrambools were traditionally used as drinking points during longer cross-country trips. Warrambool sites continue to hold significance both as a record of this past lifestyle and as a part of the dreaming path between the Queensland Border and Narran Lake (Ted Fields Snr[68]).

4.5 Implications for natural resource management policy

Indigenous communities along the Narran River valley have clearly maintained a sense of connection with traditional cultural values of the natural environment. It will be imperative that the strength of this linkage be considered in any natural resources management for the region, particularly in relation to flow issues. Within the Narran Lakes Reserve, integration of indigenous information and involvement into this process is already evident. For example the NSW NPWS has a current policy for managing disturbance to Aboriginal sites within the Narran Lakes Nature Reserve[49], stating (among other things) that:

- The Walgett Local Aboriginal Land Council and others will be consulted and actively involved in all aspects of Aboriginal site management; and,
- As far as possible, Aboriginal sites will be protected from human disturbance other than for authorised research purposes.

The policy further states that the following actions will be undertaken to achieve the above objectives:

- Systematic survey and recording of archaeological material and sites will be progressively undertaken in the nature reserve; and,
- Where necessary and feasible, stabilisation works will be undertaken to prevent further erosion of significant Aboriginal sites.

Two issues arise here. First, possible impacts from flow alteration (e.g. riverbank erosion, changed patterns in vegetation distribution) are not specifically mentioned in relation to this policy. It would seem pertinent that any current or future problems be viewed on an equal basis to any direct anthropogenic disturbance. Second, it is important to note that the above policy does not extend to sites outside the current reserve boundary. Mechanisms will need to be considered which promote the integration of indigenous cultural protection into flow management decisions for the broader valley and floodplain. These should consider both tangible and intangible aspects, although these are often difficult to separate.

As an example of the latter, the Walgett Aboriginal community has grave concerns that decreased flows to the Narran lakes have altered the distribution of Lignum, particularly within the reserve area. Changes here are seen from an aesthetic perspective (Ted Fields Snr, pers. comm.). Nevertheless, they are also seen to have limited the abundance of suitable waterbird rookery habitat and made shelter for wild pigs. Similarly the 'social health' of local communities is promoted by the ability to hold regular camping retreats to harvest traditional aquatic and riparian foods (Ted Fields Snr, pers. comm.). The distribution and/or abundance of species such as yabbies and mussels will undoubtedly be affected by flow changes, as will riparian plants harvested for food or medicines.

In terms of tangible cultural aspects (e.g. midden erosion), the current effort by NSW NPWS to record indigenous sites and associated values along the Narran River floodplain in conjunction with local elders (Ted Fields, pers. comm.) is a necessary first step. The recognition of such sites by natural resource management agencies in Queensland and NSW will be critical for protecting them from damage through adverse flow or landuse patterns. Importantly, similar recording efforts do not seem to be underway for the Queensland portion of the Narran River floodplain, and this should be considered as a priority.

5 INTERNATIONAL OBLIGATIONS IN RELATION TO THE NARRAN LAKES RAMSAR SITE, AND THE COMMONWEALTH'S *ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999*

5.1 Introduction

This section of the report examines the specific 'interests' that the Commonwealth Government has in the Narran Lakes and Lower Balonne floodplain through the *Environment Protection and Biodiversity Conservation Act 1999*. The EPBC Act establishes a new Commonwealth process for the assessment of proposed actions that are likely to have a significant impact on matters of 'national environmental significance'. The Act identifies Wetlands of International Importance (Ramsar sites) as matters of national environmental significance as well as (among other things) World Heritage properties, nationally threatened species and communities and migratory species protected under international agreements.

Apart from the Ramsar site status of the Narran Lakes, the area provides habitat for species listed under Australia's bilateral migratory bird agreements with Japan and China and the Convention on Migratory Species. It also includes two plant species of interest, one that is listed at the national level as 'endangered' and another that is listed as 'vulnerable'. These constitute three potential 'triggers' under the EPBC Act that could be activated in the event of proposed or actual actions that are likely to have a significant negative impact on these matters of 'national environmental significance'.

The Ramsar, migratory species and threatened species and ecological communities 'triggers' can operate independently, or be linked and possibly triggered jointly in relation to the Ramsar status of the Narran Lakes. In terms of meeting the requirements of the EPBC Act, on-going ecological monitoring of the area needs to take each 'trigger' into consideration. Equally, any actions (as defined by the Act — see below) proposed in the catchment that could, or are deemed likely to have impacts in relation to these three matters of 'national environmental significance' will require consideration and possible assessment by the Commonwealth Government.

5.2 Obligations in relation to the Ramsar Convention on Wetlands and the Ramsar 'trigger' of the EPBC Act

5.2.1 The Ramsar Convention on Wetlands

As a Contracting Party to the Ramsar Convention on Wetlands, Australia has accepted a range of obligations in relation to the management of sites that are designated as Wetlands of International Importance, or Ramsar sites. These obligations are described in the text of the Convention as follows:

Article 3.1

'*The Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory*'

Article 3.2

'*Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological development, pollution or other human interference. Information on such changes shall be passed without delay to the organization or government responsible for the continuing bureau duties specified in Article 8*.'

Since the adoption of the above texts, Conferences of the Contracting Parties to the Ramsar Convention (most notably the 5th Conference in Kushiro, Japan, 1993, Resolutions 5.1 and 5.7) have seen fit to interpret these obligations as an undertaking on the part of the Contracting Parties to manage their Ramsar sites so as to retain the 'ecological character' that allowed the designation of the site in the first place. This management undertaking is considered synonymous with the term '*to promote the conservation of the wetlands included in the List,…*' (Article 3.1).

The 6th Ramsar Conference (Brisbane, Australia, 1996) adopted Resolution VI.1 which provided working definitions of 'ecological character' and 'change in ecological character' as well as guidelines for describing and maintaining the 'ecological character' of listed sites. The subsequent Conference (San Jose, Costa Rica, 1999) revised and adopted definitions of 'ecological character' and 'change in ecological character' based on expert advice from the Convention's Scientific and Technical Review Panel. These definitions, as adopted by Resolution VII.10, are as follows:

- Ecological character is the sum of the biological, physical and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions and attributes; and
- Change in ecological character is the impairment or imbalance in any biological, physical and chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes.

The 4th Ramsar Conference (1990) established the so-called Montreux Record of sites where change in 'ecological character' had occurred, is occurring, or is likely to occur. Sites are added to this Record in a totally voluntary way by the Party concerned as a way of indicating that threats do, or may, impact negatively on the 'ecological character' of the site. The *Guidelines for the Operation of the Montreux Record* were adopted at the 6th Ramsar Conference (1996) through Resolution VI.1. Those Parties that add sites to the Montreux Record do so to indicate that problems exist with the management of a site, either now on in the future, and to indicate that actions are being taken to see the threats removed. As such, the action of entering a site into the Montreux Record is seen by the Convention as Parties taking their obligations under Article 3.2 (see above) seriously.

In terms of Wetlands of International Importance the Ramsar Convention expects its Parties to describe the 'ecological character' of their designated sites (ideally at the time of designation), and from that time on, manage the site to retain this 'ecological character'. In practice, few sites have had their 'ecological character' described in sufficient detail to allow 'change in ecological character', as defined above, to be monitored or demonstrated (except in cases of severe degradation). The baseline or 'benchmark' against which most sites are managed is the description provided in the official site account (the Ramsar Information Sheet) at the time of designation. Parties are encouraged to update these descriptions every three years and this was last done for the Narran Lakes Ramsar site in June 2001.

The current official Ramsar Information Sheet (RIS) for the Narran Lakes site, as prepared by the NSW NPWS in collaboration with Environment Australia, is reproduced in Appendix A. This is a detailed description of the various attributes of the site, but it could not be said to constitute a description of the 'ecological character' of the site as per the definition adopted by the Convention. Despite this, the RIS establishes a clear appreciation of the ecological values of the site which justified its listing as a Wetland of International Importance. In the absence of detailed studies to indicate the underlying ecological, hydrological and biophysical processes operating within the Narran Lakes ecosystem, these site attributes are the demonstrable and immediately measurable values of the Ramsar site against which management actions can be based and judged.

Section 9 of the RIS (Appendix A) gives the criteria against which the site was designated under the Ramsar Convention, and Section 12 then provides justification for these claims. Sections 14, 15, 16, 17 and 18 then elaborate further on these justifications by describing the physical features, hydrological values, ecological features, noteworthy flora and noteworthy fauna, respectively, of the site. When taken together, this information provides the best description of its 'ecological character' available at present. A summary of the species and ecological communities found at Narran Lakes is provided at the end of this Chapter (Table 5.1). Significantly, this information shows the importance of the site for state and national-level biodiversity conservation of species and communities, the importance of the site for waterbirds, and the reliance on the site by several migratory waterbird species. To be certain that the 'ecological character' of the Ramsar site is being retained, Australia's obligation is to manage the site so that these attributes continue, or at least are not lost because of human-induced impacts.

While the 'ecological character' of the Narran Lakes Ramsar site has not yet been described down to the level of ecological, hydrological and biophysical processes, the 'surrogate' expression of ecological character is the presence of those species and ecological communities which were used to justify designation of the site. Therefore, from a Ramsar Convention perspective there is an expectation that the site will be managed to ensure it remains an important habitat for these species. A failure to do so would contravene Australia's obligations under the Convention.

5.2.2 Implications of the Ramsar 'trigger' of the EPBC Act

The EPBC Act, which came into force on 16 July 2000, provides a legal framework for seeing that the 'ecological character' of all Australian Ramsar sites is retained. The EPBC Act requires that, except in limited circumstances, a person must not take an action that has, will have, or is likely to have a significant impact on the 'ecological character' of a Ramsar wetland, without approval from the Commonwealth Minister for the Environment and Heritage. An exception to this is where an accredited management plan exists for the site and where the action is consistent with that plan. At present, while there is a management plan for the Narran Lakes Nature Reserve (which represents some 82% of the Ramsar site – the other 18% is adjoining land owned and managed by the NSW NPWS) it has not thus far been accredited under the EPBC Act.

The term ‘action’ is defined under the EPBC Act as:

“*An action includes a project, development, undertaking or an activity or series of activities. A decision by a government body to grant an authorization (for example, a permit or licence) or to provide funding is not an action*.”

Significantly, an action does not require approval if it is a lawful continuation of a use of land, sea or seabed that was occurring before the commencement of the Act. That is, the Act cannot apply retrospectively. Importantly, however, an enlargement, expansion or intensification of an existing use is not considered a continuation of a pre-existing use.

The *Administrative Guidelines on Significance* produced by the Commonwealth Government to assist interpretation and implementation of the EPBC Act provide the following additional advice on actions:

- The guidelines are intended to provide general guidance on the types of actions that will require approval and the types of actions that will not require approval. They are not intended to be exhaustive or definitive.
- In order to decide whether an action is likely to have a significant impact, it is necessary to take into account the nature and magnitude of potential impacts.

In determining the nature and magnitude of the impact of an action, it is important to consider matters such as:

- all on-site and off-site impacts;
- all direct and indirect impacts;
- the frequency and duration of the action;
- the total impact which can be attributed to that action over the entire geographic area affected, and over time;
- the sensitivity of the receiving environment, and,
- the degree of confidence with which the impacts of the action are known and understood.

When deciding whether an action is likely to have a significant impact on a matter of ‘national environmental significance’, the Act provides that the Minister must take account of the precautionary principle. Accordingly, a lack of scientific certainty about the potential impacts of an action does not justify a decision that the action is not likely to have a significant impact.

Wetlands of International Importance

A declared Ramsar wetland is an area that has been designated under Article 2 of the Ramsar Convention or declared by the Minister for the Environment to be a ‘declared’ Ramsar wetland in accordance with section 16 the Act (see Section 5.2.3 below).

An action that has, will have, or is likely to have a significant impact on the ‘ecological character’ of a declared Ramsar wetland might take place outside the boundaries of the wetland.

An action has, will have, or is likely to have a significant impact on the ecological character of a declared Ramsar wetland if it does, will, or is likely to result in the following criteria:

- areas of the wetland being destroyed or substantially modified; or,

- a substantial and measurable change in the hydrological regime of the wetland — for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland; or,
- the habitat or lifecycle of native species dependent upon the wetland being seriously affected; or,
- a substantial and measurable change in the physico-chemical status of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature that may adversely impact on biodiversity, ecological integrity, social amenity or human health; or,
- an invasive species that is harmful to the ecological character of the wetland being established in the wetland[1].

Therefore, in terms of the Ramsar 'trigger', the EPBC Act requires that, except in limited circumstances, a person must not take an action that has, will have, or is likely to have a significant impact on the 'ecological character' of a Ramsar wetland, without approval from the Commonwealth Minister for the Environment and Heritage. If it is accepted that the best measure of 'ecological character' available today is the occurrence there of the species and ecological communities described in the Ramsar Information Sheet (see Appendix A and Table 5.1), then the EPBC Act expects the Commonwealth Minister to seek to prevent or modify any action (as defined by the Act) in order to stop these attributes being lost. In so determining, the Act expects the Minister to take the precautionary principle into account. It is also significant that in exercising the Ramsar 'trigger' of the EPBC Act, actions taken or proposed both within and outside the declared Ramsar area need to be considered.

The adoption of a Water Allocation and Management Plan for the Condamine-Balonne system itself would not constitute an action under the Act, but other actions taken pursuant to it, or independent of it, that may be considered likely to affect the 'ecological character' should be referred for Commonwealth consideration, and may trigger assessment under the Act.

5.2.3 'Declaration' of other important wetlands in the catchment

As referred to above, the EPBC Act (Section 17A specifically) gives the Commonwealth Minister for Environment and Heritage the option of 'declaring' any wetland in the country that, in his/her opinion is of international importance because of its ecology, botany, zoology, limnology or hydrology, and where the 'ecological character' is under threat. The key word here is threat because the Act does not specify that the site is being threatened by a specific action, as is the case with both the Ramsar and migratory species 'triggers'. In considering the use of this power under the Act there is an expectation that the Commonwealth Minister would exercise 'best endeavours' to have the threat addressed, prior to taking the step of 'declaring' a site which is not at the time already Ramsar-listed.

In this regard it is notable that within the Lower Balonne catchment two other wetland sites have been recognized as nationally important through their inclusion in the 3rd edition of the *Directory of Important Wetlands in Australia*. These sites are the Balonne River Floodplain (Queensland site 84) and the Culgoa River Floodplain (NSW site 170). Both have outstanding natural values and a preliminary review of their natural attributes indicates that a strong argument could be put for them both being Ramsar-listed. In particular, the Culgoa River Floodplain could be listed because of the diversity of its plant communities.

The implications of Section 17A of the EPBC Act are that in formulating future water and land

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[1] Introducing an invasive species into or near the wetland may result in that species becoming established. An invasive species may cause harm by direct competition with native species, modification of habitat, or predation.

management regimes and plans for the Lower Balonne catchment and floodplains, the Queensland and NSW Governments need to be mindful that the Commonwealth Government has available to it the option to 'declare' sites should it believe that these are worthy of Ramsar listing or are under potential threat.

5.3 Obligations in relation to the Convention on Migratory Species and the Japan-Australia and China-Australia Migratory Bird Agreements, and the migratory species 'trigger' of the EPBC Act

The EPBC Act also provides a legal framework for the protection of 'listed migratory species' that are considered as matters of 'national environmental significance' under the Act. The migratory species 'trigger' refers to Australia's obligations under the Convention on the Conservation of Migratory Species of Wild Animals (more commonly called the Bonn Convention) and the bilateral agreements Australia has with both Japan and China for migratory bird conservation. The species lists attached to each of these agreements form the 'listed migratory species' under the EPBC Act.

The specific obligations imposed on Australia by these agreements are detailed in the following sections.

5.3.1 Convention on the Conservation of Migratory Species of Wild Animals

This Convention has two Appendices of migratory species: Appendix I, which lists migratory species considered endangered at the global level; and Appendix II, which provides a list of migratory species of 'unfavourable conservation status'. Parties to the Bonn Convention are expected to take action in relation to the species included in these appendices. For Appendix I species, Parties are expected to ensure, through a range of indicated actions, that the species is conserved. For Appendix II the Convention expects Parties to pursue multilateral agreements that will promote cooperative conservation efforts between the Range States. As indicated in the attached Ramsar Information Sheet (Appendix A, and see Table 5.1), species from Appendix II have been recorded at Narran Lakes.

At the more generic level, the Bonn Convention imposes a broader obligation to protect migratory species through Article II, paragraph 1 as follows:

"*The Parties acknowledge the importance of migratory species being conserved and of Range States agreeing to take actions to this end whenever possible and appropriate, paying special attention to migratory species the conservation status of which is unfavourable, and taking individually or in co-operation appropriate and necessary steps to conserve such species and their habitats.*"

5.3.2 The Japan–Australia and China–Australia Migratory Bird Agreements

These two bilateral agreements while generally very similar do have one significant difference. The Japan–Australia Migratory Bird Agreement (JAMBA) includes special references and two annexes in relation to birds (not necessarily migratory ones) which are endangered in both Australia and Japan, as well as an annex of species known to migrate between the two countries. The China–Australia Migratory Bird Agreement (CAMBA) refers only to species known to migrate between the two countries. Significantly, the Ramsar Information Sheet (Appendix A) indicates that 11 JAMBA species (not endangered ones) and 15 CAMBA species occur in the Narran Lakes.

Notable text from these two agreements, which provides relevant obligations on Australia, is as follows.

JAMBA

- Article IV, paragraph 3 — 'Each Government shall encourage the conservation of migratory birds and birds in danger of extinction.'
- Article V — 'Each Government shall endeavour to establish sanctuaries and other facilities for the management and protection of migratory birds and birds in danger of extinction and also of their environment.'
- Article VI, paragraph (a) — 'Each Government shall seek means to prevent damage to such birds and their environment.'
- Article VII — 'Each Government agrees to take measures necessary to carry out the purpose of this Agreement.'

CAMBA

- Article III, paragraph 3 — 'Each Contracting Party shall encourage the conservation of migratory birds, especially those species in danger of extinction.'
- Article IV — 'Each Contracting Party shall endeavour, in accordance with its laws and regulations in force, to:

  a) establish sanctuaries and other facilities for the management and protection of migratory birds and also of their environment; and

  b) take appropriate measures to preserve and enhance the environment of migratory birds. In particular, each Contracting Party shall:

    i. seek means to prevent damage to migratory birds and their environment, ……'

5.3.3 Implications of the migratory species 'trigger' of the EPBC Act

The *Administrative Guidelines on Significance* produced by the Commonwealth Government to assist interpretation and implementation of the EPBC Act states that:

'An action will require approval from the Environment Minister if the action has, will have, or is likely to have a significant impact on a listed migratory species.'

Lists of migratory species are established by the Minister for the Environment under Part 13, Division 2, Subdivision A of the Act. The lists are available through the Environment Australia homepage at <www.environment.gov.au>. Hard copies of lists can be obtained by contacting Environment Australia's Community Information Unit. Note that some migratory species are also listed as threatened species. The criteria below are relevant to migratory species that are not threatened.

An action has, will have, or is likely to have a significant impact on a migratory species if it does, will, or is likely to result in the following criteria:

- substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of *important habitat* of the migratory species; or

- result in invasive species that are harmful to the migratory species becoming established[2] in an area of *important habitat* of the migratory species; or
- seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an *ecologically significant proportion* of the population of the species.

An area of important habitat is:

- habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species; or
- habitat utilised by a migratory species which is at the limit of the species range; or
- habitat within an area where the species is declining.

Listed migratory species cover a broad range of species with different life cycles and population sizes. Therefore, an ecologically significant proportion of the population varies with the species (each circumstance will need to be evaluated).

When considering the possible application of the migratory species EPBC 'trigger' in the case of the Narran Lakes Ramsar site it is notable that the RIS (Appendix A and Table 5.1) indicates that several of the listed migratory species regularly found there have either restricted breeding range in NSW or are considered of 'conservation concern'. Also, for several species it is claimed in the RIS that the site is either nationally or internationally important based on the Ramsar criteria that the site is used by 1% or more of the known population of that species (see Section 12 of the RIS).

It is also important to note that the migratory species 'trigger' is not restricted in its application to Ramsar-listed areas. Therefore, it is necessary to consider all potential impacts on these listed species across the Narran Lakes and Lower Balonne floodplain. As explained in Section 5.2, within the Narran Lakes Ramsar site itself, the Ramsar and migratory species 'triggers' work in concert, because the presence of these listed species constitutes a part of the 'ecological character' of the Ramsar site.

The Ramsar Information Sheet (Appendix A) indicates that a number of EPBC listed species (that is JAMBA, CAMBA and Bonn Convention-listed species) occur in Narran Lakes. Assuming that Narran Lakes can be considered 'important habitat' for these species (as defined by EPBC) and that within the lakes 'ecologically significant proportions' of the same species are found, then any proposed action will require approval from the Commonwealth Environment Minister if the action has, will have, or is likely to have a significant impact on a listed migratory species. The migratory species 'trigger' applies across the Narran Lakes and Lower Balonne floodplain areas, and within the Ramsar-listed area of the Narran Lakes, because the listed migratory species found in these areas also constitute part of the 'ecological character' of the site.

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[2] Introducing an invasive species into the habitat may result in that species becoming established. An invasive species may harm a migratory species by direct competition, modification of habitat, or predation.

5.4 Obligations in relation to the Narran Lakes and Lower Balonne floodplain and the threatened species and ecological communities 'trigger' of the EPBC Act

As indicated above, the Narran Lakes Ramsar site includes within it populations of a nationally endangered plant species and nationally vulnerable plant species (Appendix A and Table 5.1). These occurrences have been used to justify (in part) the Ramsar listing of the site and the presence of these species can be considered to constitute part of the ‘ecological character’ of the site. While neither species is believed to be a waterplant (so to speak) this does not diminish the obligation on Australia to see them protected as part of the Ramsar-listed area.

Because of the status of these plant species at a national level, the EPBC threatened species and ecological communities ‘trigger’ is also relevant and would apply within the declared Ramsar area. Should these plant species be found more widely across the Narran Lakes and Lower Balonne floodplain, then this ‘trigger’ would also apply equally to those areas.

5.4.1 Implications of the threatened species and ecological communities ‘trigger’ of the EPBC Act

The EPBC Act *Administrative Guidelines on Significance* offer the following guidance on the threatened species and ecological communities ‘trigger’:

An action will require approval from the Environment Minister if the action has, will have, or is likely to have a significant impact on a species listed in any of the following categories:

- Extinct in the wild;
- Critically endangered;
- Endangered; or
- Vulnerable.

Some of the criteria below refer to the concept of ‘habitat critical to the survival of a species or ecological community’. This includes the critical habitat for many species and communities identified in recovery plans for those species/communities and the critical habitat on the Register maintained by the Minister for the Environment under the Act. However, there may not be recovery plans in place for all listed species and communities, as plans take some time to prepare. Similarly, the Register may not be comprehensive. The absence of a recovery plan or the fact that an area may not be listed on the Register of Critical Habitat does not mean that there is no habitat critical to the survival of the species or community.

Habitat critical to the survival of a species or ecological community may include areas that are necessary:

- for activities such as foraging, breeding, roosting, or dispersal;
- for succession;
- to maintain genetic diversity and long term evolutionary development; or
- for the reintroduction of populations or recovery of the species / community.

Habitat critical to the survival of a species or ecological community will depend largely on the particular requirements of the species/community in question. For example, areas only used incidentally by a vulnerable species, and which the species is unlikely to be dependent upon for its survival or recovery, are not areas of habitat critical to the survival of a species or ecological community.

Some of the criteria below refer to actions likely to lead to a 'long-term decrease' in the size of a population or a 'long-term adverse affect' on a community. Depending on the level of endangerment and the nature of the action, not all actions that create an immediate decrease in the population of a nationally listed threatened species or impacts on a community will have long-term consequences. For example, an action which causes injury or death to only one or a very small number of a species will not, except in the case of the most endangered of species, generally lead to a long-term or irreversible decrease in the population that normal processes, rates of mortality and recruitment could not buffer.

Critically endangered and endangered species

An action has, will have, or is likely to have a significant impact on a critically endangered or endangered species if it does, will, or is likely to result in the following criteria:

- lead to a long-term decrease in the size of a population; or
- reduce the area of occupancy of the species; or
- fragment an existing population into two or more populations; or
- adversely affect habitat critical to the survival of a species; or
- disrupt the breeding cycle of a population; or
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline; or
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat[3]; or
- interfere with the recovery of the species.

Vulnerable species

An action has, will have, or is likely to have a significant impact on a vulnerable species if it does, will, or is likely to result in the following criteria:

- lead to a long-term decrease in the size of an '*important population'* of a species; or
- reduce the area of occupancy of an '*important population'*; or
- fragment an existing '*important population'* into two or more populations; or
- adversely affect habitat critical to the survival of a species; or
- disrupt the breeding cycle of an '*important population'*; or
- modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline; or
- result in invasive species that are harmful a vulnerable species becoming established in the vulnerable species' habitat[4]; or
- interfere substantially with the recovery of the species.

[3] Introducing an invasive species into the habitat may result in that species becoming established. An invasive species may harm a critically endangered or endangered species by direct competition, modification of habitat, or predation.
[4] Introducing an invasive species into the habitat may result in that species becoming established. An invasive species may harm a vulnerable species by direct competition, modification of habitat, or predation.

An '*important population'* is one that is necessary for the long-term survival and recovery of a species. This may include populations that are:

- key source populations either for breeding or dispersal; or
- populations that are necessary for maintaining genetic diversity; and/or
- populations that are near the limit of the species range.

The threatened species and ecological communities 'trigger' also applies for the Ramsar-listed area of Narran Lakes as the two plant species in question form part of the 'ecological character' of the declared site. For any assessment undertaken pursuant to EPBC in relation to possible impacts on these two species, factors such as those outlined in the *Administrative Guidelines* (and given above) would need to be considered. At present, recovery plans are not in place for these two species and so any such assessment could not rely on these to guide the referral and assessment processes.

As with the migratory species 'trigger', the threatened species and ecological communities 'trigger' also applies outside the Ramsar-listed area. Hence, a broader consideration and appreciation of the distribution of these species within the Narran Lakes and Lower Balonne floodplain is required, for confidence that EPBC requirements are not being violated.

5.5 Conclusions

For the Narran Lakes and Lower Balonne floodplain the Commonwealth EPBC Act has four particular areas of interest. These relate to:

- that part of the catchment which is listed as a Wetland of International Importance or Ramsar site;
- the two nationally, and possibly internationally, important wetlands found in the catchment;
- the presence of several listed migratory waterbird species; and,
- the presence of one nationally endangered and one nationally vulnerable plant species.

For the Ramsar, migratory species and threatened species and communities 'triggers' under the Act (i, iii and iv above), careful determinations of real or possible impacts of any proposed new actions (as defined by the Act) will be necessary. The possible 'declaration' of the Culgoa River floodplain and the Balonne River floodplain under Section 17A of the EPBC Act would need to be based on a determination of the international importance of these areas in terms of ecology, botany, zoology, limnology or hydrology, and any perceived or real threat to the 'ecological character' of these wetlands.

In relation to the Ramsar-listed Narran Lakes, Australia's obligation is to ensure the 'ecological character' of the site is retained. In the absence of the necessary detailed understanding of the underlying ecological, hydrological and biophysical processes which 'drive' and maintain this system, and constitute its 'ecological character', it is recommended that the presence and abundance of certain species, the presence of certain ecological communities and the activities (breeding, feeding and resting) of many waterbirds be the present benchmark for managing the Narran Lakes Ramsar site (Table 5.1). This information would constitute the 'ecological character' until such time as the underlying drivers in the system are better described and understood. As such, any new action proposed, or taken, in the Narran Lakes and Lower Balonne floodplain which has the potential to disturb these species and communities would warrant referral and possible assessment under the EPBC Act.

Where potential impacts on the ‘ecological character’ of the Narran Lakes are under examination, the EPBC Act, Ramsar, migratory species and threatened species and ecological communities ‘triggers’ need to be considered. This is a consequence of the migratory waterbirds and endangered and vulnerable plant species found there also being recognised as part of the ‘ecological character’ of the Ramsar site. Elsewhere in the catchment, the migratory species and threatened species and ecological communities ‘triggers’ may also apply, and will need to be considered on a case by case basis.

Table 5.1 Proposed management ‘benchmarks’ for the Narran Lakes Wetland of International Importance. These are based on the Ramsar Information Sheet of June 2001 (Appendix A) which specifies the important ecological attributes of the site. The order of presentation relates to the Ramsar Criteria against which the site qualifies in order to be designated as a Wetland of International Importance.

Attribute	Ramsar Criterion	NSW conservation status information	National conservation status information
Lignum (*Muehlenbeckia florulenta*)	1	Among the most significant remaining in NSW, considered vulnerable and poorly conserved in NSW (Benson, 1989)	
Brolga (*Grus rubicunda*) Breeding	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	EPBC listed (Bonn Convention)
Blue-billed Duck (*Oxyura australis*) Breeding	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Freckled Duck (*Stictonetta naevosa*) Breeding	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Magpie Goose (*Anseranas semipalmata*) Breeding	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Australian Bustard (*Ardeotis australis*)	2	Listed under the *Threatened Species Conservation Act 1995* as endangered	
Grey Falcon (*Falco hypoleucus*)	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Pink Cockatoo (*Cacatua leadbeateri*),	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Black-tailed Godwit (*Limosa limosa*)	2 (& 4)	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	EPBC listed (J-CAMBA, Bonn)
Barking Owl (*Ninox connivens*)	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Masked Owl (*Tyto novaehollandiae*)	2	Listed under the *Threatened Species Conservation Act 1995* as vulnerable	
Winged Peppercress (*Lepidium monoplocoides*)	2	Listed under the *Threatened Species Conservation Act 1995*	EPBC listed (nationally endangered)
Macbarron’s Goodenia (*Goodenia macbarronii*)	2	Listed under the *Threatened Species Conservation Act 1995*	EPBC listed (nationally vulnerable)
River Red Gum (*Eucalyptus camadulensis*)–Silver-leaved Ironbark (*Eucalyptus melanophloia*) woodland	2	Considered vulnerable and poorly conserved in NSW (Benson, 1989)	

Table 5.1 (cont.)

Attribute	Ramsar Criterion	NSW conservation status information	National conservation status information
Ironwood (*Acacia excelsa*)–White Cypress Pine (*Callitris glaucophylla*) shrubland	2	Considered vulnerable and poorly conserved in NSW (Benson, 1989)	
Old Man Saltbush (*Atriplex nummularia*) shrubland	2	Considered endangered and poorly conserved in NSW (Benson, 1989)	
Mitchell Grass (*Astrebla* spp.) grassland	2	Considered endangered and poorly conserved in NSW (Benson, 1989)	
Bimble Box (*Eucalyptus populnea*) woodland	2	Considered endangered and poorly conserved in NSW (Benson, 1989)	
Australian Pelican (*Pelecanus conspicillatus)*	4	Restricted breeding distribution in NSW	
Great Cormorant (*Phalacrocorax carbo)*	4	Restricted breeding distribution in NSW	EPBC listed (J-CAMBA)
Pied Cormorant (*Phalacrocorax varius)*	4	Restricted breeding distribution in NSW	
Darter (*Anhinga melanogaster)*	4	Restricted breeding distribution in NSW	
Rufous Night Heron (*Nycticorax caledonicus)*	4	Restricted breeding distribution in NSW	
Large Egret (*Ardea alba)*	4	Restricted breeding distribution in NSW, Significant breeding population	EPBC listed (J-CAMBA)
Little Egret (*Ardea gazetta)*	4	Restricted breeding distribution in NSW	
Intermediate Egret (*Ardea intermedia)*	4	Restricted breeding distribution in NSW	
Glossy Ibis (*Plegadis falcinellus)*	4	Restricted breeding distribution in NSW, Significant breeding population	EPBC listed (CAMBA)
Australian White (Sacred) Ibis (*Threskiornis molucca)*	4	Restricted breeding distribution in NSW, Significant breeding population	
Straw-necked Ibis (*Threskiornis spinicollis)*	4	Restricted breeding distribution in NSW, Significant breeding population	
Great Crested Grebe (*Podiceps cristatus)*	4	Restricted breeding distribution in NSW	
Royal Spoonbill (*Platalea regia)*	4	Restricted breeding distribution in NSW, Significant breeding population	
Gull-billed Tern (*Sterna nilotica)*	4	Restricted breeding distribution in NSW	

Table 5.1 (cont.)

Attribute	Ramsar Criterion	NSW conservation status information	National conservation status information
Little Bittern (*Ixobrychus minutus*)	4	Conservation concern in western NSW	EPBC listed (Bonn)
White-bellied Sea-eagle (*Haliaaetus leucogaster*)	4	Breeds at the site	EPBC listed (CAMBA)
Cattle Egret (*Ardea ibis*)	4		EPBC listed (J-CAMBA)
Bar-tailed Godwit (*Limosa lapponica*)	4		EPBC listed (J-CAMBA, Bonn)
Latham's Snipe (*Gallinago hardwickii*)	4	Conservation concern in western NSW	EPBC listed (J-CAMBA, Bonn)
Common Greenshank (*Tringa nebularia*)	4		EPBC listed (J-CAMBA, Bonn)
Wood Sandpiper (*Tringa glareola*)	4		EPBC listed (CAMBA, Bonn)
Sharp-tailed Sandpiper (*Calidris acuminata*)	4		EPBC listed (J-CAMBA, Bonn)
Curlew Sandpiper (*Calidris ferruginea*)	4		EPBC listed (J-CAMBA)
Caspian Tern (*Sterna caspia*)	4	Conservation concern in western NSW	EPBC listed (CAMBA)
White-winged Black Tern (*Chlidonias leucopterus*)	4	Conservation concern in western NSW	EPBC listed (J-CAMBA)
Black-winged Stilts (*Himantopus himantopus*)	6		
Red-necked Avocets (*Recurvirostra novaehollandiae*)	6		
Marsh Sandpiper (*Tringa stagnatilis*)	6 (& 4)		J-CAMBA
Straw-necked Ibis (*Threskiornis spinicollis*)	6		
Red-kneed Dotterel (*Erythrogonys cinctus*)	6		

6 ECOLOGICAL MONITORING FRAMEWORK FOR NARRAN LAKES

6.1 Introduction

There are two main purposes of an ecological monitoring program. The first is to provide information to managers about the ecological condition of an ecosystem, in a way that enables them to evaluate whether the management of that system is meeting its stated environmental objectives. The second is to assess the effects of specific human activities that might cause change in the ecological condition of an ecosystem. In the Lower Balonne and the Narran Lakes, these human activities include water resource development and land clearing. It would be difficult to develop a monitoring program that could separate out the effects of these two activities; even detecting general changes in ecological condition in a complex ecosystem like the Narran Lakes is a great challenge. We note that the objective in this study is to provide a monitoring *framework*, not the design of the monitoring program itself. The latter would require formal analysis of available data, much of which we have not been provided with, to determine crucial components of monitoring such as spatial and temporal scales, effect sizes and therefore sample sizes and sampling frequencies.

The purpose of this section is to propose a framework for the development of a monitoring program to assess changes in ecological condition of the Narran Lakes, particularly those that occur in response to human activities such as water resource development and land clearing. We have used the general term *condition* deliberately, because of the potential confusion and misinterpretation of terms like ecological health and integrity that imply comparison with more pristine reference ecosystems. While such comparisons may be possible (Section 6.2), reference systems are difficult to find and may differ from the Narran Lakes in ways that confound interpretation. We have decided to focus on ecological character as a measure of ecological condition because parts of the Narran Lakes are a Ramsar Convention-listed Wetland of International Importance, and this brings with it additional obligations of protection and monitoring. Australia has an obligation in relation to the Ramsar-listed site to ensure the ecological character of the site is retained. Ecological character is the sum of biological, physical and chemical components of a wetland ecosystem and the interactions between these components. Change in ecological character is considered to have occurred if an impairment or imbalance in the components result in a failure to maintain the wetlands' functions and attributes.

Monitoring of ecological condition requires that components of ecological character be specified as measurable variables. In the case of the Narran River and its floodplain and terminal lakes, the physical components include those related to hydrology and geomorphology, the chemical components include quality of water and fluxes of nutrients, and the biological components refer to the biota and their interactions. We recommend that the ecological monitoring program be primarily based on these components of ecological character. Our view is that ecological responses to changing flow regimes in these dryland river systems are likely to be mediated through the availability of habitat, and this implies two crucial parts of a research program that feed into the monitoring framework. First, it will be necessary to determine which components of habitat are critical to key biota or ecological processes; second, it will be necessary to assess how habitat, including its availability and quality, is altered by different flow scenarios.

Although parts of the Narran Lakes were listed as a Ramsar site based on information collected and summarised in the Ramsar Information Sheet (RIS; Appendix A), we probably do not have enough information about many underlying aspects and drivers to describe the ecological character of the Narran Lakes in the manner defined by the Ramsar Convention. Nonetheless, the RIS does list many ecologically significant features of the Narran Lakes, which clearly demonstrate that it meets the criteria for designation as a Wetland of International Importance. As stated in the previous chapter, the absence of a true understanding of the ecological character of the Ramsar site means that the species and communities for which the site was listed must become part of the benchmark for managing the site. Thus, a monitoring program must include consideration of these specific components of ecological character and investigate the potential impacts from anthropomorphic activities. Further, there are matters of ‘national environmental significance’ within the Lower Balonne system: apart from the Ramsar site, there are the nationally significant wetlands of the Culgoa and Lower Balonne River floodplains (as listed by Environment Australia), listed migratory birds and threatened plant species. Thus, the ecological monitoring framework must consider the Ramsar site and be applicable to the Lower Balonne/Culgoa region in general.

The specific objectives of monitoring based on ecological character of the Narran Lakes include:

- description of the current ecological character of the Lower Balonne and Narran Lakes. This task has only been partly completed for the Ramsar site as part of the Ramsar listing.
- description of the hydrological and geomorphological responses of the Narran Lakes to different water inflows that may represent different water resource development scenarios. This objective should be met via a combination of hydrological modelling and field mapping. The input/response model will enable predictions of extent of inundation, changes in availability of key habitat and wetting and drying cycles from inflows. We note, however, that our knowledge base, particularly on habitat requirements and availability, does not allow such a model to finalised without additional empirical research.
- further analyses of all available ecological data to determine patterns of temporal and spatial variability and detectable effect sizes of components of character in response to human activities. These analyses are essential to guide the spatial and temporal intensity of sampling frequency, which in turn, ensures that the monitoring program can detect changes in ecological character.
- determination of whether past or future changes in ecological character are related to water resource development or land management practices. This objective will require temporal comparisons to historical data and spatial comparisons to control or reference systems.

6.2 Design issues

A range of ecological information is required to determine whether the management of the system is protecting its ecological character. However, much of this information is not currently available. This framework outlines the steps that we believe need to be undertaken to develop a monitoring program for the Narran Lakes.

6.2.1 Task 1 — Conceptual model

Because assessment of all the ecological elements of a system is not possible, most ecological monitoring programs rely on indicators. The use of indicators is based on the hypothesis that a change in the indicator process or taxon will be correlated with changes in other components of the system. Selection of appropriate indicators relies on the construction of a conceptual model to generate these hypotheses. This project has generated a conceptual model of the Narran Lakes. Because of the paucity of ecological information, it lacks the detail required to generate hypotheses that could be tested by a monitoring program. The current conceptual model does, however, allow us to identify the major knowledge gaps and initiate an investigation of the ecological character of the lakes (Task 3).

6.2.2 Task 2 — Hypotheses

The next step in the design of a monitoring program is to develop a series of hypotheses about the relationships between human activities, management and the ecology of the system. Once again, the conceptual model has a key role to play in this process, but, as noted above, it currently lacks the detail required to generate specific hypotheses. It is possible to generate a general hypothesis about the relationship between management and the ecology of the Narran Lakes ecosystem. The primary hypothesis being addressed by this ecological monitoring program will be that change in the ecological condition or character of the Narran Lakes is different from what we would expect if there were less water resource development and less floodplain degradation. There are two important components to this hypothesis: the first is that it concerns change, and the second is that it is concerned with the change that arises as a result of management of the system.

6.2.3 Task 3 — Current condition and character, including the magnitude of variability

To develop the conceptual model to the point where it can be used to select indicators and propose hypotheses about the impacts of our management on the system, it is necessary to quantify the current condition of the Lakes. This process is also important because it will generate the baseline information against which our assessment of change will be made. The Narran Lakes are semi-arid-region terminal lakes that receive an unpredictable and unreliable supply of water from their catchment. This means that one of the characteristics of the ecology of the Narran Lakes will be its variability and any change in this variability should be considered a form of degradation. Therefore, ecological characterisation must involve measuring the extent of natural variability. These measures are also essential for the design of any on-going monitoring program, to ensure the best compromise between the statistical power to detect trends and the cost-effectiveness of monitoring.

There are numerous sources of information that might contribute to the assessment of current ecological character of the Narran River, its floodplain and terminal lakes. The Ramsar Information Sheet lists ecologically significant taxa and communities that may make the Narran Lakes unusual, although these data are not quantitative and could not be easily used for measuring change, except in the case of species losses. We have also identified existing data that will contribute to the measurement of current condition. Unfortunately, much of the available information has been derived from anecdotal observations or from fragmented or poorly coordinated investigations. It is clear that additional data collection and analysis will be necessary for describing current ecological condition.

6.2.4 Task 4 — Development of input/response model

A fundamental management question is how changes in water resource development will affect the hydrology and geomorphology of the Narran Lakes. Such information can be used to build our conceptual model and predict ecological consequences. A model that relates flows down the Narran River to patterns of inundation of the Narran Lakes and its surrounding floodplain should be constructed. Combined with detailed bathymetric maps and information on the habitat requirements of the key biota, this model should enable predictions of extent of inundation, changes in availability of key habitat and wetting and drying cycles from inflows. This model would require the implementation of specific research projects to fill gaps in our current knowledge, especially bathymetric mapping and habitat requirements of key biota.

6.2.5 Task 5 — On-going monitoring program to detect change

Once the initial characterisation is complete, data can be incorporated into the conceptual model and more specific hypotheses generated about the relationship between particular taxa or processes and the ecological character of the Narran Lakes. Temporal trends in one or more ecological variables, starting with the current condition, can be measured for the Narran ecosystem. This type of monitoring is common in both aquatic and terrestrial habitats but has some limitations. First, it is very difficult to attribute temporal changes in some ecological variables to changes in human activities (e.g. increased water abstraction). Ecological variables almost certainly change naturally and can be affected by both local and larger-scale factors (e.g. global warming). Second, different ecological variables will respond to human activities on very different time scales. For example, breeding success of waterbirds may only respond to changes in water availability over the long term, whereas abundance of macrophytes may respond very quickly. Monitoring programs need to be flexible enough to deal with these different time scales. Third, statistical detection of temporal trends is a challenging task, because the replication contributing to the power of any test is the number of time points. For some variables, only annual monitoring is sensible (e.g. bird breeding success) so the detection of trends will require many years of data.

6.2.6 Task 6 — Determine whether the change is a response to management

In order to determine whether the changes observed in Narran Lakes are a response to management changes in the Narran catchment requires comparison with control systems that have not been exposed to a similar change in management. A control system is one that is in similar condition to Narran at present but will not be subject to future changes in some aspects, such as increases in water abstraction. Control locations are very common and important parts of monitoring designs to detect point-source impacts in aquatic habitats. However, they are more difficult to find when we are dealing with large spatial scales and more diffuse impacts. Also, we would probably have to use systems that are part control and part reference because there are so few systems that are even vaguely comparable to the Narran Lakes.

Possible control systems for the Narran River, its floodplain and its terminal lakes are listed in Table 6.1. A high priority would be an evaluation of the suitability of these possible control/reference ecosystems for comparison with the Narran Lakes system.

Table 6.1 Possible control systems for use in an ecological monitoring framework for Narran river, floodplain and terminal lakes. R = river, FP = floodplain, ALL = terminal wetlands, floodplain and riverine components.

System	Comparison with Narran	Basis of reference	Confounding?
Paroo	All	Original flow and vegetation	
Culgoa National Park	R, FP	Original vegetation	
Warrego	R, FP	Original flow and vegetation	
Bulloo	All	Original flow and vegetation	Different climate and biogeography
Nebine	R, FP	Original flow and vegetation	
Cooper	All	Original flow and vegetation	Different climate and biogeography

6.2.7 Task 7 — Determine whether change is positive or negative

Due to the listing of the Narran Lakes as a Ramsar wetland, we are obliged to protect its ecological character. As a consequence the current management focus is on ensuring that water resource development and floodplain management do not adversely affect the ecological character of Narran Lakes. In the future, however, improved management of the floodplain, economic forces and more sustainable irrigation practices may mean that the condition of the Narran Lakes can be partially rehabilitated. If this is a possibility, then managers will need to know whether the changes they observe represent further degradation or an improvement in the condition of the lake. This evaluation is undertaken by comparing the character/condition of the lake to a reference condition. Given the widespread degradation of floodplain ecosystems in the Murray-Darling Basin it is not possible to find any lakes that are entirely suitable as reference lakes. The best solution to this is to synthesise a reference condition from disparate data sources. The types of data that can be used include data from less disturbed lakes (controls) or anecdotal, modelled and palaeolimnological data. For example, cores from the lakebeds or riverine floodplain can provide information on past sedimentation rates, soil and vegetation types, water levels and even nutrient status.

6.2.8 Recommendations

The on-going ecological monitoring of the Narran ecosystem should be based on the seven steps just described, focusing on an assessment of current condition or ecological character. On-going monitoring should include assessment of temporal trends in relevant components of ecological character and also comparisons of the Narran system with relevant systems that have less or different forms of human activities. Historical comparisons, to assess the effects of previous water and land management practices through palaeoecological techniques, will be important for interpretation of temporal trends but are best considered as part of the research component (Chapter 7).

The final design issue of general importance is the pattern of monitoring through time. Traditionally, monitoring programs use a regular pattern, whereby measurements are taken at monthly or seasonal or annual intervals. This approach provides a consistent design for comparing between sites and ensures that seasonal differences are accounted for. The difficulty for dryland systems like the Narran is that key hydrological events may be missed by such a design. For example, monthly sampling may miss an important high flow event when ecological activity might be greatest. An alternative then is to use event-based sampling, whereby key hydrological events or periods are targeted for monitoring. For the Narran Lakes, sampling could focus on the post-flood period, the main drying phase and the low water level phase. We recommend that a regular frequency of monitoring, and measurements focused on hydrological events, should both be used for determining current condition.

6.3 Variables to monitor

We see three important groups of variables that are related to ecological character of the Narran River, its floodplain and terminal lakes; namely physical, chemical, biological components. These groups of variables need to be included in any assessment of current condition, along with any variables that may trigger the EPBC Act, such as abundances of threatened species or area occupied by ecologically significant assemblages. The specific variables that are chosen for on-going monitoring will depend on analysis and results of data on current ecological character. In particular, we need estimates of spatial and temporal variation to design further sampling and determine appropriate sample sizes. Our focus here will be assessment of current condition but a subset of these variables will also be included in the on-going monitoring.

6.3.1 Hydrology

Detailed analyses of hydrological data for the Condamine-Balonne WAMP and those presented in Chapter 2 indicate that there has been a 30% reduction in total annual flow in the Narran River, decreases in small and medium flows, and a decrease of about 31% in the number of high flow events.

However, there is only one gauge on the Narran River (Wilby Wilby) with useful flow data and the gauge in Narran Lake has produced only two years of useable data. Therefore, we are not in a position to accurately predict the effects of current flow regimes, or future flows under various WAMP scenarios, on extent of flooding or wetting and drying cycles of the Narran River floodplain or the terminal lakes. Further hydrological analyses of flows from existing data sets from the Narran River are required, and should make particular use of the latest daily-flow version of the IQQM models. These analyses are essential for the development of an input/response model for Narran Lakes. Such analyses may provide estimates of total volumes of water reaching Narran Lakes under various management scenarios. We also know little about the role of groundwater in the hydrological cycle of the Narran Lakes. Aerial mapping that is planned as part of the National Action Plan for Salinity and Water Quality may provide information to fill this knowledge gap. Climatological data are also required for determining evaporation rates in the area.

Current hydrological data also do not allow us to predict how changes in flow regimes and water volumes in the Narran River influence the frequency and duration of flooding events in the Narran Lakes and surrounding floodplain. It is essential that a component of on-going monitoring for Narran Lakes be the installation of gauging stations in all three lakes (Narran, Back and Clear). These gauges must be linked to one in the Narran River, or to a new gauge that is installed closer to the lakes. Analyses of data from these gauging stations will greatly improve our understanding of the potential effects of water resource development in the Condamine-Balonne catchment on the Narran Lakes.

6.3.2 Water quality and sedimentation

Current levels of water abstraction and floodplain agriculture in the catchment may have reduced water quality in the Narran River and its terminal lakes. These effects on water quality may be compounded by altered flooding regimes that reduce river–floodplain interactions along the Narran River. Additionally, previous land clearing and grazing are likely to result in increased sediment loads to the river and the wetlands. Associated with these increased sediment loads may be elevated levels of pollutants such as pesticides. Unfortunately, the available data do not permit any tests of whether there are long-term trends in water quality nor whether the water quality of the Narran Lakes is worse than we would expect from comparisons with reference systems.

It is a priority to establish a water quality monitoring program that specifically assesses current water quality and monitors temporal trends in relation to reference/control sites. This program should be linked to flow gauging stations and record basic physical and chemical variables, including temperature (plus a depth component to determine stratification), pH, salinity, turbidity and nutrient levels (total and reactive P, total N and NOx). Data loggers are the most efficient method of monitoring water quality and permit great flexibility in the time scale over which variables can be integrated. Data loggers also ensure that key hydrological events as well as seasonal changes are recorded. If data loggers are not possible, then a combination of regular sampling and event-based sampling seems sensible. Replication within lakes and the river is essential because water quality variables are likely to show considerable spatial variability. The scale and level of replication will need to be determined from the assessment of current water quality.

We also need to record rates of sedimentation in the terminal lakes. Sediment traps can be established and retrieved after specific flow events. These data should be linked to a research program investigating the palaeo-history of the floodplain and lakes, including historical patterns in sedimentation rates, sources of eroded materials, distribution of vegetation and chemical composition of sediments.

6.3.3 Geomorphic and biotic habitat

An important link between patterns in diversity and abundance of biota and altered hydrology may be the availability of specific types of habitat. For example, altered flooding regimes in the Narran Lakes may change the extent of wetted areas of Lignum, an important breeding habitat for the ibis, cormorants and spoonbills.

Detailed maps of the Narran system including topography, soil type and distribution, surface water areas and vegetation type and distribution are desperately needed. The bathymetric maps described above will provide some of the topographic information but knowing the distribution of major vegetation types is the highest priority. Some results of previous mapping are available but need to be further analysed and ground-truthed. Additionally, on-going mapping is necessary to monitor temporal changes in vegetation types.

6.3.4 Biota and ecological processes

Relevant biotic data for a monitoring program can be of two types: measurements on structure and composition (e.g. species richness, abundance of particular taxa, assemblage composition), and measurements of processes (e.g. primary productivity). It is surprising how little information we have on the composition and spatial and temporal variability of the biota in the Narran River and its terminal lakes. There are counts of bird populations and unpublished data on fish. There is limited work on aquatic invertebrates and plants but no comprehensive assessments of these aspects. Terrestrial vegetation and vertebrates have been surveyed in several studies and relatively good species lists exist. Some of this information may be useful for assessing current condition and for providing input into the design of a monitoring program.

The biotic components of ecological character that may respond to changes in wetting/drying cycles in the lakes, and which are practical to measure, are phytoplankton, aquatic and terrestrial vegetation, zooplankton, aquatic macroinvertebrates, fish and waterbirds. Some of these groups are commonly incorporated in riverine monitoring programs. For example, phytoplankton, zooplankton and fish are included in on-going monitoring of Menindee lakes, and macroinvertebrates form the basis of much of Australia's river health monitoring. The spatial design of sampling is important, as biota will show great variability on a range of spatial scales. Pilot studies combined with available data on some groups (e.g. fish) from Narran or comparable lakes like Menindee will be a crucial aspect of the monitoring program.

Phytoplankton

Phytoplankton in the water column in lakes are known to respond rapidly to changing water levels and alterations in nutrient regimes. Recent work by the CRCFE has also shown that much of the primary productivity in lowland rivers might be driven by phytoplankton. Blooms of phytoplankton can cause serious environmental and economic damage, especially when toxic blue-green algae are involved (e.g. the Darling River bloom of the early 1990s). Monitoring of phytoplankton should include, as a minimum, concentrations of chlorophyll-*a* in the water column (as a surrogate for algal productivity) and cell counts for important groups such as blue-green algae. More detailed monitoring can measure relative abundances of different taxa of algae to determine the composition of algal assemblages. However, we currently do not have simple predictions of how the assemblage might respond to changes in flooding regimes, and measuring relative abundance of different taxa is time-consuming and potentially expensive.

Macrophytes and floodplain vegetation

Aquatic plants have been recommended as sensitive indicators of ecosystem changes that occur in response to altered water regimes in wetlands along the River Murray. They can often survive dry periods because of sediment seed banks, and different flooding regimes would be expected to produce different assemblages of aquatic plants in the Narran Lakes. Assessment of the distribution and abundance (cover) of aquatic plants should be part of a study to determine baseline character of the lakes.

Terrestrial vegetation on the floodplain is also very important. Two species of plants that occur within the Narran Lakes Nature Reserve are listed as endangered or vulnerable nationally and as threatened in NSW. Additionally, nearby wetlands and floodplains are considered significant because of their plant associations and the very low percentage of exotic species. Indeed, the ratio of native to exotic plants may be an important indicator or ecological response to changes in flow regime.

Both aquatic and terrestrial plants provide crucial habitat for other biota, especially birds. Any information on plant distribution should be incorporated in the mapping exercise described above for geomorphic features, and be part of the GIS database.

Invertebrates

Zooplankton respond quickly to changes in water level in wetlands. Several crustacean species lay their eggs in sediment and these eggs will only hatch after the sediment has dried and been re-wetted. In the longer-term, we might also expect that some species of zooplankton might disappear from the system if the interval between floods, and hence the length of the dry period, increases because their eggs might not remain viable in the sediment. Note that the same argument will apply to aquatic plants. Methods are available for sampling zooplankton in standing water bodies like the Narran Lakes, and this group of biota should be incorporated into any assessment of baseline character of the lakes. These initial data can be used to decide whether zooplankton are feasible and cost-effective for on-going monitoring.

Macroinvertebrates are the basis of many river health assessments throughout Australia. Macroinvertebrates are used in a number of different indices, as well as in predictive comparisons with reference conditions under the AUSRIVAS monitoring framework. A number of sites in the Lower Balonne catchment have been used for macroinvertebrate surveys and these will assist in the design of future monitoring. Macroinvertebrates should be part of an assessment of current condition, especially of the terminal wetlands, and these data can be used to assess their value for longer-term monitoring.

Fish

Fish can respond to changes in water regime in rivers and wetlands in a number of ways. Flooding can initiate spawning and migrations associated with breeding, although recent research by the CRCFE suggests that some lowland river fish species might require low flows for successful recruitment. However, water regime can influence both native and exotic species of fish, and flooding in a wetland may benefit introduced species like carp. Large overbank floods also allow fish access to the floodplain (although movement onto the floodplain may also be through flood runners without an overbank flood) and new food and habitat resources. We would predict that reductions in the frequency of floods in the Narran River and in the terminal lakes would change the assemblages of fish in both systems. Standard techniques (seine netting, fyke netting, electrofishing) can be used to describe the assemblages of fish in the river and the floodplain lakes as part of an assessment of current condition. Previous data might be extremely useful for determining methods, spatial extent of sampling and frequency of sampling.

Waterbirds

The Narran Lakes have a public profile because of their importance as breeding and feeding resources for waterbirds. It was the recognition of this potential that led to the site being listed under the Ramsar Convention as a Wetland of International Importance. The difficulty of birds as a focus for monitoring is the great temporal variability in their patterns of breeding and migration and the spatial unpredictability in the wetlands they might use in any given year. Additionally, different species of birds have very different habitat requirements for feeding, breeding and roosting. Therefore, bird populations are probably not very useful short-term indicators of the ecological effects of altered flooding cycles in the Narran Lakes, unless such impacts are very severe. Nonetheless, waterbirds may well integrate other components of ecological character because of their use of vegetated habitat for roosting and breeding, and their use of various biota as food resources. An important knowledge gap is our limited understanding of the habitats used by waterbirds at various stages of their annual cycle.

Clearly, measures of abundance and breeding success of waterbirds should be a major component of any long-term monitoring of ecological character of Narran Lakes and would contribute to fulfilment of Australia's obligations under the Ramsar Convention. In particular, species listed in the Ramsar Information Sheet and those included under the various Migratory Bird Agreements must be monitored regularly. It is also important that any monitoring of bird populations and breeding at Narran Lakes should consider the broader context wetland–bird associations throughout the entire Murray-Darling Basin. We need to establish the regional usage of wetlands by waterbirds, and the relative importance of each wetland system. The NSW NPWS has a monitoring framework for waterbirds at Narran Lakes and this program should form the basis for bird monitoring. However, it should be extended to include other important wetlands within the Murray-Darling Basin.

6.4 Summary

It is important that any monitoring program for the Narran River, floodplain and terminal lakes takes into account other research and monitoring being conducted in the region or in comparable habitats. For example, biologists from Queensland Natural Resources and Mines have initiated a monitoring program in the Condamine-Balonne catchment that records a range of simple and sophisticated measures of river health. While the primary focus of this program is to test for links between flow variability and river health, the assessment of the efficacy of the various indicators used in this monitoring would make an important contribution to the development of a monitoring program for the Narran River and lakes.

Our recommended monitoring framework involves seven steps, including the derivation of hypotheses from a clear conceptual model. The development of an input/response model from further analyses of hydrological information, as well as new information from additional gauges, is also important. The design of monitoring of specific ecological responses includes three components:

- a full quality control and statistical analyses of existing ecological datasets;
- survey work to describe current ecological condition or character of the Narran lakes and floodplain; and
- consideration of both these datasets and analyses to design an on-going monitoring program for those key variables that are likely to produce a statistically reliable outcome.

A sensible strategy for a monitoring program might also be to develop an inclusive partnership of key stakeholders (resource managers, irrigators and other water users, conservationists, scientists) to oversee the monitoring and interpretation. Such a partnership, possibly based on the model used in the South East Queensland Regional Water Quality Management Strategy (SEQRWQMS), will help ensure acceptance of the results of monitoring and a more cooperative approach to river management.

6.4.1 Specific recommendations for a monitoring framework

Our priority recommendations for the development of an ecological monitoring framework are provided below. These recommendations vary in their specificity. For example, we can be quite specific about the requirements for monitoring hydrology because the background information from this or similar systems is detailed. In contrast, our knowledge of the biota and ecological processes is much less detailed and only broad recommendations about collecting better data can be made. It is important to note that this monitoring program should be coordinated with an integrated research program to fill the large gaps in our knowledge about how the Narran ecosystem functions. Only then will we be able to interpret ecological changes in the system and whether these changes, historical or future, are related to land and water management practices.

General

- Refine the conceptual models for the Narran Lakes ecosystem with further input from other scientists and further analyses of current data.
- Focus on the development of an input/response model, where the flows in the Narran River are linked to changes in flooding extent and duration on the floodplain and the terminal lakes, and to the availability of key habitat.
- Assess hydrological and ecological similarities and differences between the Narran River and its floodplain and terminal lakes and the possible reference/control systems listed in Table 1. Evaluate the suitability of possible control/reference ecosystems for comparison with the Narran Lakes and floodplain.
- Ensure that the monitoring program is coordinated with an integrated research program that addresses key knowledge gaps for the Narran Lakes.

Hydrology

- Install functioning gauging stations in Narran, Back and Clear lakes and link these to the gauge at Wilby Wilby.
- Analyse the resulting data to develop predictive models for the effects of various upstream water abstraction scenarios on the extent of flooding and wetting/drying cycles of the Narran Lakes and the floodplain. The use of the latest IQQM models with daily data is essential.

Water quality and sedimentation

- Design and initiate a water quality monitoring program that measures baseline conditions and also focuses on event-based (flooding and drying) sampling.
- Measure rates of sedimentation into the terminal lakes and compare these rates with those determined from analysis of sediment cores.

Geomorphic and biotic habitat

- Undertake detailed topographic, bathymetric and habitat mapping of the Narran Lakes and floodplain. This mapping is essential for the development of an input/response model that links flows in the Narran River to ecological responses.
- Identify habitat requirements of key biota.
- Build a GIS database with layers for hydrology, waterbird use, vegetation communities, and the distributions of other biota. This 'atlas of significant species' could incorporate a large part of the data already collected, and integrate scattered information.

Biota and ecological processes

- Design and implement a baseline survey of the main aquatic biota groups. This assessment of current condition should include regular sampling over one year at both the Narran Lakes and appropriate reference/control systems.
- Design and initiate a biotic monitoring program focusing on those groups suggested by the baseline study as being useful indicators. A combination of regular sampling to set the baseline conditions and event-based sampling for flooding and drying phases is recommended.
- In collaboration with NSW NPWS, continue and extend the monitoring program to measure abundance and breeding success of waterbirds at the Narran Lakes and other wetlands within the Murray-Darling Basin.

7 IMPLICATIONS OF WATER RESOURCE DEVELOPMENT: SUMMARY AND PRIORITIES FOR FUTURE WORK

7.1 Assessment of previous management plans

There are three main draft management plans that pertain to the Lower Balonne region and Narran Lakes in particular. These are dealt with separately in the following sections.

7.1.1 Draft Condamine/Balonne WAMP[135]

One of the main outcomes of the WAMP process for the Condamine-Balonne catchment will be a cap on levels of water resource abstraction. Three different scenarios (A, B, C) were discussed in the draft WAMP report, the first based on setting a cap at mid-1999 levels, and the other two imposing additional reductions in water usage. For the Narran Lakes, these different scenarios result in a range of mean annual inflows into Narran Lakes of 42.3% of natural (A) to 49.7% of natural (C) and a range of median annual inflows into Narran Lakes of 24.1% of natural (A) to 41.6% of natural (C). It is important to note that these are all marked improvements on the inflows into Narran Lakes without any WAMP cap implemented, illustrating the necessity for explicit water management plans and some cap on water abstraction in this catchment. The main limitation on the interpretation of predicted inflows into the Narran Lakes under different water resource development scenarios is the quality of flow data that feed into the models. The closest operational gauge is at Wilby Wilby, a considerable distance upstream of the lakes. The effects of different scenarios on inflows into the Narran Lakes will be unclear until we have better flow data closer to the lakes.

The WAMP used traffic light diagrams to summarise the impacts of the different water resource development scenarios at various locations within the catchment. These diagrams show percent of natural for a flow statistic, from 0% to 100%, and indicate where the various scenarios (termed ‘planned development limits’, PDLs) occur within this range. Superimposed on these diagrams are two measures of ecological impact. The first is a colour grading representing ecological impacts from very poor (red) to good (green). The second is the environmental flow limit (EFL), representing the level below which there is an increased risk of unacceptable environmental degradation. This EFL is nearly always placed at the boundary between red and green, usually a small interval of yellow representing intermediate impacts between good and poor.

For the Narran Lakes, all three water resource development scenario PDLs were well within the red zone on these diagrams, except for the 10% fill level in the lakes, and well below the EFL. This suggests that clawing back small amounts of water under scenarios B and C will not reduce ecological impacts beyond poor, and the risk of unacceptable degradation will remain high. Some may argue then that there is little justification for adopting anything other than scenario A since the other PDLs will not make any ecological difference.

We suggest that this argument is flawed. The traffic light diagrams and the exact positions of the EFLs are based on limited data and understanding of the relationship between various components of flow and ecological condition or health, as is acknowledged by the Technical Advisory Panel (TAP) in the WAMP report. There will be some type of continuum in the relationship and any increase in water allocated to the river will result in *some* improvement in ecological condition. The difficulty we face with incomplete knowledge is determining the magnitude of the improvement. The WAMP TAP sensibly adopted a precautionary approach, using available data and expert judgement to model the relationship between flow and ecological condition. They highlighted that the current levels of water use mean that it will be difficult to improve the condition of the Narran Lakes outside the range of poor under the planned scenarios. This does NOT mean that the different scenarios won't make any difference. Any movement from the red towards the green bands, and closer to the EFL, in the traffic light diagrams is an improvement and provides a stronger base for future management and protection of the lakes.

As on-going research and monitoring improves our understanding of the effects of flow changes on ecological condition of dryland rivers generally, and the Narran River and terminal lakes specifically, we will be in a better position to evaluate the magnitude of the improvements caused by different water resource development scenarios.

7.1.2 Draft Floodplain Management Framework[111]

This document provides a management framework for the Lower Balonne floodplain — in this case that area between Beardmore Dam and the NSW/Queensland border and represents an agreement among landholders on the sharing of flows on the floodplain. It attempts to recognise existing water harvesting licences, the benefits of flooding for economic activity and the environment, and the responsibility of the floodplain community to pass water downstream to meet the needs of downstream landholders and the environment. The management framework uses the output of a Decision Support Tool (DST), developed by the Snowy Mountains Engineering Corporation (SMEC) during Phase 2 of the Lower Balonne Floodplain Management Study, to define the entitlements of landholders to overland flows. The DST also models the harvesting of water from streams and channels by licensed water harvesters, and produces maps of flood extents and plots of end-of-system hydrographs.

The report summarises a number of ecosystem components in the Lower Balonne Floodplain but does not deal with the Narran Lakes. Patterns of flooding, soils, vegetation and the benefits of flooding are detailed. The main focus of the Lower Balonne Floodplain Management Plan Phase 2 is the development of a DST, which is built around a hydrological model linked to a flood mapping routine that operates within a GIS. The DST is similar to IQQM in that the hydrological model represents the floodplain by a network of nodes and links. It then uses the Muskingum flood routing procedure to model the movement of the flood through this network. This procedure requires the evaluation of modelling parameters by calibration against historical floods. The hydrological model takes into account the diversion of flows by licensed water harvesters, and attempts to model the filling of on-farm storages to determine the diversion rate and the quantity of water that will be diverted. The primary outputs of the DST are plots of hydrographs at the end of system (in this case, the Queensland/NSW border), and a map of the maximum extent of flooding.

The main purpose of the DST was to provide a basis for sharing flood flows. It enables estimation of the effect of any developments on the floodplain or changes to water harvesting activities on patterns of flooding and end-of-system flows, and determines the quantity of 'Type A' water that each landholder is entitled to harvest. Type A water is defined as that portion of floodwater that would have been consumed by an approved levee protected area if the levees were not there. The quantity of Type A water depends on the area within the levees that would have been inundated if there were no levees, the soil moisture replenishment that occurs as a result of this inundation, and the quantity of evaporation from the water surface of that inundated area.

The principles agreed by Lower Balonne Advisory Committee for the sharing of floodplain flows are as follows:

1. Floodplain flows should be allowed to flow along historical flow paths
2. Peaks of 'critical' flows should be allowed to pass unhindered down the floodplain
3. Each holding should receive a share of flow similar to the share it would receive with the floodplain in its historical (natural) state
4. Subject to principles 1 to 3, each holding should be able to choose how best to make use of its share of floodplain flow
5. Works and structures for harvesting of floodplain flows should be constructed under licence from the Department of Natural Resources and Mines. Works and structures must be capable of allowing flow to pass down the floodplain without undue interference
6. Diversion of water from the floodplain by works or structures should be quantified or measured in the most cost-effective way for each individual case
7. There should be no charge for water harvested from floodplain flows
8. Floodplain flows should be managed by the Queensland Department of Natural Resources and Mines
9. Due consideration should be given to interstate flow sharing agreements, environmental requirements, and the sustainability of both floodplain and development in the management of floodplain flows.

The Management Plan appears to neglect the possible impact of present and potential water resource and floodplain development on the ecological character and functioning of the Lower Balonne floodplain and Narran Lakes, because it is restricted in scope to the Queensland side of the system.

7.1.3 Narran Lakes Nature Reserve Draft Water Management Plan[5]

The Nature Reserve only forms part of the Narran Lakes terminal wetland complex. The purpose of the document was to establish a scheme of operations clearly outlining policy and management actions with regard to the reserve. In this sense it has limited implications for the broader management of the whole Narran Lakes and Lower Balonne River floodplain. However, it does clearly recognise the importance of maintaining a natural flow regime from the Narran River into the Narran Lakes wetland complex as a whole, and acknowledges that the reserve is part of a larger ecosystem. The aim of the management plan is to maintain the high biodiversity values of the reserve and to meet the obligations under the Ramsar Convention. In particular, the maintenance of significant waterbird breeding events is seen as a priority.

The management plan reflects a historical lack of limnological work on the wetlands, with much of the emphasis of previous surveys focusing on the ecological components such as terrestrial vertebrates, floodplain vegetation and waterbirds. However, the NSW NPWS intends to play an active role in defining the environmental water requirements for the reserve and the Narran Lakes in general.

The management actions outlined will in part provide localised benefits (e.g. erosion control, feral pest control actions) but also have the potential to provide the basis of monitoring programs that will detect ecological impacts from water resource development (e.g. success of water bird breeding events). Without appropriate environmental water allocations, the continuation of water resource development upstream of the Narran Lakes system may well result in the slow degradation of these important wetlands. The limited jurisdiction/area for which the plan operates means it will act as the indicator of upstream activities, rather than directly influencing them.

Specific recommendations for water requirements include these:

- inflows of water, and lake volumes and depths, need to be established;
- upgrading of river gauges on the Narran River upstream of the lakes, and installing gauges within the lakes, is a priority;
- detailed hydrological and geomorphological studies of the lakes are needed, to determine the factors influencing water movement and balances in the lakes system. This should include a topographic survey of the lakes.
- continuation of the waterbird monitoring program in the Nature Reserve.

7.2 Impact of land use change and water resource development on the Lower Balonne floodplain and Narran Lakes

'Balancing the demands of water between the irrigation industry, environmental requirements and downstream graziers provides the greatest challenge for the future management of the Condamine/Balonne system' piv. McCosker, 1996[137]

We can identify four major changes to the Narran River and its floodplain ecosystem that are related to human activity since European settlement within the Condamine-Balonne catchment:

- Altered hydrology in Narran River because of water abstraction in the Condamine-Balonne catchment. There are a range of types of water resource developments in this catchment. These include both instream and offstream storages, direct abstraction from the river and the harvesting of overland flows. This level of water abstraction has reduced the median annual flow down the Narran River, reduced the frequency of small–medium flood events and fundamentally changed the nature of the flood pulse and the shape of the hydrograph. The result is marked changes in the duration and frequency of flooding and drying in the Narran Lakes and surrounding floodplain.
- Construction of off-stream storages and levee banks with the resulting loss of floodplain area. This will isolate more of the floodplain from the main river channel, increase fragmentation of the floodplain, and reduce lateral connectivity and movement of materials across the floodplain.
- Clearing of native vegetation will result in greater rates of erosion, altered sediment types and increased sediment delivery to the river and wetlands. Potentially associated with this increased sedimentation will be increased deposition of pesticides, increased salinisation, and increased susceptibility to invasion by exotic plants.
- Introduction and maintenance of grazing stock and feral animals (goats, rabbits, etc.). These animals reduce the rate of recovery of floodplain vegetation and exacerbate the effects caused by land clearing.

Of these four anthropomorphic changes, the first two are considered to be the most likely to be of continued importance in the future. The Condamine-Balonne WAMP describes several scenarios for water resource development, some of which will increase levels of water abstraction and off-river storages beyond 1999 levels. Land clearing is still an issue, particularly in Queensland, although the effects along the Narran River and around the Narran Lakes have probably peaked and will not be an increasing problem. However, many of the impacts of clearing over the past decade will not necessarily be evident for some time. Environmental effects from stock grazing may also be declining as much of the land use switches to crop-based agriculture, particularly the production of cotton. Nonetheless, there are likely to be on-going ecological effects of past land clearing and grazing practices unless some efforts at restoration are undertaken.

7.3 Knowledge requirements for management over the next 1, 5 and 10 years

Establishing the limnological/ecological character of the Narran Lakes terminal wetland system, developing and implementing an ecological monitoring framework, and developing an integrated set of research projects that identify and address knowledge gaps are interconnected to a large extent (Figure 7.1). A conceptual model of how the Narran Lakes ecosystem functions and how this functioning is affected by land and water management is a basic first step. This conceptual model then drives the ecological monitoring framework, which has two parts: to establish ecological character or condition of the ecosystem, and to design a monitoring program that will detect spatial and temporal trends in character, using appropriate reference sites. The description of ecological character then forms the basis of the integrated research projects, which will examine the ecological functioning and importance of the Narran Lakes ecosystem, its historical condition and model the effects of land and water management scenarios.

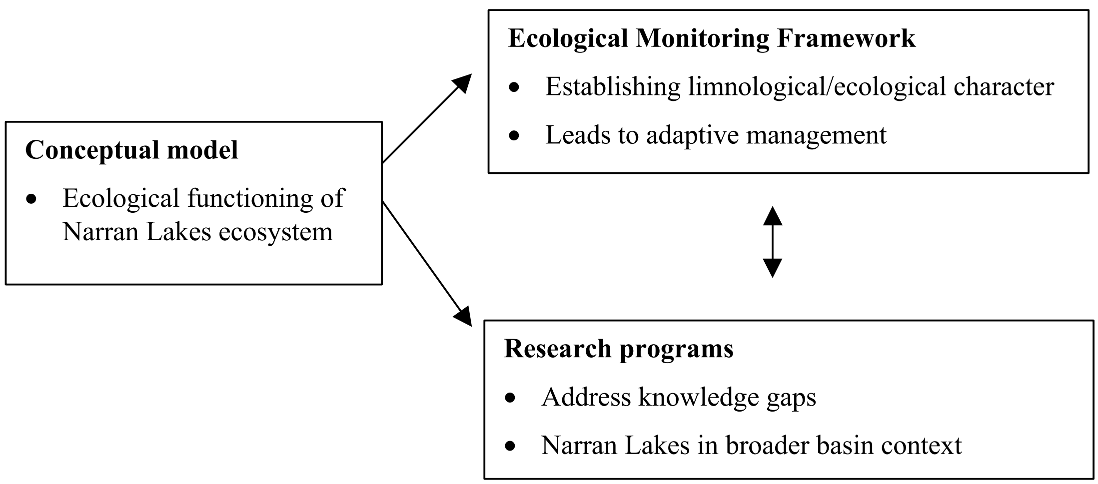

Figure 7.1 Integration of conceptual model, monitoring framework and research program.

A series of research ideas have been developed and these identify projects that would address knowledge gaps, and assist implementation of management or structural options identified by the scoping study. The project ideas include a range of research activities, data interpretation and synthesis, and evaluation and extension of current management activities. The detailed project descriptions are in a separate document, but are summarised below.

7.3.1 Indigenous heritage

- To produce a single updated reference on the indigenous use of the Narran River valley, containing a coordinated photographic, printed and video record of sites, stories, and traditional use of natural resources.
- To review past and current archaeological research on the Narran River valley.

Period: 1–5 years

7.3.2 Trophic relationships

- To understand the key trophic linkages in the Narran Lakes such that they can be protected, thereby protecting the ecological integrity of the system.

Period: 1–5 years

7.3.3 Floodplain vegetation — relationships between flooding regime and vegetation communities

- To identify the relationship between flooding regime and the maintenance of floodplain vegetation communities of the Narran River system, including its floodplain and terminal wetlands.

Period: 1–5 years

7.3.4 Habitat requirements of listed species and ecological assemblages

- To understand the ecology of species of birds and plants listed for protection under various legislative frameworks.
- To determine the distribution, both spatially and temporally, of these taxa at Narran Lakes, especially habitat requirements of the bird species.

Period: 1–5 years

7.3.5 Establishing baseline/benchmarks for the Narran system — understanding spatial and temporal variability

- To quantify the extent of variation in the community composition of key taxonomic groups within the Narran Lakes.

Period: 1 year

7.3.6 Palaeoecological study of Narran Lakes and the Narran River floodplain

- To describe the historical patterns of wetting and drying cycles in the Narran Lakes and the Narran River floodplain.
- To determine past rates of sedimentation, distribution patterns of vegetation and potentially nutrient levels in sediments.

Period: 1–5 years

7.3.7 Groundwater investigation of Narran Lakes

- To determine if groundwater is an important component of the character and functioning of the Narran Lakes ecosystem.

Period: 1–5 years

7.3.8 Key ecological processes under different water resource development scenarios

- To determine the major ecological processes in the Narran lakes. To determine how these processes are likely to vary in response to the management of the Narran Lakes and its catchment.

Period: 1–5 years

7.3.9 Importance of Narran Lakes to waterbirds

- To determine the importance of Narran Lakes as a refugium for waterbirds and migratory birds in the context of wetlands within the Murray-Darling Basin.
- To evaluate the costs, in terms of populations of waterbirds and migratory birds, of the loss of Narran Lakes wetlands due to excessive water resource development.

Period: 10 years

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Reference List

This is an annotated list of all publications/information received as at 2nd June 2001. Thus, not all references are cited in the text. Note also that the type of information ranges from refereed scientific papers to informal personal communications and memos.

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List of Acronyms

The acronyms used in this report are summarised below, in alphabetical order.

ARC	Assessment of River Condition
ARI	Average Recurrence Interval
AUSRIVAS	Australian River Assessment System
CAMBA	China-Australia Migratory Bird Agreement
CRCFE	Cooperative Research Centre for Freshwater Ecology
DST	Decision Support Tool
EA	Environment Australia
EFL	Environmental Flow Limit
EPBC Act	Environment Protection and Biodiversity Conservation Act
FPC	Flood Pulse Concept
GIS	Geographic Information System
IQQM	Integrated Quantity Quality Model
ISC	Index of Stream Condition
JAMBA	Japan-Australia Migratory Bird Agreement
MDBC	Murray-Darling Basin Commission
MDBC NRMS	Murray-Darling Basin Commission Natural Resource Management Strategy
NLWRA	National Land and Water Resources Audit
NRHP	National River Health Program
NSW	New South Wales
NSW DLWC	New South Wales Department of Land and Water Conservation
NSW NPWS	New South Wales National Parks and Wildlife Service
PDLs	Planned Development Limits
QDPI	Queensland Department of Primary Industries
Queensland EPA	Queensland Environmental Protection Agency
QNR&M	Queensland Department of Natural Resources and Mines
RCC	River Continuum Concept
RIS	Ramsar Information Sheet
RPM	Riverine Productivity Model
SEQRWQMS	South East Queensland Regional Water Quality Management Strategy
SIGNAL	Stream Invertebrate Grade Number – Average Level
SKM	Sinclair Knight Merz
SMEC	Snowy Mountains Engineering Corporation
SRA	Sustainable Rivers Audit
TAP	Technical Advisory Panel (of WAMP)
WAMP	Water Allocation Management Plan

Appendix A

Draft Information Sheet on Ramsar Wetlands

FOR OFFICE USE ONLY

DD MM YY

Designation date

Site Reference Number

1. Date this sheet was completed/updated:

June 2001

2. Country: Australia

3. Name of wetland: Narran Lake Nature Reserve

4. Geographical co-ordinates: Latitude: 29° 43' S; Longitude: 147° 26' E

5. Altitude: 120 - 140m ASL 6. Area: 5,538 hectares

7. Overview: Narran Lake Nature Reserve covers part of a large terminal wetland of the Narran River in New South Wales (NSW) at the end of the Condamine-Balonne River system which originates in Queensland. The area is internationally significant for waterbird breeding and as habitat for species including a number listed under the Japan–Australia and China-Australia Migratory Bird Agreements (JAMBA and CAMBA). The Nature Reserve also contains a variety of flora associations which are considered to be threatened in NSW.

8. Wetland Type:

marine-coastal: A • B • C • D • E • F • G • H • I • J • K • Zk(a)

inland: L • M • N • O • P • Q • R • Sp • Ss • Tp

Ts • U • Va • Vt • W • Xf • Xp • Y • Zg • Zk(b)

human-made: 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8 • 9 • Zk(c)

Please now rank these wetland types by listing them from the most to the least dominant:

Inland Wetlands N P Ts W Xf

9. Ramsar Criteria:

1 • 2 • 3 • 4 • 5 • 6 • 7 • 8

Please specify the most significant criterion applicable to the site: __4__

10. Map of site included? Please tick *yes* ☑ -or- *no* ☐

11. Name and address of the compiler of this form:

NSW National Parks and Wildlife Service	Telephone: 02 9585 6692
PO Box 1967	Fax: 02 9585 6495
Hurstville NSW 2220	Email: deborah.stevenson@npws.nsw.gov.au
AUSTRALIA	

12. Justification of the criteria selected under point 9, on previous page:

Criteria 1 Narran Lake Nature Reserve is a representative example of a natural or near-natural wetland type found within the Darling Riverine Plains biogeographic region.

The Nature Reserve comprises about a third of the Narran wetland system. The Narran wetlands are geomorphologically significant as an excellent example of a relatively undisturbed terminal lake system in NSW. The wetlands also contain a considerable diversity of habitats characteristic of this biogeographic region, including some of the largest expanses of Lignum (*Muehlenbeckia florulenta*) in NSW. These habitats are still in a relatively natural condition because there has been limited clearing at the site and the frequency of large flood events still follows a natural regime.

Criterion 2 Narran Lake Nature Reserve supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

A number of waterbirds listed under the *Threatened Species Conservation (TSC) Act 1995* have been recorded as breeding in the Nature Reserve including the Brolga (*Grus rubicundus*), Blue-billed Duck (*Oxyyura australis*), Freckled Duck (*Stictonetta naevosa*) and Magpie Goose (*Anseranas semipalmata*). The endangered Australian Bustard (*Ardeotis australis*) and the vulnerable Grey Falcon (*Falco hypoleucos*), Pink Cockatoo (*Cacatua leadbeateri*), Black-tailed Godwit (*Limosa limosa*), Barking Owl (*Ninox connivens*) and Masked Owl (*Tyto novaehollandiae*) have also been recorded in the Nature Reserve. In addition, the Painted Honeyeater (*Grantiella picta*), a mistletoe (*Amyema*) feeder, and the Red-tailed Black Cockatoo (*Calyptoerhynchus magnificus*), which inhabit eucalypt woodlands along floodplains in north western NSW, are likely to occur at the site (see Appendix 1). Two plant species, listed as threatened under both the *TSC Act* and the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*, are also known to occur at the site, Winged Peppercress (*Lepidium monoplocoides*) which is listed as endangered, and Macbarron's Goodenia (*Goodenia macbarronii*) which is listed as vulnerable (see Appendix 2).

Criteria 4 Narran Lake Nature Reserve supports plant and/or animal species at a critical stage in their life cycles.

The Narran Lake wetlands flood more frequently than most other wetlands in north-western NSW and therefore provide important breeding habitat for waterbirds in this semi-arid area. Waterbirds, which are considered to have a restricted breeding distribution in western NSW, have been recorded breeding in Narran Lake Nature Reserve (Smith *et al*, 1995) and include:

	Australian Pelican	*Pelecanus conspicillatus*
	Great Cormorant	*Phalacrocorax carbo*
	Pied Cormorant	*Phalacrocorax varius*
	Darter	*Anhinga melanogaster*
	Rufous Night Heron	*Nycticorax caledonicus*
*	Large Egret	*Ardea alba*
	Little Egret	*Ardea gazetta*
	Intermediate Egret	*Ardea intermedia*
*	Glossy Ibis	*Plegadis falcinellus*
*	Australian White (Sacred) Ibis	*Threskiornis molucca*
*	Straw-necked Ibis	*Threskiornis spinicollis*
	Great Crested Grebe	*Podiceps cristatus*
*	Royal Spoonbill	*Platalea regia*
	Gull-billed Tern	*Sterna nilotica*

* = significant breeding populations

The Narran wetlands are considered to be both nationally and internationally significant as a major breeding site not only for the above species of waterbirds, but for many other species as well (see Appendix 1 and the Narran Lake Nature Reserve Plan of Management for other species recorded breeding in Narran Lakes area). Breeding populations of Straw-necked Ibis (*Threskiornis spinicollis*), Little Black Cormorant (*Phalacrocorax sulcirostris*) and Royal Spoonbill (*Platalea regia*) are the largest recorded in Australia (Ley 1998a). During the 1994-96 Murray-Darling Basin Water Monitoring Project, run by Birds Australia, the Narran wetlands were among the highest ranked sites for species richness, number of breeding species and total number of birds.

Narran Lake Nature Reserve also supports a number of internationally-important migratory bird species. These species are listed under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA) and are noted in Appendix 1 as being covered by international agreements (int).

The significance of the Narran wetlands is also reflected in its listing on the Register of the National Estate.

Criterion 6 Narran Lake Nature Reserve regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

The large numbers of Black-winged Stilts (*Himantopus himantopus*), Red-necked Avocets (*Recurvirostra novaehollandiae*), Marsh Sandpiper (*Tringa staganatilis*), Straw-necked Ibis (*Threskiornis spinicollis*) and Red-kneed Dotterel (*Erythrogonys cinctus*) recorded in Narran Lake wetlands suggests that these wetlands are of national and international importance for these species (Ley, 1998a).

13. General location: The Narran Lake Nature Reserve is situated in central north-western New South Wales, Australia. It is approximately 75 kms north west of Walgett and 50kms north east of Brewarrina within the Murray-Darling Basin.

14. Physical features: The geology of the Narran Lake Nature Reserve consists primarily of Quaternary sediments which include floodplain, outwash areas and drainage flats of black, red and white sandy to silty clay and clayey sand, and silt with areas of black and grey clayey silt and sand deposited in claypans and lakes. The remainder of the Nature Reserve to the north consists of sediments of the Rolling Downs Group of Quaternary talus material obscuring Cretaceous sediments (Offenberg, 1966). These sediments tend to be salty and highly alkaline (Martin, 1979; NPWS, 1995).

Cretaceous sandstone and quartzite sediments are exposed on the ridge country in the eastern part of the Nature Reserve. These ridges are capped in some places with Cainozoic silcrete. Soils on the ridges are generally red sandy loams, with gravelly soils in the highest areas. These soft red soils are prone to erosion and gullying. The Rolling Downs sediments are overlain by Quaternary sediments on the Narran River floodplain which consists of dark organic lake muds in the lakes and adjacent wetlands, and light grey clays in nearby playa lakes. The lunettes within the Nature Reserve consist of orange sand, while the younger dunes consist of yellow-white sands. Severe wind and water erosion in this area has resulted in extensive scalding and the production of claypans (NPWS, 1995).

The Narran Lake Nature Reserve is comprised of two land systems. These are the Narran Land System, which covers the majority of the Nature Reserve, and the Lightning Ridge Land System in the north- and south-east corner of the Reserve. The Narran Land System is characterised by an extensive lake bed with its associated discontinuous lunette and sandy levee, which has a relief to 5m as well as drainage depressions and isolated salina which are periodically inundated by the Narran River. The Lightning Ridge Land System consists of undulating ridges of Cretaceous claystone, siltstone and sandstone with slightly sloping sandy plateaux, narrow dendritic drainage lines and small rounded pans with a relief to 20m (Walker, 1991).

Roughly half of the Nature Reserve consists of wetland areas subject to inundation from the Narran River. These wetlands comprise the north-eastern section of the Narran Lake system. The Reserve contains two open water areas (small lakes), Clear Lake and Back Lake, surrounded by extensive channelised wetlands vegetated with Lignum (*Muehlenbeckia florulenta*), River Cooba (*Acacia stenophylla*), and River Red Gum (*Eucalyptus camaldulensis*). The Narran River forms the south-western boundary of the Reserve. Since the removal of persistent grazing pressure from the Nature Reserve, Lignum is recolonising a large part of Back Lake. The eastern half of the Reserve is low, gently undulating, sandy and rocky ridge country. A number of semi-saline playa lakes and drainage depressions, which fill from local rainfall, are located in this area east of Clear Lake. Between the wetland shore and the ridge country is an area of discontinuous aeolian lunettes and sandy levees. These were formed by deflation of the lake beds and accumulation of sand grains and salt by strong westerly winds (NPWS, 1995).

The Narran River lies within the Murray-Darling Basin in NSW and is a distributary of the Balonne River in Queensland. The catchment of the Narran River extends to the Condamine River in the mountains of central-southern Queensland (Smith, 1993). The Balonne River is regulated by Beardmore Dam and flows reach the Narran River when high flows occur in the Balonne. Considerable recent growth in on-farm water storage capacity has added to the impacts of Beardmore Dam. Narran River itself is, however, at present unregulated and minimal water extraction takes place. There has been an embargo on additional extraction from the Narran River in NSW since 1984 (Magrath, 1991).

Flooding in the Narran Lakes is predominantly (85%) a Summer and Autumn event. However, floods have also been recorded in Narran Lakes in Winter and Spring (Smith, 1993). Annual inflows to the Narran wetlands are highly variable and more than one flood per year has occurred in 25% of the years for which flood data have been recorded. Back and Clear Lakes (within Narran Lake Nature Reserve) will usually retain water for approximately 4-6 months following inundation if no further inflows are received before they dry out. Narran Lakes is a terminal lake system and therefore outflows from the Lakes within the Nature Reserve occur largely through drainage to Narran Lake, and by evaporation and seepage. Although exceptional events can cause water to overflow the Lakes and eventually reach the Barwon River (Aldis, 1987). Narran Lakes have an average inundation frequency of one in two years and, as such, provide more frequent waterbird habitat than other inland wetlands in NSW (Magrath, 1991). For further information on the hydrology of the Nature Reserve see point 15 below and refer to the Narran Lake Nature Reserve Plan of Management (NPWS 2000) and the report by Henderson (2000).

The climate of the Narran Lakes area is semi-arid with average annual rainfall varying between 358mm and 425mm. Monthly rainfall in this area is highly variable, with summer and winter peaks. The most reliable rainfall occurs in January, February and March. Unlike rainfall, temperatures are very consistent, with a long hot summer followed by a short cold winter. There are great fluctuations in diurnal temperature, as well as large differences between summer and winter temperatures. Average maximum summer temperature is 36^0C while the average winter minimum temperature is 5^0C (Martin, 1979).

15. Hydrological values: The Narran River, like a number of other inland rivers, has a small shallow main channel with a contiguous floodplain. A number of lakes lie along the floodplain and the river terminates in the lakes and wetlands of the Narran Lake system (NPWS 2000). The Narran River flows intermittently as a result of heavy rainfall in Queensland and annual flows are highly variable. The Narran Lakes system receives water at lower flows than the lake beds further north along the Narran River and hence floods more often and holds water for longer periods.

During a large flood event, the Narran River branches to fill Clear Lake, whilst simultaneously flowing towards, and filling, Narran Lake. Once Clear Lake has filled the water overflows to fill the smaller lakes in the Nature Reserve (Back Lake and the Long Arm) (Henderson, 2000). When Clear Lake is full, more water flows into Narran Lake. The water levels in the Nature Reserve can drop very quickly if flows are not large enough to keep the levels up in both Narran and Clear Lakes (NPWS, 1995). Once inundated, the Nature Reserve can hold water for up to 12 months without any new flows, while Narran Lake can hold water for up to 2 years. During times of low flow, water may not reach Narran Lake.

The internal hydrology of Narran Lakes is poorly understood and requires further research. For additional information on the hydrology of the Nature Reserve and its importance with respect to waterbird breeding refer to the Narran Lake Nature Reserve Plan of Management (NPWS 2000) and the reports by Henderson (1999 and 2000), Ley (1998a, 1998b and 2000) and McGrath (1991).

16. Ecological features: There are six major vegetation communities within the Nature Reserve, including chenopod low open shrublands; ephemeral herbfields; mixed low woodlands; riparian open forest; and spinifex grasslands (NPWS, 2000). The wetlands within the Nature Reserve contain a variety of associations. These include:

- sedges and ephemeral herbs on the playa lakes and the main lake beds following receding flood waters;
- Lignum (*Muehlenbeckia florulenta*) occurs in extensive areas and forms a dense shrubland in, and around, Clear and Back Lakes;
- Common Reed (*Phragmites australis*) occurs in small patches amongst the Lignum; and,
- the River Red Gum (*Eucalyptus camaldulensis*) - Coolibah (*Eucalyptus coolabah*) - Black Box (*Eucalyptus largiflorens*) - River Cooba (*Acacia stenophylla*) association fringes the Narran River and the wetland channels. Understorey species within this community include Lignum, Boobiallah (*Myoporum sp*.), Quinine Bush (*Alstonia constricta)*, Umbrella Mulga (*Acacia brachystachya)* and Warrego Grass (*Paspalidium jubiflorum)*.

Extensive areas of River Cooba with Lignum occur to the south and a relatively large area of River Red Gum occurs to the north-east of Clear Lake. Lignum, River Red Gum, River Cooba and Coolibah all require flooding to grow and regenerate. The ecological tolerances of these species are imprecisely defined but there is strong evidence that the more frequent the flooding, the more productive these species and the communities they support. All are capable of withstanding infrequent, prolonged periods without water. However, an increased frequency and duration of dry periods may eventually eliminate some communities, for example the River Red Gums, by preventing recruitment.

The sandy lakeshore and dune areas within the Nature Reserve are generally treeless due to past grazing regimes. Areas with minimal erosion support a scattered cover of Windmill Grass (*Chloris truncata*), Cane Grass (*Eragrostis eriopoda*), Mallee Lovegrass (*Eragrostis deilsii)* and chenopods such as Grey Copperburr (*Sclerolaena diacantha*) and Copperburr (*Sclerolaena decurrens*) (NPWS, 1995).

The sandy ridge country within the Nature Reserve supports a predominantly Bimble Box (*Eucalyptus populnea*) - White Cypress Pine (*Callitris glaucophylla*) woodland community. Other species present within this community include Ironwood (*Acacia excelsa*), Whitewood (*Atalaya hemiglauca*), Budda (*Eremophila mitchellii*), Western Beefwood (*Grevillea striata*), Wilga (*Geijera parviflora*), Ruby Saltbush (*Enchylaena tomentosa)*, Goathead Burr (*Sclerolaena bicornis)*, Hop Bush (*Dodonaea viscosa* subsp. *angustissima)* and Rice Flower (*Pimelia microcephala)*. Old Man Saltbush (*Atriplex nummularia*) occurs occasionally throughout this community and Mulga (*Acacia aneura*) also occurs in small patches in rocky areas (NPWS, 1995).

A Silver-leaved Ironbark (*Eucalyptus melanophloia*) - Kurrajong (*Brachychiton populneus* subsp. *trilobus*) - Coolabah Apple (*Angophora melanoxylon*) - Wilga - Beefwood woodland association occurs on two areas of sandy ridge country within the Nature Reserve. Other species which occur in this community include Spinifex *(Triodia mitchelli*), Wattle (*Acacia murrayana)* and Needlewood (*Hakea leucoptera)*.

Common weeds along the Narran River include Noogoora Burr *(Xanthium occidentale*) and Bathurst Burr (*Xanthium spinosum*). Golden Dodder (*Cuscuta campestris*) has invaded the wetlands, particularly areas of Lignum. Some African Boxthorn (*Lycium ferrocissimum*) also occurs in the Reserve (NPWS, 1995).

17. Noteworthy flora: The Nature Reserve contains some of the largest expanses of Lignum (*Muehlenbeckia florulenta*) in NSW. Lignum shrubland occurs as vast expanses in and around Clear and Back Lakes (NPWS 2000). There are few expanses of Lignum left in the state and consequently the community is considered to be vulnerable and inadequately conserved in NSW (Benson, 1989).

The Silver-leaved Ironbark (*Eucalyptus melanophloia*) **-** Kurrajong (*Brachychiton populneus* subsp. *trilobus*) **-** Coolabah Apple (*Angophora melanoxylon*) – Wilga (*Geijera parviflora*) – Beefwood (*Grevillea striata*) woodland association, which is considered to be of conservation significance in the western region of NSW, occurs on two areas of sandy ridge country within the Nature Reserve. Spinifex (*Triodia mitchellii*) and Sandplain Wattle (*Acacia murrayana),* which also occur within this community, are restricted to deep sandy soils and are considered to be poorly conserved in the western region of NSW (NPWS, 1995).

The Old Man Saltbush (*Atriplex nummularia*) shrubland; Mitchell Grass (*Astrebla spp.*) grassland; and Bimble Box (*Eucalyptus populnea*) woodland are all considered to be endangered and poorly conserved in NSW (Benson, 1989).

The Western Beefwood (*Grevillea striata*) – Mulga (*Acacia aneura*) shrubland; Black Box (*Eucalyptus largiflorens*) woodland; Native Fuschia (*Eremophila maculata*) shrubland; Gidgee (*Acacia cambagei*) shrubland; and Common Reed (*Phragmites australis*) sedgeland communities are all considered to be inadequately conserved in NSW (Benson, 1989).

The River Red Gum (*Eucalyptus camaldulensis*) woodland; Silver-leaved Ironbark (*Eucalyptus melanophloia*) woodland; and Ironwood (*Acacia excelsa*) – White Cypress Pine (*Callitris glaucophylla*) shrubland are all considered vulnerable and inadequately conserved in NSW (Benson, 1989).

Two plant species, Winged Peppercress (*Lepidium monoplocoides*) and Macbarrons Goodenia (*Goodenia macbarronii*), listed as threatened under the *TSC* Ac,t have been recorded in the Nature Reserve (see Appendix 2).

18. Noteworthy fauna: Sixty-five species of waterbird have been recorded on the Narran wetlands since surveys first began 10 years ago. Forty-six of these breed in the area. Five species listed under the *TSC Act* have been recorded at the Nature Reserve: Brolga (*Grus rubicundus*), Blue-billed Duck (*Oxyyura australis*), Freckled Duck (*Stictonetta naevosa*), Magpie Goose (*Anseranas semipalmata*) and Black-tailed Godwit (*Limosa limosa*). Waterbird species recorded breeding in significant numbers in the Nature Reserve are listed under point 12 above. Ibis, spoonbills, cormorants, pelicans, as well as other waterbirds, breed in the Lignum, while the fringing River Red Gums and River Cooba are used for nesting and roosting by a number of species. Many swans and duck species also breed on Narran Lake and its associated channels. The extensive area of Lignum in the channels surrounding Back and Clear Lakes is particularly important for waterbird breeding and large ibis rookeries occur here. Small ephemeral lakes, which hold water following local rain (often at times when the main lakes are dry), provide feeding areas which complement the breeding grounds of the main lakes in the Reserve. Narran Lake, which holds water for longer than either Clear or Back Lakes, is an important feeding area for birds that breed in the Reserve. Large numbers of waders congregate on freshly exposed mudflats in the area following receding floodwaters. Migratory waders, listed under both CAMBA and JAMBA, also use the Reserve between September and April. For more detailed information on waterbirds at the Nature Reserve refer to the reports by Henderson (1999), Ley (2000, 1998a and b) and McGrath (1991).

One hundred and five species of landbird have been recorded in the Narran area, most of which are dependent on the woodland habitats. A number of landbirds recorded in the Nature Reserve are listed under the *TSC Act* including the endangered Australian Bustard (*Ardeotis australis*), the vulnerable

Grey Falcon (*Falco hypoleucos*), Pink Cockatoo (*Cacatua leadbeateri*), Barking Owl (*Ninox connivens*) and Masked Owl (*Tyto novaehollandiae*). For a full list of birds recorded in the Nature Reserve see Appendix 2.

Typical of other wetlands in semi-arid areas, the ephemeral wetlands of the Nature Reserve provide important habitat for native fish. Five native fish species have been recorded in Clear Lake including a high abundance of Golden Perch (*Macquaria ambigua*) (NPWS 2000).

Mammals recorded in the Nature Reserve are listed in Appendix 1, which also notes the conservation status of these species. The Water Rat (*Hydromys chrysogaster*), which is of conservation concern in the region, has been recorded closeby and almost certainly occurs in the Reserve. Koalas (*Phascolarctos cinereus*), which are near their western limit in this area, probably use the riverine areas of the Reserve at times. The survival of these colonies is dependent upon the health of the River Red Gum–Coolibah communities that fringe the Narran River (NPWS 2000). Woodlands along the Narran River are important habitat for other aboreal mammals, bats, amphibians and reptiles. The endangered Kultarr (*Antechinomys laniger*), which has been recorded in open shrub and mallee woodlands as well as along floodplains in this region of north western NSW, is also likely to occur in the Reserve, as are the Swamp Wallaby (*Wallabia bicolor*) and the Common Brushtail (*Trichosurus vulpecula*), which are of conservation concern in the region due to declining tree cover.

At least 25 species of reptile and amphibian have been recorded in the Nature Reserve and the Narran wetlands area. The Long-necked Tortoise (*Chelodina longicollis*), which is of conservation concern in the region due to hydrological changes in the river systems of western NSW, occurs in the Nature Reserve (NPWS 2000).

Knowledge of the native animal species in the Nature Reserve is limited and further research is required (see Smith (1993) for further information on the vertebrate fauna of the Reserve).

19. Social and cultural values: The Narran Lakes area is of extremely high archaeological value and also has very high traditional, as well as contemporary, social and spiritual significance for Aboriginal people. The Narran wetlands are considered to be significant due to the widespread evidence of Aboriginal people's long-term use of the area; the traditional status of the lakes as a meeting place for the peoples in this region; dreaming paths which lead to the lakes; and Aboriginal people's need for involvement with land which is largely unspoilt. Traditionally, the area was a common meeting place for the people of the Ngemba, Euahalyi and Murawari tribes, and possibly others, and a number of Aborginal people in the district have historical links with the area. In more recent times, the lake area has been used by local Aboriginal communities for educational purposes because the archaeological remains provide impressive evidence of their traditional way of life (NPWS 2000).

A large number and variety of Aboriginal sites exist within the Narran Lake Nature Reserve. These include shell middens, shell mounds, hearth sites with clay ovens, quarries, artefact scatters and scarred trees, which occur in a relatively natural condition. The shell middens are the most extensive complexes known from north-western NSW and several different stone tool complexes have been found at Nature Reserve. The silicrete quarries are archaeologically important as few such quarries are known. Such a distinctive suite of sites has not yet been found elsewhere in north-western NSW. This is probably because the Narran area is particularly suited for intensive archaelogical research and analysis of cultural sequences (Witters, 1986). The Narran wetlands are of major mythological significance as the site of convergence of several dreaming paths which link the landscape features of the area. These dreaming paths still retain considerable spiritual significance for local Aborginal peoples. The Narran Lake Nature Reserve Plan of Management and the report by Witter (1986) contain further information on the archaeological, spiritual and cultural significance of the Narran wetlands for Aboriginal peoples.

Thomas Mitchell was the first known European to travel through the Narran area. His party passed through lignum beds just south of Clear Lake in 1846 on route to the Culgoa River. Settlement of the district by Europeans began soon after Mitchell's visit (Aldis, 1987). Prior to its dedication, the Narran Lake Nature Reserve comprised Western Lands leasehold land primarily used for grazing purposes.

Remaining structures within the Nature Reserve include fence lines, ground tanks, bores, stockyard, a boundary riders hut and a shearing shed (NPWS, 1995). The significance of these items of early European heritage have not yet been assessed (NPWS 2000). For more detailed information on the European cultural values of the Narran Lake area see the Narran Lake Nature Reserve Plan of Management (NPWS 2000).

20. Land tenure/ownership: The lands within the Ramsar site include Nature Reserve which is permanently gazetted under the NSW *National Parks and Wildlife Act, 1974* and managed by the NSW National Parks and Wildlife Service. The lands surrounding the Nature Reserve consist mainly of Western Lands leases, which are managed by private landholders, plus additional Service-owned land that has not yet been gazetted.

21. Current land use: The lands within the Ramsar site are owned by the National Parks and Wildlife Service and are managed primarily for nature conservation purposes. The lands surrounding the Nature Reserve consist mainly of Western Lands leases managed primarily for grazing of sheep and cattle. Lakebed cropping also occurs in floodplain areas (NPWS, 1995).

22. Factors (past, present or potential) adversely affecting the site's ecological character, including changes in land use and development projects:

(a) at the site – Trespassing cattle from neighbouring properties and feral animals (ie. pigs). These have a minor impact under the current management regime of the Narran Lake Nature Reserve. Wind and water erosion, following grazing of the lunette areas within the Reserve prior to gazettal, has resulted in scalding and the formation of claypans. Continued erosion also threatens archaeological sites in the dunes and along the lake shores. Stabilisation of these sites is required to prevent further erosion and to protect significant habitat and archaeological remains.

(b) around the site – Cropping of the main Narran lakebed may potentially alter its wetland values. The relationship between the main lake and the wetlands within the Nature Reserve, in terms of waterbird use, is probably very important, but requires further research. Conditions attached to cultivation permits issued by DLWC take account of the ecological and cultural values of the area.

Of greatest concern is the impact of continued and increasing levels of water extraction from the Condamine-Balonne system in Queensland on the Narran wetlands. The rich biodiversity of the Narran wetlands has evolved in concert with the natural flooding patterns of the Narran River. Consequently, extensive changes to this regime are likely to have an adverse impact on the flora and fauna of the wetlands (NPWS 2000). In 1994, it was estimated that water being diverted for irrigation in Queensland had reduced annual average flows to the Narran wetlands by about 30% (Henderson 2000). This rate of extraction has increased rapidly over the last five years and is now impacting the full range of flows in the Condamine-Balonne system, including the larger flows that are required to fill the Narran wetland complex. Continued reduction in water flowing into the Nature Reserve will inevitably have a deleterious impact upon the ecology of these important wetlands. The small flows are critical for maintaining waterbird-breeding habitat, particularly in the Lignum and River Red Gum communities. The medium and large flows trigger and support waterbird breeding. Impacts expected from reducing small flows is gradual deterioration in the quality of breeding habitat; from reducing medium flows is increasingly frequent abandonment of well-advanced breeding events; and from large flows is an overall reduction in recruitment to waterbird populations. As well as altering the inundation patterns of the Narran wetlands, increased irrigation and floodplain cultivation upstream of this important site could result in a decline in the quality of water entering the wetlands which would further impact on the health of this significant ecosystem. More detailed information about the impacts of altered flow patterns on the conservation values Narran system is contained within the Narran Lake Nature Reserve Plan of Management and the Condamine-Balonne WAMP environmental flows technical report (DNR 2000b).

The Queensland Government is in the process of drafting a Water Allocation and Management Plan (WAMP) for the Condamine-Balonne River system which will outline water management options for Narran Lakes over the ten year life of the WAMP.

23. Conservation measures taken: The Ramsar site has been gazetted as a Nature Reserve under the NSW *National Parks and Wildlife Act, 1974*. A Plan of Management has been developed for the Nature Reserve (NPWS 2000) and is currently being implemented. The general objectives relating to the management of Nature Reserves apply at this site: the protection and preservation of natural features; the maintenance of natural processes; the conservation of wildlife; the preservation of Aboriginal sites and historic features; and the encouragement of scientific and educational enquiry (NPWS 2000). More specifically, the Plan aims to maintain the diverse, healthy and productive wetland habitat and the value of the Reserve as a major waterbird breeding area (NPWS 2000). A draft Water Management Plan has also been prepared for the Nature Reserve (Henderson 2000). The efficacy of this draft plan will rely heavily on the outcomes from the Condamine-Balonne WAMP. There is an on-going bird monitoring program for the Nature Reserve as well as a pest control plan. A vegetation survey was completed in 1999 (see Appendix 2), but a fire management plan has yet to be commenced. For further information on the specific conservation objectives and policies for Narran Lake Nature Reserve, as well as priority areas for implementation see the Narran Lake Nature Reserve Plan of Management (NPWS 2000).

24. Conservation measures proposed but not yet implemented: Should the river flow patterns be changed permanently for the worse, structures may be needed to manage limited flows better. A feasibility study for locating low level regulators at strategic points is being contemplated pending the outcome of the WAMP process. However, this would be a last resort and would only be undertaken after considering the impacts of such a structure on the whole Narran Lakes complex.

25. Current scientific research and facilities: Because of its isolation, little research has been carried out at the site other than archaeological studies and wildlife surveys by NPWS, and hydrological investigations by DLWC.

Ongoing research being undertaken at the Nature Reserve by, and for, NPWS comprises:

- monitoring of waterbird breeding and numbers; and,
- excavations of oven mounds (Australian Museum archaeologists and local Aboriginal community) and general archaeological studies.

There are currently no on-site research facilities.

There is a lot of potential for further research into wetland ecology, Aboriginal heritage and the biology/ecology of arid land plants and animals at Narran Lake Nature Reserve, because it is still in a relatively natural state. The Narran Lake Nature Reserve Plan of Management (NPWS 2000) outlines future priority research areas at the Nature Reserve.

26. Current conservation education: The Reserve has the potential to be a valuable educational resource for both cultural and ecological studies, but it is critical that any visits by educational groups do not cause damage to archaeological sites or disturb important wildlife habitat. The local Aboriginal communities use the Narran Lake Nature Reserve as an educational resource to teach their children about traditional Aboriginal ways of life. However, access to the wetlands is normally strictly controlled since the primary purpose of the site is to conserve wildlife and protect significant cultural heritage. For further information on how the area will be managed for educational purposes refer to the Narran Lake Nature Reserve Plan of Management (NPWS 2000).

27. Current recreation and tourism: The Ramsar site is gazetted as a Nature Reserve and, as such, existing public use of the area is limited to visits by the Aboriginal community, educational groups and, bird watchers. Public vehicle access to the Nature Reserve is permitted for the above purposes where it will not be detrimental to the natural and cultural heritage values of the area. The National Parks Association together with the Inland Rivers Network have secured funding for a Wetland Education Officer. Narran Lake Nature Reserve is one of the sites being utilised as part of this project.

28. Jurisdiction:

Territorial: Government of New South Wales

Functional: NSW National Parks and Wildlife Service

29. Management authority:

National Parks and Wildlife Service, New South Wales (Western Directorate, Northern Plains Region, Narrabri Area).

Address: Regional Manager
PO Box 72
Narrabri NSW 2390
Phone: (02) 6799 1740
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Appendix 1 of the Ramsar Information Sheet: Fauna species recorded in narran lake nature reserve

Common name	*Scientific name*	*Status*
BIRDS		
Emu		
Emu		b
Quails		
Stubble Quail		
Waterbirds		
Magpie Goose		*, b
Plumed Whistling-duck		b
Blue-billed Duck		*
Musk Duck		
Freckled Duck		*
Black Swan		b
Australian Wood Duck		b
Pacific Black Duck		b
Australasian Shoveler		
Grey Teal		b
Chestnut Teal		
Pink-eared Duck		b
Hardhead		b
Australasian Grebe		b
Hoary-headed Grebe		b
Great Crested Grebe		w, b
Darter		w, b
Little Pied Cormorant		b
Pied Cormorant		w, b
Little Black Cormorant		b
Great Cormorant		w, b, int
Australian Pelican		w, b
White-faced Heron		
Little Egret		w
White-necked Heron		
Great Egret		w, b, int
Intermediate Egret		w
Cattle Egret		int
Nankeen Night Heron		w, b
Little Bittern		w, int
Glossy Ibis		w, b, int
Australian White Ibis		w, b
Straw-necked Ibis		w, b
Royal Spoonbill		w, b
Yellow-billed Spoonbill		b
Birds of Prey		
Black-shouldered Kite		
Black Kite		
Whistling Kite		b
White-bellied Sea-eagle		b, int
Swamp Harrier		

Common name	*Scientific name*	*Status*
Black-breasted Buzzard		*
Bar-tailed Godwit		int
Marsh Sandpiper		int
Brown Goshawk		
Collared Sparrowhawk		
Wedge-tailed Eagle		
Little Eagle		
Brown Falcon		
Black Falcon		
Australian Hobby		
Grey Falcon		*
Peregrine Falcon		
Nankeen Kestrel		
Swamp Birds and Waders		
Brolga		*, b
Black-necked Stork		*
Australian Spotted Crake		
Purple Swamphen		
Dusky Moorhen		
Black-tailed Native-hen		b
Eurasian Coot		b
Latham's Snipe		w, int
Black-tailed Godwit		*, int
Common Greenshank		int
Wood Sandpiper		int
Sharp-tailed Sandpiper		int
Curlew Sandpiper		int
Black-winged Stilt		b
Red-necked Avocet		b
Red-capped Plover		b
Black-fronted Dotterel		b
Red-kneed Dotterel		b
Banded Lapwing		b
Masked Lapwing		b
Australian Prantincole		
Gulls and Terns		
Silver Gull		w
Gull-billed Tern		w, b
Caspian Tern		w, int
Whiskered Tern		w, b
White-winged Black Tern		w, int
Grassland Birds		
Australian Bustard		E
Pigeons and Doves		
Common Bronzewing		
Crested Pigeon		
Diamond Dove		
Peaceful Dove		
Bar-shouldered Dove		

Common name	*Scientific name*	*Status*
Cockatoos and Parrots		
Galah		
Cockatiel		
Pink Cockatoo		*
Red-winged Parrot		
Pale-headed Rosella		w
Australian Ringneck		
Blue Bonnet		
Red-rumped Parrot		
Mulga Parrot		
Budgerigar		
Cuckoos		
Pallid Cuckoo		
Black-eared Cuckoo		
Horsfields Bronze-Cuckoo		
Fan-tailed Cuckoo		
Shining Bronze-Cuckoo		w
Night Birds		
Barking Owl		*
Masked Owl		*
Southern Boobook		
Tawny Frogmouth		
Spotted Nightjar		b
Australian Owlet-nightjar		
Kingfishers, Bee-eaters and Rollers		
Laughing Kookaburra		
Sacred Kingfisher		
Rainbow Bee-eater		
Dollarbird		
Songbirds		
Brown Treecreeper		
Splendid Fairy-wren		
Variegated Fairy-wren		
White-winged Fairy-wren		
Spotted Pardalote		
Striated Pardalote		
Weebill		
Western Gerygone		
Inland Thornbill		
Chestnut-rumped Thornbill		
Yellow-rumped Thornbill		
Yellow Thornbill		
Southern Whiteface		
Spiny-cheeked Honeyeater		
Striped Honeyeater		b
Noisy Friarbird		w
Little Friarbird		b
Blue-faced Honeyeater		
Yellow-throated Miner		

Common name	*Scientific name*	*Status*
Singing Honeyeater		
White-plumed Honeyeater		b
Brown-headed Honeyeater		
Brown Honeyeater		
Black Honeyeater		
Crimson Chat		
Orange Chat		
White-fronted Chat		
Jacky Winter		
Red-capped Robin		
Hooded Robin		
Eastern Yellow Robin		
Crested Bellbird		
Golden Whistler		w
Rufous Whistler		
Grey Shrike-thrush		b
Restless Flycatcher		
Grey-crowned Babbler		
Magpie-lark		b
Richard’s Pipit		
Grey Fantail		
Willie Wagtail		b
Black-faced Cuckoo-shrike		
White-bellied Cuckoo-shrike		
Ground Cuckoo-shrike		
White-winged Triller		
White-breasted Woodswallow		b
Masked Woodswallow		
White-browed Woodswallow		
Black-faced Woodswallow		
Little Woodswallow		b
Grey Butcherbird		
Pied Butcherbird		
Australian Magpie		
Australian Raven		
Little Raven		
Little Crow		
White-winged Chough		
Apostlebird		b
Spotted Bowerbird		
Zebra Finch		
Double-barred Finch		
Diamond Firetail		w
Silvereye		
Common Starling		X
Mistletoebird		
Welcome Swallow		b
Tree Martin		
Fairy Martin		

Common name	*Scientific name*	*Status*
Clamorous Reed-warbler		
Richard's Pipit		
Little Grassbird		
Brown Songlark		
Rufous Songlark		
AMPHIBIANS		
Green Tree Frog	*Littoria caerulea*	
Spotted Grass-Frog	*Limnodynastes tasmaniensis*	
Barking Marsh Frog	*Limnodynastesflectheri*	
Bibron's Toadlet	*Pseudophryne bibronii*	
Peron's Tree Frog	*Litoria peronii*	
Desert Tree Frog	*Litoria rubella*	
Salmon-striped Frog	*Limnodynastes salmini*	
MAMMALS		
Wallaroo	*Macropus robustus*	
Red Kangaroo	*Macropus rufus*	
Grey Kangaroo	*Macropus giganteus*	
Western Grey Kangaroo	*Macropus fuliginosus*	elr
Swamp Wallaby	*Wallabia bicolor*	ccr
Bridled Nailtail Wallaby	*Onychogalea fraenata*	
Brush-tailed Possum	*Trichosurus vulpecula*	ccr
Yellow-footed Antechinus	*Antechinus flavipes*	
Kultarr	*Antechinomys laniger*	E
Fat-tailed Dunnart	*Sminthopsis crassicaudata*	
Narrow-nosed Planigale	*Planigale tenuirostris*	
Paucident Planigale	*Planigale gilesi*	
Water Rat	*Hydromys chrysogaster*	
Quoll	*Dasyurus sp.*	
Echidna	*Tachyglossus aculeatus*	
Koala	*Phascolarctos cinereus*	*, wlr
Little Mastiff Bat	*Mormopterus loriae*	
Gould's Wattled Bat	*Chlalinolobus gouldii*	
Little Red Flying-fox	*Pteropus scapulatus*	ccr
Little Forest Eptesicus	*Vespadelus vulturnus*	
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	
Gould's Long-eared Bat	*Nyctophilus gouldi*	ccr
Western Broad-nosed Bat	*Scotorepens balstoni*	
Pig	*Sus scrofa*	
House Mouse	*Mus musculus*	
Fox	*Vulpes vulpes*	
Feral Cat	*Felis catus*	
Rabbit	*Oryctolagus cuniculus*	
Hare	*Lepus capensis*	
Goat	*Capra hircus*	

Common name	*Scientific name*	*Status*
REPTILES		
Gecko	*Diplodactylus steindachneri*	
Tesselated Gecko	*Diplodactylus tessellatus*	
Soft-spined Gecko	*Diplodactylus williamsi*	
Prickly (Bynoe's) Gecko	*Heteronotia binoei*	
Tree Delta	*Gehyra variegata*	
Marbled Velvet Gecko	*Oeduera marmorata*	
Beaked Gecko	*Rhynchoedura ornata*	
Sand Monitor	*Varanus gouldii*	
Black-headed Monitor	*Varanus tristis spp tristis*	
Gilberts Dragon	*Lophognathus gilberti*	
Lined Earless Dragon	*Tympanocryptis lineata*	
Skink	*Cryptoblepharus carnabyi*	
Skink	*Ctenotus allotropis*	
Tree Skink	*Egernia striolata*	
Skink	*Lerista muelleri*	
Skink	*Lerista punctatovittata*	
Skink	*Menetia greyii*	
Skink	*Morethia boulengeri*	
Shingleback	*Trachydosaurus rugosus*	
Western Brown Snake	*Pseudonaja nuchalis*	
Long-necked Tortoise	*Chelodina longicollis*	ccr

KEY
* = vulnerable (TSC Act)
E = endangered (TSC Act)
w = conservation concern in western NSW
b = breeding record
X = introduced
int = covered by international agreements (CAMBA, JAMBA, Bonn)
rbw = restricted breeding distribution in the Western Division of NSW (Ley, 1997)
ptw = possibly threatened in western NSW (Ley, 1997)
pv = potentially vulnerable in NSW (Smith, 1993)
rr = rare on a regional level (Smith, 1993)
elr = near eastern limit of distribution in NSW
wlr = near western limit of distribution in NSW
ccr = of conservation concern in the Western region of NSW

Appendix 2 of the Ramsar Information Sheet: Flora Species of Narran Lake Nature Reserve
John T. Hunter with water plants identified by Dorothy Bell (17 Jan 1999)

Taxon list with recognised authorities and common names.
♣ Indicates TSC act listed; ♦indicates ROTAP listed; ♥ indicates taxon at edge of range; ♠indicates regionally rare taxon; *indicates introduced taxon.

Algae
Characeae
Nitella sp.

Pteridophytes

Azollaceae	
Azolla filiculoides var. *rubra* (R.Br.) Strasburger	Red Azolla
Isoetaceae	
Isoetes drummondii Braun	Quillwort
Marsileaceae	
Marsilea costulifera D.L.Jones	Narrow-leaf Nardoo
Marsilea drummondii A.Braun.	Common Nardoo
Salviniaceae	
**Salvinia molesta* D.Mitch.	Salvinia
Sinopteridaceae	
Cheilanthes sieberi Kunze subsp. *sieberi*	Narrow Rock Fern

Gymnosperms

Cupressaceae	
Callitris glaucophylla Joy Thomps. & L.A.S.Johnson	White Cypress Pine

Monocotyledons

Alismataceae	
Damasonium minus (R.Br.) Buchenau	Starfruit
Amaryllidaceae	
Crinum flaccidum Herb.	Darling Lily
Anthericaceae	
Anthropodium minus R.Br.	Small Vanilla Lily
Thysanotus tuberosus R.Br. subsp. *tuberosus*	Common Fringe-lily
Asphodelaceae	
Bulbine semibarbata (R.Br.) Haw.	Wild Onion
Centrolepidaceae	
Centrolepis strigosa (R.Br.) Roem. & Schult.	Hairy Centrolepis
Commelinaceae	
Commelina cyanea R.Br.	Scurvy Weed
Cyperaceae	
Bulbostylis barbata (Rottb.) C.B.Clarke	Sedge
Cyperus bifax C.B.Clarke	Downs Nutgrass

Cyperus difformis L.	Dirty Dora
**Cyperus eragrostis* M.Vahl.	Umbrella Sedge
Cyperus flaccidus R.Br.	Sedge
Cyperus gymnocaulos Steud.	Spiny Sedge
Cyperus squarrosus L.	Bearded Flat-sedge
Eleocharis pallens S.T.Blake	Pale Spikerush
Eleocharis plana S.T.Blake	Ribbed Spikerush
Eleocharis pusilla R.Br.	Small Spikerush
Fimbristylis dichotoma (L.) Vahl	Common Fringe Rush
Fimbristylis velata R.Br.	Fringe Rush
Isolepis victoriensis (N.A.Wakef.) K.L.Wilson	Isolepis
Schoenoplectus dissachanthus (S.T.Blake) J.Raynal.	Schoenoplectus
Hydrocharitaceae	
Ottelia ovalifolia (R.Br.) Rich	Swamp Lily
Juncaceae	
Juncus flavidus L.A.S.Johnson	Rush
Lemnaceae	
Lemma disperma Hegelm.	Duckweed
Phormiaceae	
Dianella longifolia var. *porracea* R.J.F.Hend.	Blue Flax-lily
Poaceae	
Aira cupaniana Guss.	Silvery Hairgrass
Agrostis avenacea (L.) Vahl. var. *avenacea*	Blown Grass
Amphibromus neesii Steud.	Swamp Wallaby-grass
Amphipogon caricinus F.Muell. var. *caricinus*	Long Greybeard Grass
Aristida jerichoensis subsp. *subspinulifera* Henrard	Jericho Wiregrass
Astrebla elymoides F.Muell. ex F.M.Bailey	Hoop Mitchell Grass
Astrebla lappacea (Lindl.) Domin	Curly Mitchell Grass
Astrebla pectinata (Lindl.) F.Muell. ex Benth.	Barley Mitchell Grass
Astrebla squarrosa C.E.Hubb.	Blue Mitchell Grass
Austrostipa scabra (Lindl) S.W.L.Jacobs & J.Everett subsp. *scabra*	Speargrass
**Bromus cartharticus* Vahl.	Prairie Grass
**Cenchrus ciliaris* L.	Buffel Grass
Chloris truncata R.Br.	Windmill Grass
Cynodon dactylon (L.) Pers.	
Dactyloctenium radulans (R.Br.) P.Beauv.	Button Grass
Dichanthium sericeum S.T.Blake subsp. *sericeum*	Queensland Bluegrass
Digitaria ammophila Hughes	Silky Umbrella Grass
Diplachne fusca (L.) P.Beauv.	Brown Beetle Grass
Enteropogon acicularis (Lindl.) Lazarides	Curly Windmill Grass
Eragrostis dielsii Pilger	Mallee Lovegrass
Eragrostis eriopoda Benth.	Woollybutt
Eragrostis lacunaria F.Muell. ex Benth.	Purple Lovegrass
Eragrostis laniflora Benth.	Woollybutt
Eragrostis parviflora (R.Br.) Trin	Weeping Lovegrass
Eragrostis setifolia Nees	Neverfail
**Festuca pratensis* Huds.	Meadow Fescue
Homopholis proluta (F.Muell.) R.D.Webster	Coolah Grass
**Hordeum leporinum* Link	Barley Grass
Monachather paradoxa Steud.	Bandicoot Grass

Neurachne munroi (F.Muell.) F.Muell.	Mulga Grass
Panicum decompositum R.Br.	Native Millet
**Panicum miliacem* L.	Millet Panic
Paspalidium jubiflorum (Trin.) Hughes	Warrego Grass
Perotus rara R.Br.	Comet Grass
Phragmites australis (Cav.) Trin ex Steud.	Common Reed
Sporobolus actinocladus (F.Muell.) F.Muell.	Katoora Grass
Sporobolus caroli Mez	Fairly Grass
Themeda triandra Forssk.	Kangaroo Grass
Thyridolepis mitchelliana (Nees) S.T.Blake	Mulga Mitchell Grass
Thyridolepis xerophila (Domin) S.T.Blake	Mulga Grass
Tragus australianus S.T.Blake	Small Burr-grass
Triodia mitchellii Benth.	Buck Spinifex
Triraphis mollis R.Br.	Purple Needle-grass
Tripogon loliiformis (F.Muell.) C.E.Hubb.	Five Minute Grass
Urochloa gilesii (Benth.) Hughes	Hairy-edged Grass

Dicotyledons

Acanthaceae	
Rostellularia adscendens	
subsp. *adscendens* var. *pogonanthera* (F.Muell.) R.T.Baker	Pink Tongues
Aizoaceae	
Mollugo cerviana (L.) Ser.	Wire-stem Chickweed
Tetragonia tetragonoides (Pallas) Kuntze	New Zealand Spinach
Trianthaema triquetra Willd.	Small Hogweed
♥♠*Zaleya galericulata* (Melville) Hj.Eichler	Hogweed
Amaranthaceae	
Alternanthera angustifolia R.Br.	Narrow-leaf Joyweed
Alternanthera denticulata R.Br.	Lesser Joyweed
**Alternanthera pungens* H.B.Kunth	Khaki-weed
Ptilotus obovatus (Gaudich.) F.Muell. var. *obovatus*	Smoke Bush
Ptilotus polystachyus (Gaudich.) F.Muell. var. *polystachyus*	Long-tails
Anacardiaceae	
**Schinus areira* L.	Pepper Tree
Apiaceae	
♠*Actinotus paddisonii* R. Baker.	Flannel Flower
Daucus glochidiatus (Labill.) Fisch., C.A.Meyer & Ave-Lall. form C	Australian Carrot
♠*Trachymene ochracea* (F.Muell.) Benth.	Native Parsnip
Apocynaceae	
Alstonia constricta F.Muell.	Quinine Bush
Parsonsia eucalyptophylla F.Muell.	Gargaloo
Parsonsia lanceolata R.Br.	Silkpod
Asclepiadaceae	
Marsdenia australis (R.Br.) Druce	Doubah
Asteraceae	
Actinobole uliginosum (A.Gray) Hj.Eichler	Flannel Cudweed
Angianthus brachypappus F.Muell.	Spreading Cup-flower

Brachyscome basaltica var. *gracilis* Benth.	Swamp Daisy
Brachyscome ciliaris (Labill.) Less var. *ciliaris*	Variable Daisy
Brachyscome goniocarpa Sonder & F.Muell.	Dwarf Daisy
Brachyscome gracilis G.L.R.Davis	Daisy
Brachyscome heterodonta DC. var. *heterodonta*	Lobed-seed Daisy
Brachyscome sp. A	Daisy
Brachyscome sp. B	Daisy
Bracteantha bracteata (Vent.) Anderberg & Haegi	Golden Everlasting
Calocephalus sonderi F.Muell.	Pale Beauty-heads
Calotis cuneifolia R.Br.	Purple Burr-daisy
Calotis lappulacea Benth.	Yellow Burr-daisy
Calotis scapigera Hook.	Tufted Burr-daisy
**Centaurea solstitialis* L.	St Barnaby's Thistle
Centipeda cunninghamii (DC.) R.Br. & Aschers	Common Sneezeweed
Centipeda minima (L.) A.Braun & Asch. var. *minima*	Spreading Sneezeweed
Centipeda thespidioides F.Muell.	Desert Sneezeweed
Chrysocephalum apiculatum (Labill.) Steetz.	Common Everlasting
Chrysocephalum semipapposum (Labill.) Steetz	Clustered Everlasting
Chthonocephalus pseudovax Steetz.	Ground-heads
**Conyza albida* Willd. ex Spreng.	Tall Fleabane
**Conyza bonariensis* (L.) Cronq.	Flaxleaf Fleabane
Eclipta platyglossa F.Muell.	Yellow Twin-heads
Eriochlamys behrii Sonder & F.Muell. ex Sonder	Woolly Mantle
Euchiton sphaericus (Willd.) Holub.	Cudweed
Glossogyne tannensis (Spreng.) Garnock-Jones	Cobbler's Tack
**Hedypnois rhagadioloides* subsp. *cretica* (L.) Hayek	Cretan Weed
**Hypochaeris glabra* L.	Smooth Catsear
Ixiolaena brevicompta F.Muell.	Plains Plover-daisy
**Lactuca serriola* L.	Prickly Lettuce
Lemooria burkittii (Benth.) P.Short	Wires-and-wool
Millotia greevesii subsp. *greevesii* var. *glandulosa* Schodde	Creeping Millotia
Minuria integerrima (DC.) Benth.	Smooth Minuria
♠*Pluchea dentex* R.Br. ex Benth.	Bowl Daisy
Podolepis jaceoides (Sims) Voss	Copper-wire Daisy
Podolepis longipedata A.Cunn. ex DC.	Copper-wire Daisy
Psuedognaphalium luteoalbum (L.) Hilliard & B.L.Burtt	Jersey Cudweed
Pycnosorus chrysanthes (Schldl.) Sonder	Pale Billy Buttons
Rhodanthe floribunda (DC.) Paul G. Wilson	White Sunray
Rhodanthe moschata (DC.) Paul G. Wilson	Musk Sunray
Senecio quadridentatus Labill.	Cotton Fireweed
Senecio runcinifolius J.H.Willis	Tall Groundsel
**Sigesbeckia orientalis* L. subsp. *orientalis*	Indian Weed
**Soliva anthemifolia* (A.L.Juss) R.Br. ex Lourdon	Dwarf Jo-Jo
**Sonchus oleraceus* L.	Common Sowthistle
Stuartina muelleri Sonder	Spoon Cudweed
**Verbesina encelioides* (Cav.) A.Gray subsp. *encelioides*	Crownbeard
Vittadinia cervicularis N.T.Burb. var. *cervicularis*	Fuzzweed
Vittadinia pustulata N.T.Burb.	Fuzzweed
Vittadinia sulcata N.T.Burb.	Fuzzweed
**Xanthium italicum* Moretti	Hunter Burr
**Xanthium occidentale* Bertol.	Noogoora Burr
**Xanthium spinosum* L.	Bathurst Burr

Boraginaceae

Cynoglossum australe R.Br. var. australe	Hound's-tongue

**Heliotropium supinum* L.	Prostrate Heliotrope
Brassicaceae	
Harmsiodoxa brevipes var. *major* E.Shaw	Short Cress
**Lepidium bonariense* L.	Cut-leaf Peppercress
♣♦*Lepidium monoplocoides* F.Muell.	Winged Peppercress
Lepidium pseudohyssopifolium Hewson	Peppercress
Lepidium sagittulatum Thell.	Fine-leaf Peppercress
♥♠*Rorippa eustylis* (F.Muell.) L.A.S.Johnson	River Cress
Cactaceae	
**Opuntia stricta* (Haw.) Haw.	Prickly Pear
Campanulaceae	
Wahlenbergia fluminalis (J.M.Black) F.Wimmer & Hj.Eichler	River Bluebell
Wahlenbergia graniticola Carolin	Granite Bluebell
Wahlenbergia stricta subsp. *alterna* P.J.Sm.	Tall Bluebell
Capparaceae	
Apophyllum anomalum F.Muell.	Warrior Bush
Capparis lasiantha R.Br. ex DC.	Nepine
Capparis mitchellii Lindl.	Wild Orange
Caryophyllaceae	
Gypsophila tubulosa (Jaub. & Spach) Boiss.	Annual Chalkwort
Polycarpaea corymbosa var. *minor* Pedley	Allseed
**Spurgula arvensis* L.	Corn Spurry
**Spurgularia diandra* (Guss.) Boiss	Lesser Sandspurry
Spurgularia rubra (L.) J.S. & C.Presl.	Sandspurry
Stellaria angustifolia Hook.	Swamp Starwort
Chenopodiaceae	
Atriplex holocarpa F.Muell.	Pop Saltbush
Atriplex nummularia Lindl.	Old Man Saltbush
Atriplex vesicaria subsp. *macrocystidia* Parr-Smith	Bladder Saltbush
Chenopodium auricomum Lindl.	Golden Goosefoot
Chenopodium curvispicatum Paul G. Wilson	Cottony Saltbush
Chenopodium desertorum (J.M.Black) J.M.Black subsp. *desertorum*	Desert Goosefoot
Chenopodium melanocarpum (J.M.Black) J.M.Black	Black Crumbweed
Dissocarpus paradoxus (R.Br.) F.Muell. ex Ulbr.	Cannonball Burr
Einadia nutans subsp. *eremaea* Paul G. Wilson	Climbing Saltbush
Einadia nutans subsp. *linifolia* (R.Br.) Paul G. Wilson	Climbing Saltbush
Einadia nutans (R.Br.) A.J.Schott subsp. *nutans*	Climbing Saltbush
Enchylaena tomentosa R.Br.	Ruby Saltbush
Halosarcia pergranulata (J.M.Black) Paul G. Wilson	Samphire
Maireana appressa (Benth.) Paul G. Wilson	Maireana
Maireana coronata (J.M.Black) Paul G. Wilson	Maireana
Malacocera albolanata (Ising) Chinnock	Malacocera
Neobassia proceriflora (F.Muell.) A.J.Scott	Soda Bush
Osteocarpum dipterocarpum (F.Muell.) Volkens	Babbagia
Sclerolaena bicornis Lindl. var. *bicornis*	Goathead Burr
Sclerolaena birchii (F.Muell.) Domin	Galvanized Burr
Sclerolaena convexula (R.Anderson) A.J.Scott	Tall Copperburr
Sclerolaena decurrens (J.M.Black) A.J.Scott	Green Copperburr
Sclerolaena diacantha (Nees) Benth.	Grey Copperburr

Sclerolaena divericata (R.Br.) Domin	Tangled Copperburr
Sclerolaena parallelicuspis (R.Anderson) A.J.Scott	Western Copperburr
Salsola kali L. var. *kali*	Buckbush
Clusiaceae	
Hypericum gramineum Forst.f.	Small St. John's Wort
Convolvulaceae	
Convolvulus erubescens Sims	Bindweed
**Cuscuta campestris* Yuncker	Golden Dodder
Evolvulus alsinoides var. *decumbens* (R.Br.) Ooststr.	Evolvulus
**Ipomoea hederifolia* L.	Morning Glory
Crassulaceae	
Crassula helmsii (Kirk) Cockayne	Swamp Stonecrop
Crassula sieberiana (Schultes & Schultes f.) Druce	Stonecrop
Cucurbitaceae	
**Citrullus lanatus* (Thunb.) Matsum & Nakai	Paddy Melon
Droseraceae	
Drosera peltata Thunb.	Scarlet Sundew
Elantinaceae	
Elatine gratioloides A.Cunn.	Waterwort
Euphorbiaceae	
Chamaesyce drummondii (Boiss.) Hassall	Caustic Weed
Phyllanthus virgatus G.Forst.	Spurge
Poranthera microphylla Brongn.	Small Poranthera
Fabaceae	
Acacia acuminata subsp. *birkittii* (F.Muell. ex Benth.) Kodela et Tindale	Sandhill Wattle
Acacia aneura F.Muell. ex Benth.	Mulga
Acacia brachystachya Benth.	Umbrella Mulga
Acacia cambagei R.T.Baker	Gidgee
Acacia caroleae Pedley	Carol's Wattle
Acacia deanei (R.T.Baker) Welch, Coombs & McGlynn subsp. *deanei*	Deane's Wattle
Acacia excelsa Benth.	Ironwood
Acacia ligulata A.Cunn. ex Benth.	Umbrella Bush
Acacia murrayana A.Cunn. ex Benth.	Sandplain Wattle
Acacia omalophylla A.Cunn. ex Benth.	Yarran
Acacia oswaldii F.Muell.	Miljee
Acacia pendula A.Cunn. ex G.Don.	Weeping Myall
Acacia stenophylla A.Cunn. ex Benth.	River Cooba
Aeschynomone indica L.	Budda Pea
**Astragalus hamosus* L.	Yellow Milk-vetch
Glycine canescens F.J.Herm.	Silky Glycine
Glycine clandestina Wendl.	Variable Glycine
♥♠*Kennedia procurrens* Benth.	Purple Running Pea
Muelleranthus denticulatus (J.M.Black) A.T.Lee	Sand Pea
Senna artemisioides (DC.) Randell nothosubsp. *artemisioides*	Silver Cassia
Swainsona swainsonioides (Benth.) A.T.Lee ex J.M.Black	Downy Darling Pea
Tephrosia sphaerospora F.Muell.	Mulga Trefoil
**Vicia sativa* L. subsp. *sativa*	Common Vetch

Gentianaceae	
Centaurium spicatum (L.) Fritsch.	Spike Centaury
Geraniaceae	
**Erodium cygnorum* subsp. *glandulosum* Carolin	Crowfoot
Goodeniaceae	
Brunonia australis Sm.	Blue Pincushion
Goodenia delicata Carolin	Goodenia
Goodenia glauca F.Muell.	Pale Goodenia
Goodenia gracilis R.Br.	Slender Goodenia
Goodenia hederacea Sm. subsp. *hederacea*	Forest Goodenia
♣♦*Goodenia macbarroni* Carolin	Macbarrons Goodenia
♥♠*Velleia arguta* R.Br.	Spur Velleia
Haloragaceae	
Haloragis aspera Lindl.	Rough Raspwort
Haloragis glauca Lindl.	Grey Raspwort
♥♠*Myriophyllum striatum* Orch.	Water-milfoil
Myriophyllum verrucosum Lindl.	Red Water-milfoil
Lamiaceae	
Lycopus australis R.Br.	Australian Gypsywort
Teucrium racemosum R.Br.	Grey Germander
Lobeliaceae	
Pratia concolor (R.Br.) Druce	Poison Pratia
Pratia darlingensis F.Wimmer	Darling Pratia
Loranthaceae	
Amyema miquelii (Lehm. Ex Miq.) Tiegh.	Box Mistletoe
Amyema pendula subsp. *longifolium* (Hook.) Barlow	Drooping Mistletoe
Dendrophthoe glabrescens (Blakely) Barlow	Orange Mistletoe
Lysiana exocarpi (Behr) Tiegh.	Mistletoe
Malvaceae	
Abutilon fraseri (Hook.) Hook. ex Walp.	Dwarf Lantern-flower
Abutilon leucopetalum (F.Muell.) F.Muell. ex Benth.	Lantern-bush
Hibiscus sturtii Hook. var. *sturtii*	Hill Hibiscus
Sida ammophila F.Muell. ex J.H.Willis	Sand Sida
Sida cunninghamii C.T.White	Ridge Sida
Sida sp. A	Scrambling Sida
Meliaceae	
Owenia acidula F.Muell.	Gruie Apple
Menyanthaceae	
♥♠*Nymphoides crenata* (F.Muell.) Kuntze	Wavy Marshwort
Nymphoides geminata (R.Br.) Kuntze	Marshwort
Myoporaceae	
Eremophila bignoniiflora (Benth.) F.Muell.	Eurah
Eremophila longifolia (R.Br.) F.Muell.	Emu Bush

Eremophila maculata (Ker Gawl.) F.Muell.	Native Fuschia
Eremophila mitchellii Benth	Budda
Myoporum montanum R.Br.	Western Boobialla
Myrtaceae	
Angophora melanoxylon R.T.Baker	Coolabah Apple
Eucalyptus camaldulensis Dehnh.	River Red Gum
Eucalyptus coolabah Blakely & S.W.L. Jacobs	Coolibah
Eucalyptus largiflorens F.Muell.	Black Box
Eucalyptus melanophloia F.Muell.	Silver-leaved Ironbark
Eucalyptus populnea subsp. *bimbil* L.A.S. Johnson & K.D. Hill	Bimble Box
Nyctaginaceae	
Boerhavia dominii Meikle & Hewson	Tarvine
Boerhavia repleta Hewson	Tarvine
Oleaceae	
Jasminum lineare R.Br.	Desert Jasmin
Onagraceae	
Ludwigia peploides subsp. *montevidensis* (Spreng.) Raven	Water Primrose
**Oenothera mollissima* L.	Evening Primrose
Oxalidaceae	
Oxalis chnoodes Lourteig	Wood Sorrel
Oxalis perennans Haw.	Oxalis
Pittosporaceae	
Pittosporum phylliraeoides DC.	Weeping Pittosporum
Plantaginaceae	
Plantago varia R.Br.	Variable Plantain
Polygonaceae	
Muehlenbeckia florulenta Meissn.	Lignum
Persicaria prostrata (R.Br.) Sojak	Creeping Knotweed
Rumex stenoglottis Rech.f.	Dock
Rumex tenax Rech.f.	Dock
Portulacaceae	
♠*Anacampseros australiana* J.M.Black	Pigweed
Calandrinia balonensis Lindl.	Parakeelya
Calandrinia eremaea Ewart	Small Purslane
Calandrinia ptychosperma F.Muell.	Creeping Parakeelya
Calandrinia pumila (Benth.) F.Muell.	Tiny Purslane
Portulaca filifolia F.Muell.	Slender Pigweed
Portulaca oleracea L.	Pigweed
Primulaceae	
**Anagallis arvensis* L.	Pimpernel
Proteaceae	
Grevillea striata R.Br.	Beefwood
Hakea leucoptera R.Br.	Needlewood

Rhamnaceae	
Ventilago viminalis Hook.	Supple Jack
Rutaceae	
Eremocitrus glauca (Lindl) Swingle	Desert Lime
Flindersia maculosa (Lindl.) Benth.	Leopardwood
Geijera parviflora Lindl.	Wilga
Rubiaceae	
Canthium oleifolium Hook.	Wild Lemon
Synaptantha tillaeacea (F.Muell.) Hook.f.	Synaptantha
Santalaceae	
Exocarpos cupressiformis Labill.	Native Cherry
Santalum lanceolatum R.Br.	Sandalwood
Sapindaceae	
Alectryon oleifolius (Desf.) S.T.Reynolds	Western Rosewood
Atalaya hemiglauca (F.Muell.) F.Muell. ex Benth.	Whitewood
Dodonaea viscosa var. *angustissima* (DC.) J.G.West	Hop Bush
Scrophulariaceae	
Gratiola pedunculata R.Br.	Australian Mudwort
♥*Glossostigma diandrum* (L.) Kuntze	Mountain Mudmat
Limosella australis R.Br.	Australian Mudwort
Solanaceae	
**Lycium ferocissimum* Miers	African Boxthorn
Nicotiana simulans N.T.Burb.	Native Tabacco
Solanum cleistogamum Symon	Shy Nightshade
Solanum esuriale Lindl.	Quena
Solanum ferocissimum Lindl.	Spiny Potato-bush
Solanum nigrum L.	Black Nightshade
Solanum stuartianum F.Muell.	Thargomindah Nightshade
Sterculiaceae	
Brachychiton populneus subsp. *trilobus* Guymer	Kurrajong
Melhania oblongifolia F.Muell.	Velvet Hibiscus
Thymelaeaceae	
Pimelea microcephala R.Br. subsp. *microcephala*	Shrubby Rice Flower
Pimelea trichostachya Lindl.	Spiked Rice Flower
Verbenaceae	
**Phyla nodiflora* (L.) Greene	Lippia
**Verbena officinalis* L.	Verbena
Violaceae	
Hybanthus monopetalus (Roem. & Schult.) Domin	Slender Violet Bush