Department for Environment and Heritage

Riverland Ramsar Site

Ecological Character Description

Introductory Note

This Ecological Character Description (ECD Publication) has been prepared in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (National Framework) (Department of the Environment, Water, Heritage and the Arts, 2008).

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prohibits actions that are likely to have a significant impact on the ecological character of a Ramsar wetland unless the Commonwealth Environment Minister has approved the taking of the action, or some other provision in the EPBC Act allows the action to be taken. The information in this ECD Publication does not indicate any commitment to a particular course of action, policy position or decision. Further, it does not provide assessment of any particular action within the meaning of the EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

This ECD Publication is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention.

Disclaimer

Note: There may be differences in the type of information contained in this ECD publication, to those of other Ramsar wetlands.

Department for Environment and Heritage

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Ecological Character Description

by

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Lloyd Environmental

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Contents

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LIST OF ABBREVIATIONS

ANSTO	Australian Nuclear Science and Technology Organisation
AUSRIVAS	**Aus**tralian **Riv**er **A**ssessment **S**ystem
ANZECC	Australia and New Zealand Environment and Conservation Council
CAMBA	China-Australia Migratory Birds Agreement
CEPA	Community Education and Public Awareness
DEH	Department for Environment and Heritage (South Australia)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth)
ECD	Ecological Character Description
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (a Commonwealth Act)
IBRA	Interim Biogeographic Regionalisation of Australia
JAMBA	Japan-Australia Migratory Birds Agreement
NCSSA	Nature Conservation Society of South Australia
NWC	National Water Commission
RIS	Ramsar Information Sheet
ROKAMBA	Republic of Korea-Australia Migratory Birds Agreement
SAMDB NRM Board	South Australian Murray Darling Basin Natural Resource Management Board
SIGNAL	Stream Invertebrate Grade Number – Average Level

EXECUTIVE SUMMARY

This *Ecological Character Description* (ECD) has been developed following the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008) and contains information on the Riverland Ramsar Site (hereinafter referred to as 'the Site'). This information includes: geographic and administrative details; the Site's ecological character (including components, processes, benefits and services) at the time of Ramsar listing (1987) and currently; gaps in knowledge of the Site and issues for management; actual or potential threats; changes that have occurred since listing; site monitoring needs and triggers for management action; and communication, education and public messages to facilitate management and planning.

The Site was first listed in 1987 against the (then) criteria 1a, 1b, 1c, 3b of the Ramsar Convention. Following revision of the criteria in 1999, the Site is now listed under criteria 1-8 of the revised criteria. This ECD has been compiled between September 2007 and May 2008, 20 years after the Riverland Site was first listed, but is required to reflect conditions at the time of listing. The ECD interprets studies and reports undertaken at various times to characterise conditions at the time of listing.

This ECD was prepared subsequent to a boundary revision (dated 11 September 2007) designed to remove major non-wetland areas dominated by agriculture and add a major wetland area (Lake Woolpolool, a seasonal saline lake). The removal of the non-wetland areas does not impact on the ecological character of the Riverland Ramsar Site, whereas the inclusion of Lake Woolpolool has enhanced the waterbird and vegetation diversity of the site (RIS in prep.). The revised boundary was incorporated into a revised RIS (RIS in prep.) which has been approved by the Australian Government (11 September 2007), and the Ramsar Convention on Wetlands Secretariat has been notified. In this ECD, Lake Woolpolool is assumed to be part of the Ramsar Site, and its effective time of listing is taken as 1987.

The Site

The Riverland Ramsar Site is on the floodplain of the River Murray, between Renmark, South Australia, and the State borders with Victoria and New South Wales. As the principal river of the Murray-Darling Basin, the Murray flows 2,530 km from its source in south-eastern New South Wales to its mouth at Encounter Bay, South Australia. The Murray-Darling Basin has an area of 1.073 million km^2 (14% of mainland Australia with much of the region being flat and having aeolian and alluvial deposits of sands, silts and clays. The system is fed largely by the streams which arise in the Great Dividing Range

The River Murray has five geomorphological tracts (Mackay & Eastburn 1990) and the Site is located in the ***Mallee Trench*** tract which begins near Swan Hill, Victoria, and extends to Overland Corner, South Australia. This tract is an 850 river km plain of marine origin, crossed by the river in a well-defined incised channel.

The Site, which is 30,615 ha in size, has a boundary that follows the 1956 floodline west from the New South Wales border. It includes two major anabranch systems (Chowilla and Ral Ral Creeks) along an 80 km stretch of the River Murray, incorporating a series of creeks, channels, lagoons, billabongs, swamps and lakes.

The Site contains three generally recognised land components or 'blocks' – Murtho, Calperum, and Chowilla – defined primarily on the basis of historical ownership (see Figure 2.2). The Site blocks encompass only parts of greater land components. In particular, the Calperum and Chowilla blocks within the Site only contain fractions of the larger Calperum Station and Chowilla Reserves, respectively.

Most of the site (27,213 ha) is allocated to biodiversity conservation under Australian, State and Local Government or private ownership. Stock grazing, predominantly by sheep, is the next largest land use, allocated 3,370 ha. The Site supports a significant tourism industry that relies on the Site's inherent values. Tourism operators supply houseboat hire, nature-based boat and vehicle tours, pastoral industry tours and on-site accommodation. Recreational pursuits are centred on fishing, pleasure craft boating, bush camping, canoeing, waterfowl hunting, water-skiing and driving tours. A few commercial fishers have licenses to take Bony Herring (*Nematalosa erebi)* (a common native fish), European Carp (an exotic species) and other non-native species from the backwaters of the site.

An ECD Summary

A representation of key influences occurring at the Site is displayed below. The Riverland Ramsar Site is in a generally dry environment. Most of the water that fills the creeks and wetlands comes from remote catchments of the River Murray and its tributaries. The nature of the water regime — the magnitude, frequency, duration and seasonality of flows in the river, and the rate of rise and fall of the hydrograph — governs the ecological character of the wetland complex (Figure E1).

The Site's character is described in terms of **components** (e.g. biota; habitats; landforms), **processes** (e.g. habitat creation and flux; disturbances; energy and nutrient supply and transfer) and **benefits and services** (e.g. water supply and storage; species maintenance; fodder provision for stock and wildlife). These features are used to determine the **limits of acceptable change** to the character of the Site.

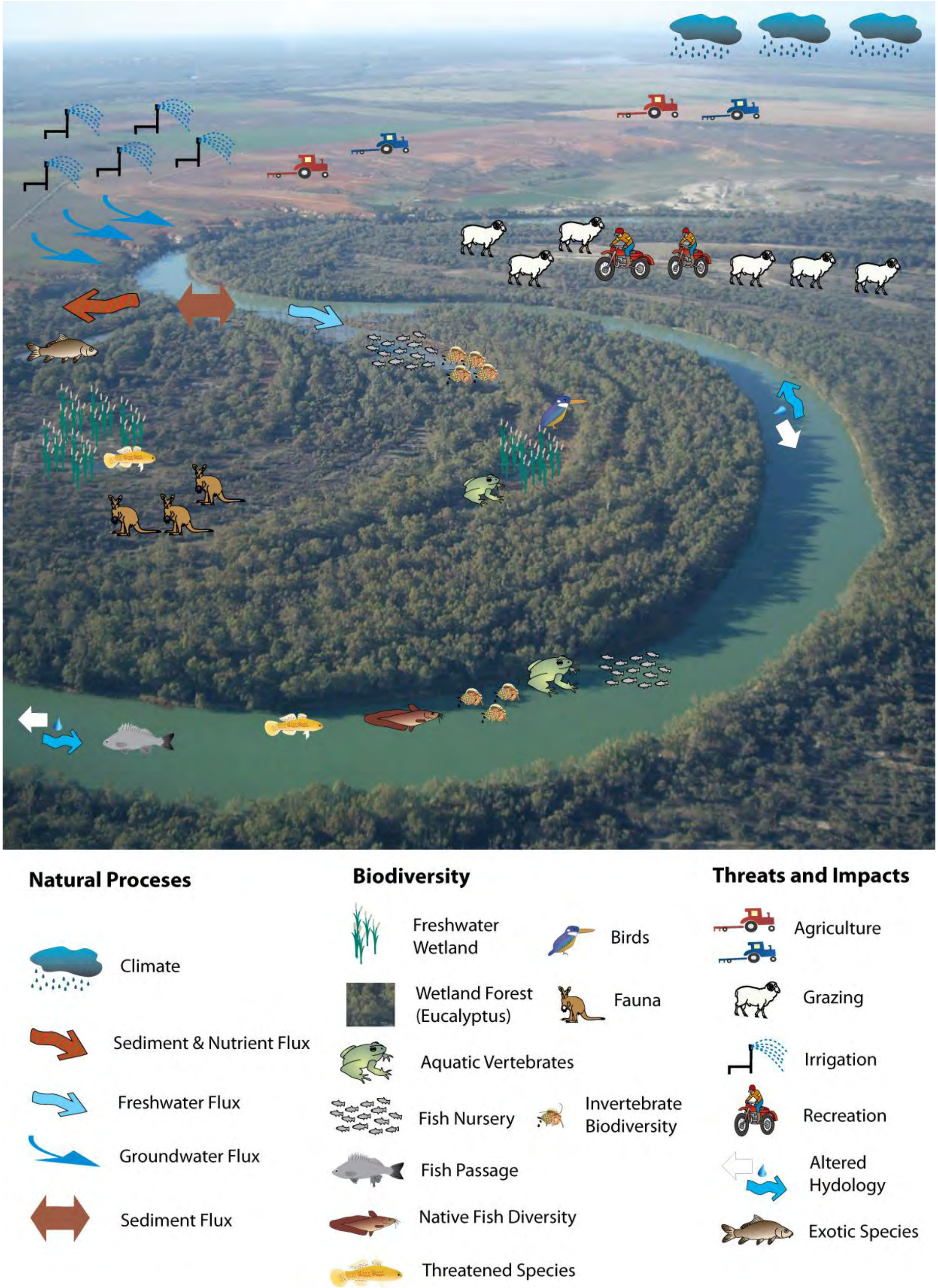


Figure E1: Riverland Ramsar Site Landscape showing components and processes.

The vegetation and habitats are influenced by the hydrology and the geomorphology of the site, with vegetation bands often delineating flooding regimes which are products of topography and elevation (Figure E2).

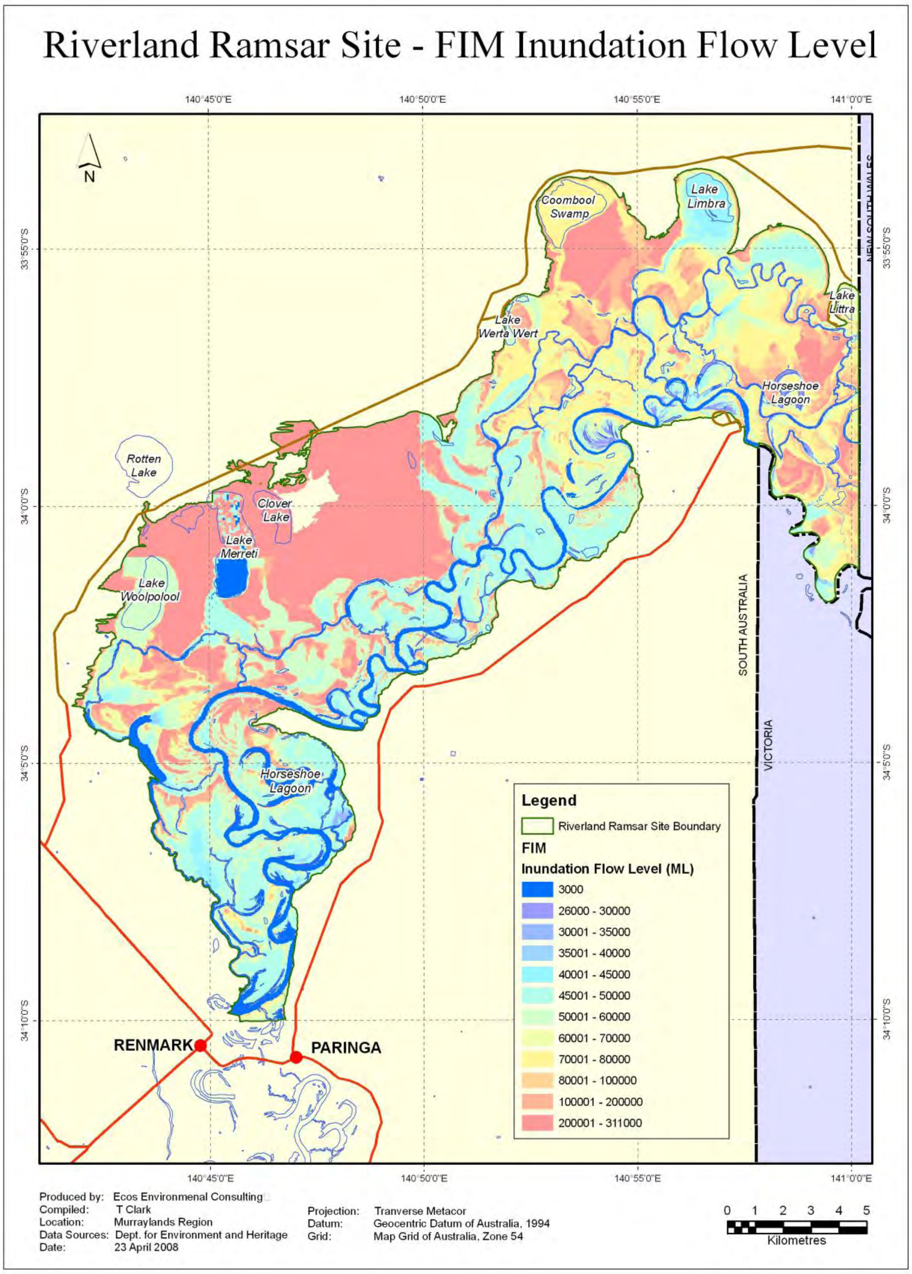


Figure E2: Flow required to inundate the Riverland Ramsar Site

Hydrology is simultaneously a component and a process. It governs the seasonality, magnitude, frequency, duration and rate of water delivery, and many biotic responses that include seed germination (including species favoured by the hydrologic regime), triggers for breeding (birds, fish, frogs), breeding success and provision of food. The season of delivery, period of inundation for ephemeral wetlands (or water level rises for permanent wetlands), fluctuations in water level and inter-annual flow variations all are influential.

Flooding is, perhaps, the most important natural process at the Site as it links the floodplain and the river. The floods replenish floodplain and lentic habitats with water and allow exchange of nutrients and biota (Figure E3).

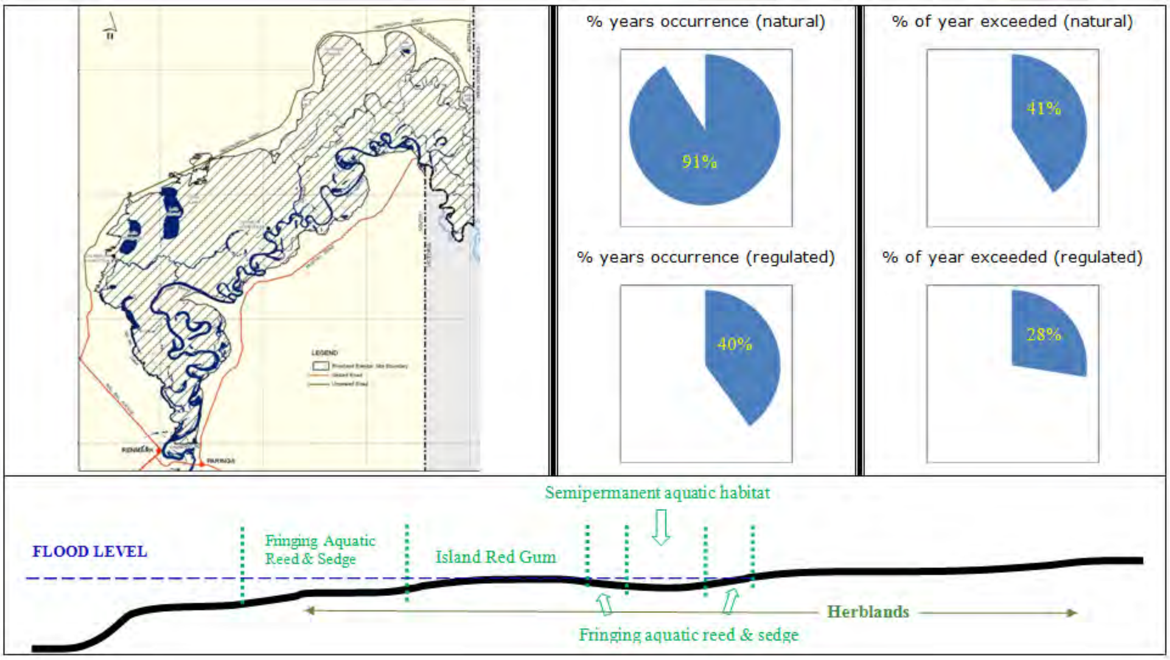


Figure E3: Conceptual model showing relationship between flood level and vegetation communities (example showing a flood of 40,000 ML day^{-1} [=40 GL day^{-1}])

Vegetation

Vegetation is a key component of the Site, contributing substantially to its ecological character and providing the habitat and landscape that form the basis of the Site's ecological services.

Vegetation of the Site encompasses a diversity of terrestrial and aquatic plant communities, from stands of *Callitris* pines on raised dunes to submerged aquatic plant meadows (in permanent wetlands). The vegetation has been surveyed on several occasions (e.g. O'Malley 1990, Margules et al. 1990, DEH 2002).

A DEH (2002) survey recognised the following wetland and floodplain vegetation communities which include arid and semi-arid hummock community: Black Box woodland; chenopod shrubland; fringing aquatic reed/sedge; herbfield, lignum shrubland, low chenopod shrubland, *Melaleuca* forest/woodland, river cooba shrubland, River Redgum woodland, River Redgum forest, river saltbush chenopod shrubland, and samphire low shrubland.

The DEH (2002) survey focuses mainly on the vegetation communities during the drier phases of the Site, although creeks and billabongs are often fringed by

Common Reed (*Phragmites australis)*, Spiny Sedge (*Cyperus gymnocaulos)* and Cumbungi (*Typha domingensis*).

There are also aquatic areas containing submergent vegetation such as Red Milfoil (*Myriophyllum verrucosum)* and Ribbonweed (*Vallisneria americana*); these areas expand during large floods (Fig E4).

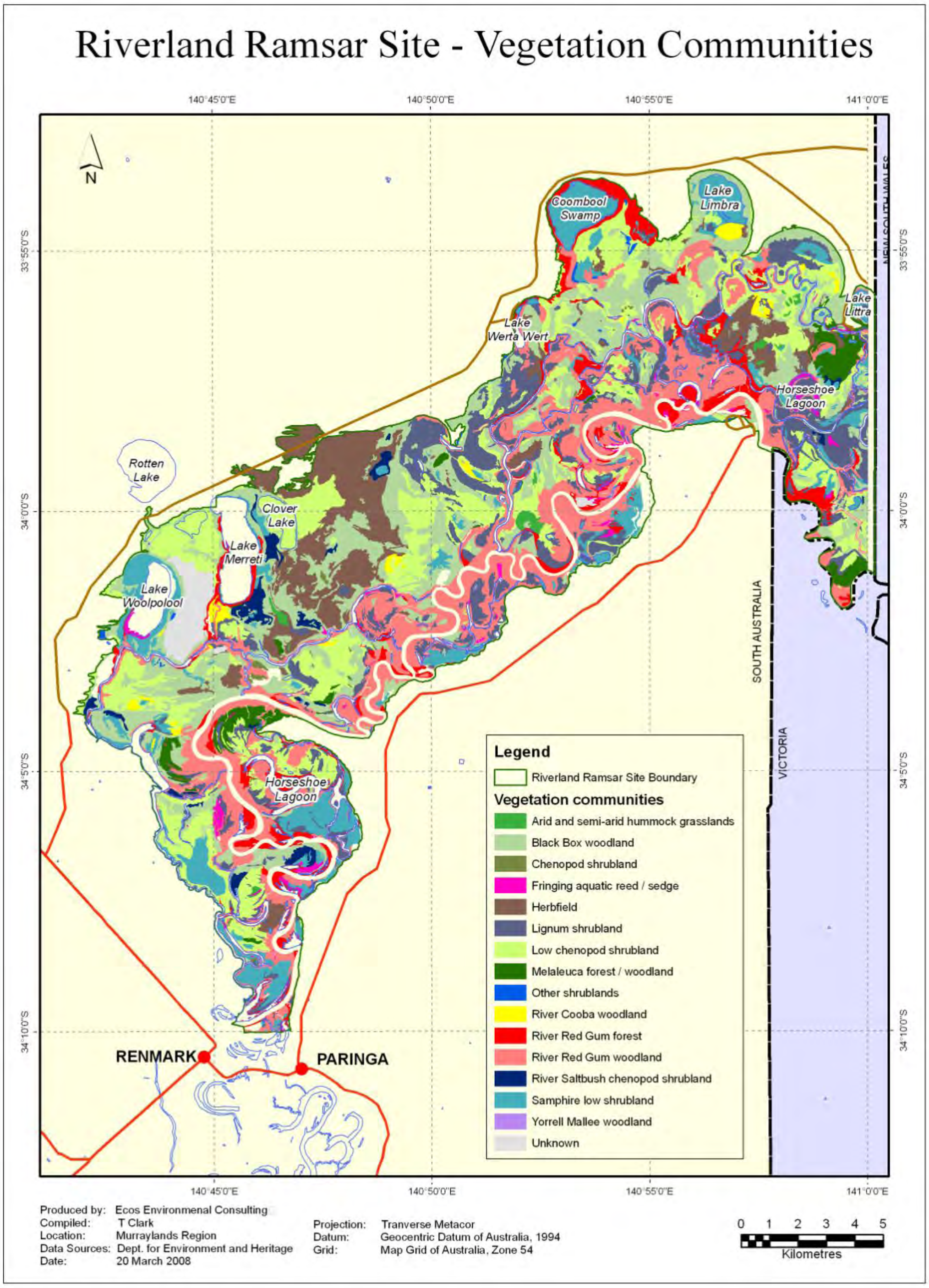


Figure E4: Vegetation Communities across the Riverland Ramsar Site.

This ECD includes two vegetation groups which were not classified above:

Fringing aquatic reed & sedge vegetation typified by Common Reed, Spiny Sedge and Cumbungi

Aquatic (permanent and semi-permanent) vegetation containing submergent vegetation such as Red Milfoil and Ribbonweed, emergent species such as Spiny sedge, Cumbungi, and Lignum, and also free-floating species such as *Azolla* spp.

The distribution of vegetation across the site is strongly determined by landform (including elevation) and hydrology. Figure E5, below, represents a diagrammatic cross-section of the landscape with the placement of the vegetation communities displays the basic relationships of hydrology, landscape and vegetation community at the Site.

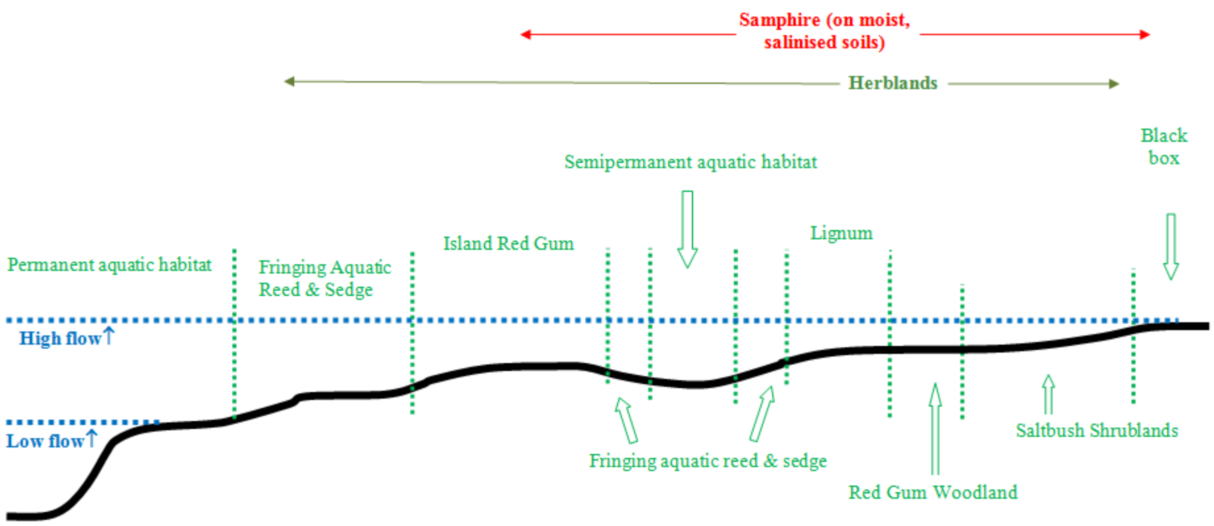


Figure E5: Vegetation community locations in relation to flood levels across the Riverland landscape

Fauna

Good information exists about the species occurrences of birds, mammals, reptiles and amphibians, fish, aquatic macroinvertebrates, molluscs and crustaceans at the Site.

Diverse **bird** assemblages include wetland, woodland, shrubland and grassland species, and species not found elsewhere in South Australia. There are 134 species recorded at Chowilla, including 30 breeding species, and Carpenter (1990) noted that 170 species had been recorded in that area. A total of 165 native bird species have been recorded across the Calperum and neighbouring Taylorville stations, including wetland, migratory and mallee-dependent species. Fifty-three species of waterbirds and two wetland raptors were recorded at Lake Woolpolool alone (Jensen et al. 2000). The most recent RIS (in prep.) reported 179 species for the whole site, including 63 wetland-dependent species. The Site supports 13 State-listed threatened bird species, eight species listed under international agreements, and one species listed nationally as 'vulnerable' under the EPBC Act.

Twenty-five (25) species of **mammals** were recorded at Chowilla, including 17 native species. The native species included eight species of bat, three species of dasyurid (two dunnart species and a planigale), two species of kangaroo (Western Grey and the Red), a species of native mouse, the native water rat, the Short-beaked Echidna and the Brush-tailed Possum. The Feather-tailed Glider is a State-listed species, endangered in South Australia, and has been recorded within the Site. The introduced species were sheep, cattle, the rabbit, Brown Hare, feral pig, feral goat, House Mouse, and Red Fox.

Thirty-eight species of **reptiles** and nine species **amphibians** have been recorded at the Site (RIS in prep.). These include three turtle species (including the Broad-shelled Turtle *Chelodina expansa*, listed as Vulnerable in South Australia and the Murray River Turtle (*Emydura macquarii*); eighteen species of lizard, comprising nine skinks (each from a different genus), five geckoes, two goannas (including the Lace Monitor, *Varanus varius* (listed as rare in South Australia) and two species of dragons; six species of snake (including the Carpet Python, *Morelia spilota variegata*, listed as rare in South Australia); and seven species of frog (including the Southern Bell Frog, *Litoria raniformis*, listed as endangered under the EPBC Act).

The aquatic habitats on the River Murray floodplain at the Site support a diverse assemblage of **macroinvertebrates**, with a total of 96 taxa being recorded during a survey of the Chowilla block of the Site in October 1988. The main channel sites within the survey supported 27 taxa, indicating that the floodplain habitats harbour a rich faunal diversity compared to the channel, reflecting its high habitat diversity. Within the Murtho block, macroinvertebrate sampling at Woolenook, Weila and Murtho Park yielded 41, 42 and 40 taxa respectively and a detailed study of the macroinvertebrates of Clover Lake, Lake Merreti and Lake Woolpolool resulted in 86, 121 and 106 taxa being identified in the three wetlands, respectively.

Two species of freshwater mussel occur in the wetland complex. The River Mussel *Alathyria jacksoni* is typical of moderate, to fast-flowing, channels, including the River Murray channel and the larger anabranches. The Floodplain Mussel *Velesunio ambiguus* prefers slow-flowing and still-water habitats, including billabongs, backwaters and impounded areas of the main channels. The River Snail *Notopala hanleyi* was formerly common in flowing-water habitats within the Site in pre-regulation times well before listing, but has virtually disappeared in South Australia except for populations surviving in a few irrigation pipeline systems, where they are an occasional pest.

The Murray Crayfish (*Euastacus armatus)* was formerly common in flowing-water habitats within the site in pre-regulation times well before listing, but now is virtually extinct in South Australia. This may be due to river regulation causing a substantial reduction in its preferred running water habitats. The smaller Yabbie

(*Cherax destructor*) is common throughout the Site's wetlands, except in fast-flowing water.

The Site supports 16 native fish species within the Murray-Darling Basin. A recent review has highlighted that Freshwater Catfish, Murray Hardyhead, Silver Perch, Trout Cod, and Southern Pigmy Perch should be regarded as endangered in South Australia whereas Flyspecked Hardyhead and Murray Cod should be regarded as vulnerable. Significant populations of exotic fish are also present within the Riverland Ramsar Site and these species include Eastern Gambusia, European Carp and Goldfish. Redfin and other exotic species may be expected in the region but have not been recorded in published reports.

Key Actual or Potential Threats to the Site

A summary of the threats include:

- Altered flow regime;
- Climate change, particularly synergies between decreased rainfall and increased evaporation;
- Salinity;
- Very high sedimentation rates for wetlands;
- Elevated and altered groundwater regime;
- Obstructions to fish passage and desnagging;
- Grazing pressure;
- Pest flora and fauna; and,
- Human access and motorised recreation.

Altered hydrology is the major threat to the ecological character of the Site. The Site's hydrology can be separated into pre-regulation and post-regulation periods:

In pre-regulation times, the river and floodplain experienced highly variable flows. High flows were cool, turbid and fast flowing, generally occurring in spring and early summer, gradually changing at end of summer to low flows which were warm, clear and slow moving during autumn and winter. There was a marked variation between years and cease-to-flow periods occurred during droughts with some water bodies contracting to saline pools fed by saline groundwater. Local anabranches formerly flowed only during floods or high flows and floodplain inundation (and the refilling of disconnected wetlands) determined by flood magnitude, proximity to the river channel and local topography.

In post-regulation times, the river and floodplain has experienced significant changes to the seasonal nature of flow regime, including permanent base flows, leading to permanent inundation of connected wetlands, and also delay in flood initiation and a reduction in flood duration. There has been a reduction in the frequency of small to moderate sized floods, leading to reduction in the moderate sized overbank flow events that covered large portions of the Site. There has been a reduced recharge of local groundwater ('freshwater lens') in semi-permanent wetlands, leaving insufficient water for trees. The river level has been raised by 3m, which has impacts that have led to permanent inundation of some ephemeral wetlands, saline groundwater intrusion into anabranches and floodplain, causing tree stress.

Within the post-regulation period, in the time since listing, the Site has experienced a major drought (or change of climate). This has resulted in an exacerbation of many of the impacts caused by regulation, including:

- further reduction (absence) of flooding;
- further reduction of recharge of ground water;
- exposure of sulphides which may release acid (e.g. at Tareena Billabong); and,
- greater salinity impacts due to decreased flushing of salts from the soil.

<u>Limits of Acceptable Change - Services</u>

Wetland of international significance (& part of Riverland Biosphere Reserve) - The short-term and long-term limits of acceptable change should both be 'no loss of any listing criteria'.

Supports populations of rare, endangered and threatened species (State & National) - Short and long term limits of acceptable change should be no loss of any rare or listed species of flora and fauna.

Provision of remnant lower River Murray floodplain habitat and species - The short term limits of acceptable change should be: no loss of any rare species of flora over any time period and no loss of any vegetation community type, excluding seasonal variations and natural annual variations. The long-term limits of acceptable change for both flora and fauna should be (a) no loss of any rare or threatened species of flora or fauna; (b) no net reduction in populations of native bird, fish, mammal, mollusc, macrocrustacean, reptile or amphibian fauna over any 10 year period; and (c) no loss of more than 20% of any vegetation type over the site as a whole within any 10 year period.

Diverse and abundant waterbirds Part 1 – Long-term limits of acceptable change should be: no loss of any rare or threatened waterbird species; and no net reduction in waterbird populations (rare, threatened or migratory) over any rolling 10 year period.

Diverse and abundant waterbirds Part 2 - Long-term limits of acceptable change should be: no loss of any rare or threatened waterbird species; and no net reduction in waterbird populations over any rolling 10 year period.

Diverse fish and invertebrate fauna - Long-term limits of acceptable change should be: no loss of any rare or threatened fish and invertebrate species; and no net reduction in fish and invertebrate populations over any rolling 10 year period.

High diversity and mosaic of both terrestrial and aquatic habitats - The short term limits of acceptable change should be no loss of any habitat type, excluding seasonal variations and natural annual variations. No further death of trees (based on CSIRO predictions for 2003) and no increase in the area of unhealthy trees should occur in any two year period. The long term limits of acceptable change should be no loss of more than 20% of any habitat type, over the site as a whole (i.e. diversity and mosaic must be maintained).

Limits of Acceptable Change – Components and Processes

The hydrological requirements for survival and recruitment of vegetation communities were used to derive the limits of acceptable change. The short term limits of acceptable change for the hydrologic regime are presented in Table E1 and long term Limits of acceptable change are presented in Table E2 below. These limits define the conditions required to support the diverse range of floodplain habitat which is a critical component of the Site's ecological character. In summary, appropriate management of the Site's hydrologic regime should form the first step in the management of the Site's ecological character.

Table E1: Required hydrologic regime: for survival (=short-term LAC))

Vegetation Community	Recurrence Interval	Duration	Timing	Magnitude	Time Between Events
Aquatic – permanent	Annual (watercourses) 1 in 2years (Billabongs and Swamps)	Permanent	Permanent	3GL/day (watercourses) 26GL/day (for Billabongs and Swamps)	0 years (watercourses) 1 Year (for Billabongs and Swamps)
Aquatic – semipermanent	1 in 2years	3-6 months	Spring/ Summer	40GL/day	1 Year
Fringing aquatic reed & sedge	1 in 2years	6 months	winter – spring/early summer	25 – 30GL/day (adjacent to channel) 45 – 60GL/day (on low relict meander plain)	1 – 2 years if well established
River Redgum forest (Flood Dependent Understorey)	1 in 3 years	4 – 7 months	winter – spring	50GL/day (for approx 1/3 of this veg comm.); 80GL/day (for approx 80% of this veg. comm.)	2 years

Vegetation Community	Recurrence Interval	Duration	Timing	Magnitude	Time Between Events
Lignum shrubland	1 in 3-10 years; more frequently in saline soils (>1.5 mS cm^{-1})	6 months (possibly as low as 3 months)	Unknown (possibly summer)	50 GL/day will reach 1/3 of community; 70 GL/day will reach 2/3)	Complete drying required between floods to enable cracking and aeration of soils
River Redgum woodland (Flood Tolerant Understorey)	1 in 3 years	4 – 7 months	winter – spring	50GL/day (for approx 1/3 of this veg comm.); 70GL/day (for approx 2/3 of this veg. comm.)	2 years
River saltbush chenopod shrubland	1 year in 30	2 – 4 months	not critical	60GL/d (for approx 1/4 of this veg comm.); 300GL/d (for majority of this veg. comm.)	Unknown (> 2 years)
Low chenopod shrubland	1 year in 30	2 – 4 months	not critical	70GL/d (for approx 1/2 of this veg comm.); 300GL/d (for majority of this veg. comm.)	Unknown (> 2 years)
Samphire low shrubland	1 in 3-10 years; more frequently in saline soils (>1.5 mS cm^{-1})	6 months (possibly as low as 3 months)	Unknown (possibly summer)	50-60 GL/day will reach 60% of community; 80 GL/day will reach 80%)	Unknown
Black Box woodland	1 year in 30	2 – 4 months	not critical	70GL/d (for approx 20% of this veg comm.); 100GL/d (for approx 40% of this veg comm.); 300GL/d (for majority of this veg. comm.)	30years

Table E2: Required hydrologic regime: for recruitment (= long-term LAC)

Vegetation Community	Recurrence Interval	Duration	Timing	Magnitude	Time Between Events
Aquatic – permanent	Annual (watercourses) 1 in 2years (Billabongs and Swamps)	Permanent	Permanent	5GL/day (watercourses) 40GL/day (for Billabongs and Swamps)	0 years (watercourses) 1 Year (for Billabongs and Swamps)
Aquatic – semipermanent	9 in 10years	Long duration, Frequently not drying out at all	Aug/Sep to Jan/Feb	40GL/day	1 Year

Vegetation Community	Recurrence Interval	Duration	Timing	Magnitude	Time Between Events
Fringing aquatic reed & sedge	1 in 1 – 2 years (nearly every year)	3 months (summer) or 6 months (winter), to enable seedlings to establish	Shallow inundation for germination, deeper water (10 – 15 cm) for seedling establishment	25 – 30GL/day (adjacent to channel) 45 – 60GL/day (on low relict meander plain)	6 - 9 months
River Redgum forest (Flood Dependent Understorey)	7 – 9 years in 10	120 days	spring	50GL/day (for approx 1/3 of this veg comm.); 80GL/day (for approx 80% of this veg. comm.)	Serial inundation 2 to 3 years in succession to optimise recruitment probability
Lignum shrubland	1 in 2-8 years; more frequently in saline soils (>1.5 mS cm^{-1})	120 days	Unknown (possibly summer)	50 GL/day will reach 1/3 of community; 70 GL/day will reach 2/3)	Complete drying required between floods to enable cracking and aeration of soils
River Redgum woodland (Flood Tolerant Understorey)	7 – 9 years in 10	120 days	spring	50GL/day (for approx 1/3 of this veg comm.); 70GL/day (for approx 2/3 of this veg. comm.)	Serial inundation 2 to 3 years in succession to optimise recruitment probability
River saltbush chenopod shrubland	1 year in 10	Long enough to saturate surface soil, with slow recession	Unknown	60GL/d (for approx 1/4 of this veg comm.); 300GL/d (for majority of this veg. comm.)	Unknown (> 2 years)
Low chenopod shrubland	1 year in 10 (2-3 years in succession every 30 years)	Long enough to saturate surface soil, with slow recession	Unknown	70GL/d (for approx 1/2 of this veg comm.); 300GL/d (for majority of this veg. comm.)	Unknown (> 2 years)
Samphire low shrubland	1 in 2-8 years; more frequently in saline soils (>1.5 mS cm^{-1})	120 days	Unknown (possibly summer)	50-60 GL/day will reach 60% of community; 80 GL/day will reach 80%)	Unknown

Vegetation Community	Recurrence Interval	Duration	Timing	Magnitude	Time Between Events
Black Box woodland	1 year in 10 (2-3 years in succession every 30 years)	Long enough to saturate surface soil, with slow recession	Unknown	70GL/d (for approx 20% of this veg comm.); 100GL/d (for approx 40% of this veg comm.); 300GL/d (for majority of this veg. comm.)	Unknown (<30years)

Changes in Ecological Character since listing

A decline in the health of the tree cover of the Site since listing represents a clear change in ecological character. The vegetation and habitat values of the Site have changed significantly due to a decrease in flood events over the past two decades. A River Redgum survey conducted in South Australia in February 2003 found that approximately 80% of the survey sites contained trees that were stressed to some degree, and 20-30% of them were severely stressed. In the area between Wentworth and Renmark (which includes the Riverland Site), more than half of all trees, including River Redgums, were stressed or dead. It is important to note that, at the time of listing, the floodplain vegetation of the Site was already experiencing significant stress, and that the continuing and increasing stress and deterioration of the site will require specific actions to maintain its ecological integrity.

A discussion of changes in vegetation and habitat values should consider not only the current condition, but also the trajectory of that condition. Assuming no intervention, the deterioration trend extends to trees currently in moderate health, which are predicted to decline further into poor health, and trees currently in poor health, which are predicted to decline further and die. Even under the more optimistic scenarios, there will be significant loss of growing trees and a commensurate decline in their role in aquatic ecology (provisions of shading, allochthonous inputs from riparian vegetation [insects, leaves, etc] and large woody debris). The current situation of only 24% of trees considered to be healthy (DEH 2003) is likely to be a threshold beyond which permanent damage to the Site occurs. Further, River RedGum and Black Box are keystone species within the Site's ecosystem and, therefore, once their populations drop to unsustainable levels the entire system will be impacted.

Knowledge Gaps

The key knowledge gaps for the Site include systematically collected data for most of the major components. The exception to this is the vegetation component, which has been surveyed in a number of studies. Natural variability is an important aspect of the components and processes that requires information. Several components (e.g. hydrology, understorey vegetation, water quality, fish, amphibians, reptiles, crustaceans, water birds) have been monitored as part of studies assessing benefits of management actions at the Site. However, these need to be evaluated in terms of whole-of-Site monitoring, natural variation, and their use for assessing Site condition in relation to maintaining ecological character.

Data should be gathered using standard methods that allow derivation of a 'point-in-time' baseline which can be compared to future monitoring programs. Therefore the initial sampling strategy must be designed in a way that is cognisant of repeatability. The data should also be gathered using approaches and methods that allow comparison with other data sets within the site, the Murray-Darling Basin, and the rest of Australia.

Key Site Monitoring Needs

The monitoring needs of the site should focus on the limits of acceptable change for the maintenance of the Site's ecological character. The major threats and the limits of acceptable change drive the monitoring needs and prioritisations. Priorities for monitoring were established by considering the highest value components which face the highest threat. Monitoring should include:

- two yearly tree health assessment using infrared satellite data;
- five yearly on-ground vegetation surveys including tree health and wetland type and fauna surveys (fauna surveys to include both aquatic and terrestrial species);
- annual bird observer counts of waterbirds;
- five yearly on-ground waterbird survey (as part of integrated sampling vegetation and fauna surveys (fauna surveys to include both aquatic and terrestrial species);
- five yearly fish and macro-invertebrate survey; and,
- the use of AUSRIVAS and Signal scores to benchmark diversity, abundance and community health of macro-invertebrate populations (this will need to be added to the 2008 survey).

Communication, Education and Public Awareness (CEPA) Messages

The primary message that needs to be communicated to relevant stakeholders is:

"An Ecological Character Description (ECD) of the Riverland Ramsar Site at the time of listing in 1987 has been prepared. The Site is listed against 8 of the 9 Ramsar listing criteria. This site is a complex riverine wetland ecosystem which provides habitat for important and nationally threatened species. The ECD documents past and current conditions, determines approaches to assess changes in condition, and identifies potential threats to the wetland's condition. The ECD identifies appropriate management considerations for future management planning and also identifies critical information gaps for management. Without active management intervention the ecological character of the site is under threat"

The stakeholders of the Riverland Ramsar Site are numerous and the messages required for each may be different, especially as part of management planning. The stakeholders for the site have been separated into four groups, according to their role and interest in the site. Initially, however, a combined set of messages, relevant to the ECD can be used to communicate the importance of the site, why it was listed, the threats to the site and future actions required.

1. INTRODUCTION

This document is an *Ecological Character Description* (ECD) for the Riverland Ramsar Site (hereinafter referred to as 'the Site'). It contains information about:

- Geographic and administrative details;
- the Site's ecological character (including components, processes, benefits and services) at the time of Ramsar listing (1987) and currently;
- gaps in knowledge of the Site and issues for management;
- actual or potential threats;
- changes that have occurred since 1987 or are currently occurring;
- site monitoring needs and triggers for management action; and,
- communication, education and public messages to facilitate management and planning.

1.1. Purpose

Ecological Character Descriptions of Ramsar listed sites address general requirements as part of the Ramsar process, and objectives based on intrinsic social, cultural and environmental features. The objectives of this ECD are:

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Commonwealth of Australia):

    a) to describe and maintain the ecological character of declared Ramsar wetlands in Australia; and

    b) to formulate and implement planning that promotes:

        i) conservation of the wetland; and

        ii) wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.

2. To assist in fulfilling Australia's obligation, under the Ramsar Convention, to advise, at the earliest possible time, if the ecological character of any declared wetland in its territory has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.

3. To supplement the description of ecological character in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, with

the Ramsar Information Sheet, form an official record of the ecological character of the Site.

4. To assist the administration of the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*, particularly:

   a) to determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or

   b) to assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.

5. To assist any person considering taking an action that may impact on a declared Ramsar wetland to decide whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.

6. To inform members of the public interested in declared Ramsar wetlands to understand and value the wetlands.

An ECD also forms the basis for understanding and managing the listed wetland site, including information required to:

- design programs for monitoring its condition,
- determine methods and approaches for assessing changes to its condition,
- identify potential threats and impacts, and evaluate risks,
- devise efficient and appropriate management plans for ongoing protection of the wetland, and
- identify critical gaps in knowledge, and a means to address these gaps.

The process for preparing an ECD should engage stakeholders, laying the foundations for alignment of goals and agreed management outcomes. The Riverland Site, with its array of significant features and potential for impacts of upstream and wider catchment actions, presents a situation where stakeholder involvement is vital.

1.2. Site Details

Introductory details are presented in Table 1.1.

The Site was first listed in 1987 against the (then) criteria 1a, 1b, 1c, 3b of the Ramsar Convention. Following revision of the criteria in 1999, the Site is now listed under criteria 1-8 of the revised convention (Refer Section 2).

Table 1.1: Introduction to the Riverland Ramsar Site

Ramsar Site	Riverland
General Location	Adjacent to the River Murray between Renmark, South Australia and the Victorian and New South Wales state borders.
Area	30,615 ha
Geographical Coordinates	North-east corner – Lat: 33° 55′ 49.7″ S; Long: 141° 00′ 9.7″ E South-east corner – Lat: 34° 01′ 142″S; Long: 140° 00′ 9.9″ E Southern central point- Lat: 34° 09′ 59.3″S; Long: 140° 46′ 45.4″E
Date of Listing	1987 (Lake Woolpolool area was added in 2007)
Date Used for Description	1987
Original Description Date	March 2008 (this document is the first description), Revised May 2009.
Version Number	2
Status of Description	First description, following site visit and consultation with stakeholders
Compiler's Name	Lance Lloyd (Lloyd Environmental Pty Ltd) lance@lloydenviro.com.au Peter Newall (Consulting Aquatic Ecologist) p.newall@bigpond.com
Ramsar Information Sheet	Ramsar Information Sheet: Riverland (last updated May 2009) Ramsar sites information service, Ramsar sites database: http://ramsar.org/ris/key_ris_index.htm Ramsar Site No.: 377 Wetlands International Site Reference No: 5AU029
Management Plan	A number of catchment and local plans regulate or promote protective actions throughout and/or adjacent to the Site. A management plan is being developed for official approval.
Responsible Management Authority	Department for Environment and Heritage Regional Conservation Directorate, Murraylands Region 28 Vaughan Terrace, Berri SA 5343, Australia Ph: (61 8) 8595 2111 Director of National Parks (for Calperum Block) Department of the Environment, Water, Heritage and the Arts GPO Box 787, Canberra ACT 2601 Australia Ph: (61 2) 6274 1111

1.3. Date of Description

This ECD has been compiled between September 2007 and July 2009, approximately 20 years after the Riverland Site was first listed, but is required to reflect conditions at the time of listing. The ECD utilises studies and reports undertaken at various times, but these have been interpreted to represent conditions at the time of listing.

This ECD was prepared subsequent to a boundary revision (dated 11 September 2007) designed to:

- excise major non-wetland areas dominated by agriculture; and,
- include a major wetland area (Lake Woolpolool, a seasonal saline lake).

The removal of the non-wetland areas does not impact on the ecological character of the Riverland Ramsar Site, whereas the inclusion of Lake Woolpolool has enhanced the waterbird and vegetation diversity of the site (RIS in prep). The revised boundary was incorporated into a revised RIS (RIS in prep) which has been approved by the Australian Government (11 September 2007), and the Ramsar Convention on Wetlands Secretariat has been notified.

In this ECD, Lake Woolpolool is assumed to be part of the Ramsar Site, and its effective time of listing is taken as 1987. Further, the non-wetland agricultural area excluded as part of the boundary change is not part of the ECD.

1.4. Relevant Treaties, Legislation or Regulations

This section describes treaties, legislation and regulations relevant to the protection of the Site, although most were enacted subsequent to 1987.

1.4.1 International treaties and strategies

Ramsar Convention

The *Convention on Wetlands of International Importance especially as Waterfowl Habitat* (Ramsar, Iran, 1971), known as the Ramsar Convention, is an inter-governmental treaty dedicated to the conservation and sustainable use of wetlands (Environment Australia 2001). Australia was one of the first 18 countries to sign the Convention in 1971, and its obligations to protect and maintain the ecological character of its Ramsar sites are recognised in the Commonwealth EPBC Act, described in Section 1.4.2.

The Ramsar Secretariat maintains a *List of Wetlands of International Importance* that includes 65 Australian sites as at September 2007 (c. 7.5 million ha). Criteria to determine international importance are set out by the Ramsar Secretariat at http://www.ramsar.org/key_guide_list2006_e.htm#V. They include considerations of representative, rare or unique wetland type, the presence of vulnerable, rare or threatened species or ecological communities, diversity of particular biogeographic regions, supporting critical life stages of plant or animal species, the support of large waterbird populations, significance to native fish populations and support for 1% or more of wetland dependent organisms.

Ramsar wetlands and the EPBC Act

Under the EPBC Act, a person is required to obtain an approval for any action that has, is likely to, or will have a significant impact on a matter of National Environmental Significance, which includes the ecological character of a wetland. Actions that would affect the ecological character of wetlands include:

- areas of wetland being destroyed or substantially modified;
- a substantial and measurable change in the hydrological regime (for example, a change to ground-water, or to the volume, timing, duration and frequency of surface-water flows);
- any change that might affect the habitat or life cycle of native species dependent on the wetland;
- a substantial and measurable change in the physico-chemical status of the wetland (for example, a change in salinity, pollutants, nutrients or water temperature which may affect biodiversity, ecological integrity, social amenity or human health); and,
- an invasive species potentially harmful to the wetland community.

The EPBC Act also sets standards for managing Ramsar wetlands through the *Australian Ramsar Management Principles*, established as regulations under the Act (Environment Australia 2001).

International conventions on migratory species

Australia is a signatory to three international conventions on migratory species:

- The Japan-Australia Migratory Birds Agreement (JAMBA);
- The China-Australia Migratory Birds Agreement (CAMBA); and,
- The Republic of Korea-Australia Migratory Birds Agreement (ROKAMBA).

JAMBA and CAMBA are bilateral agreements between the governments of Japan and Australia and China and Australia, seeking to protect migratory birds in the East Asian – Australasian Flyway. The two agreements list terrestrial, water and shorebird species (most are shorebirds) that migrate between Australia and the respective countries. They require parties to protect migratory birds from 'take or trade', except under limited circumstances, to protect and conserve habitats, exchange information and build cooperative relationships. The JAMBA agreement also includes specific provisions for conservation of threatened birds (DEWHA 2009a).

ROKAMBA, signed in Feb 2006, is a bilateral agreement similar to JAMBA and CAMBA. The agreement obliges its Parties to protect bird species which regularly migrate between Australia and the Republic of Korea, and their environment. An annex to ROKAMBA contains a list of species or subspecies of birds for which there is reliable evidence of migration between the two countries.

1.4.2 Commonwealth Legislation and Policy

The principal Commonwealth environmental legislation that relates to wetland conservation is the EPBC Act. Under the Act, any actions that have, or are likely to have, a significant impact on a matter of National Environmental Significance requires approval from the Commonwealth Environment Minister.

Seven matters of national environmental significance are identified in the Act:

- World heritage properties;
- National heritage places;
- Wetlands of international importance (Ramsar wetlands);
- Threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas; and,
- Nuclear actions (including uranium mining).

The matters relevant to the Riverland Site are Ramsar listing, nationally-threatened species and ecological communities and migratory species.

EPBC Act and protection of species listed under international conventions

The species that are the subject of the agreements or conventions are listed as 'migratory species', a matter of National Environmental Significance under the EPBC Act. Any action that may affect these species requires the Commonwealth Minister for the Environment to decide whether the action will, or is likely to, have a significant impact on the listed species, and whether the action will require approval under the EPBC Act. If this approval is required, an environmental assessment is carried out. The Minister decides then whether to approve the action, and what conditions (if any) to impose.

1.4.3 State Legislation

Pertinent South Australian legislation includes the:

- Aboriginal Heritage Act 1988 – protects sites and artefacts;
- Development Act 1993 – controls development;
- Environmental Protection Act 1988 – controls pollution and waste disposal;
- Fisheries Act 1982 – protects and manages state fisheries;
- Harbors and Navigation Act 1993 – controls boat access and use;
- National Parks and Wildlife Act 1972 – protects and manages conservation sites and native flora and fauna;
- Native Vegetation Act 1991 – controls clearing of native vegetation, Heritage Agreements;
- Pastoral Land Management and Conservation Act 1989 – manages pastoral land;

- River Murray Act 2003 – promotes integrated management of river resources; and,
- Natural Resource Management Act 2005 – integrates regional natural resource management.

2. DESCRIPTION OF THE SITE

2.1 Setting

The Riverland Ramsar Site is on the floodplain of the River Murray, between Renmark, South Australia, and the state borders with Victoria and New South Wales (Figure 2.1) (RIS in prep.). As the principal river of the Murray-Darling Basin, the Murray flows 2,530 km from its source in south-eastern New South Wales to its mouth at Encounter Bay, South Australia.

The Basin has an area of 1.073 million km^2 (14% of mainland Australia), including four states and one federal territory. Much of the region is flat, with extensive aeolian and alluvial deposits of sands, silts and clays. An outcrop of folded metamorphic rocks provides slightly-elevated relief in the north-west, and the high metamorphic and igneous rock outcrops of the Great Dividing Range from the eastern and southern borders (Murray-Darling Basin Ministerial Council 1987; RIS in prep.).

The River Murray has five geomorphological tracts (Mackay & Eastburn 1990):

The Headwaters: a tract extending about 450 river km from the source. The catchment is <2% of the Basin area, but contributes nearly 40% of the discharge.

The Riverine Plains: a flat, 800 river km tract of river and lake deposits where the River Murray flows in shallow, branching, meandering channels.

The Mallee Trench: an 850 river km plain of marine origin, crossed by the river in a well-defined, incised channel.

The Mallee Gorge: a 350 river km channel flanked by steep limestone cliffs.

The Lakes and Coorong: including the terminal lakes, Lake Alexandrina and Albert, and the Coorong. This area also is a Ramsar site.

The Riverland Ramsar Site is located in the 'Mallee Trench', which begins near Swan Hill, Victoria, and extends to Overland Corner, South Australia.

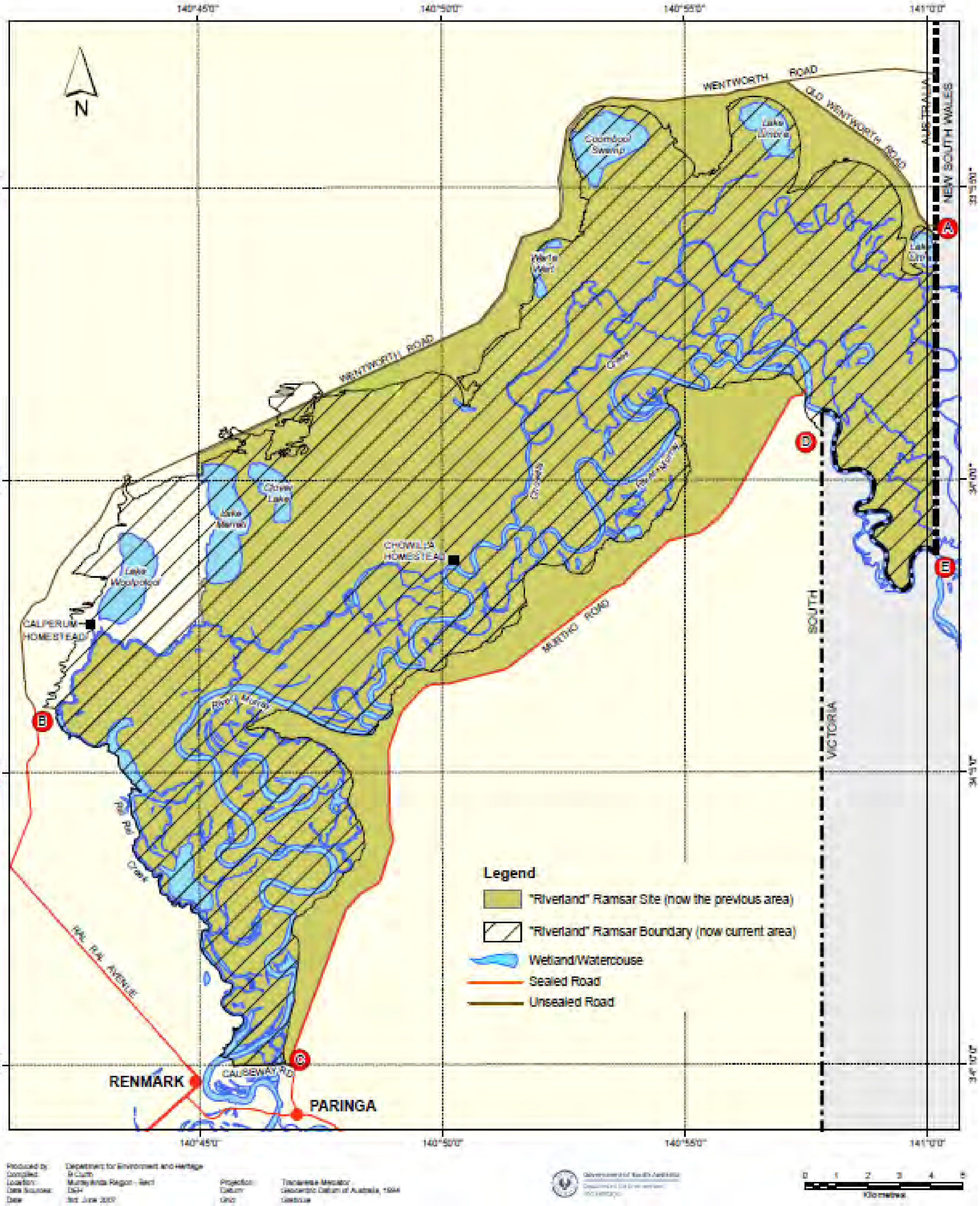


Figure 2.1: Map of Ramsar Site (with boundary change gazetted on 11/09/2007)

The Site is situated in an ancient riverine plain with alluvial fans composed of unconsolidated sediments with evidence of former stream channels. The River Murray and Murrumbidgee River and their major tributaries, the Lachlan and Goulburn Rivers, flow westwards across this plain. Vegetation consists of River Redgum and Black Box forests, Box woodlands, saltbush shrublands, extensive grasslands and swamp communities (Environment Australia 2000).

2.2 Riverland Ramsar Site

The whole of the Riverland Ramsar site is in the Riverland Biosphere Reserve (http://www.riverland.net.au/~bbwaters/page4.html). The Site contains three generally recognised land components or 'blocks' – Murtho, Calperum, and Chowilla – defined primarily on the basis of historical ownership (see Figure 2.2). The Site blocks encompass only parts of greater land components. In particular, the Calperum and Chowilla blocks within the Site only contain fractions of the larger Calperum Station and Chowilla Reserves, respectively.

2.2.1 Murtho Block

The Murtho block of the Site is the southern-most section and for the purposes of this document contains the land within the River Murray National Park (Bulyong Island) and Murtho Forest Reserve, and the adjacent sections of private land to the east, within the Site (see Figure 2.2 for a map of land tenure of the Site).

2.2.2 Calperum Block

The Calperum block is the middle portion of the Site that intersects with the Calperum Station. The vast majority (approximately 97 percent of the 245,800 ha) of the Calperum Station is outside the Riverland Ramsar Site, leaving approximately 8,500 ha within the site (Parks Australia 2005). Within this 8,500 ha, there is approximately 20 km of River Murray frontage and many more kilometres of anabranch and creek frontage, including the Ral Ral Creek Anabranch (Figure 2.3).

2.2.3 Chowilla Block

The Chowilla block of the Site intersects with most of the Chowilla Game Reserve, to the south of the Chowilla Regional Reserve. The two Chowilla reserves are run by the DEH and also form part of the much larger Riverland Biosphere Reserve. This part of the Site is also part of the Chowilla Floodplain and Lindsay-Wallpolla Living Murray Icon site.

While the different blocks are separated on the basis of human historical, rather than environmental, features, there are some habitat differences between the blocks. Within the Riverland Ramsar Site, the Chowilla block contains River Redgum forest, River Redgum woodland, Black Box woodland and chenopods shrublands, with the Murtho block more similar to the moister, low elevation parts of Chowilla block. The Calperum block contains many wetlands (some of which are permanent due to river regulation) and also dryer, slightly more elevated parts similar to areas of Chowilla.

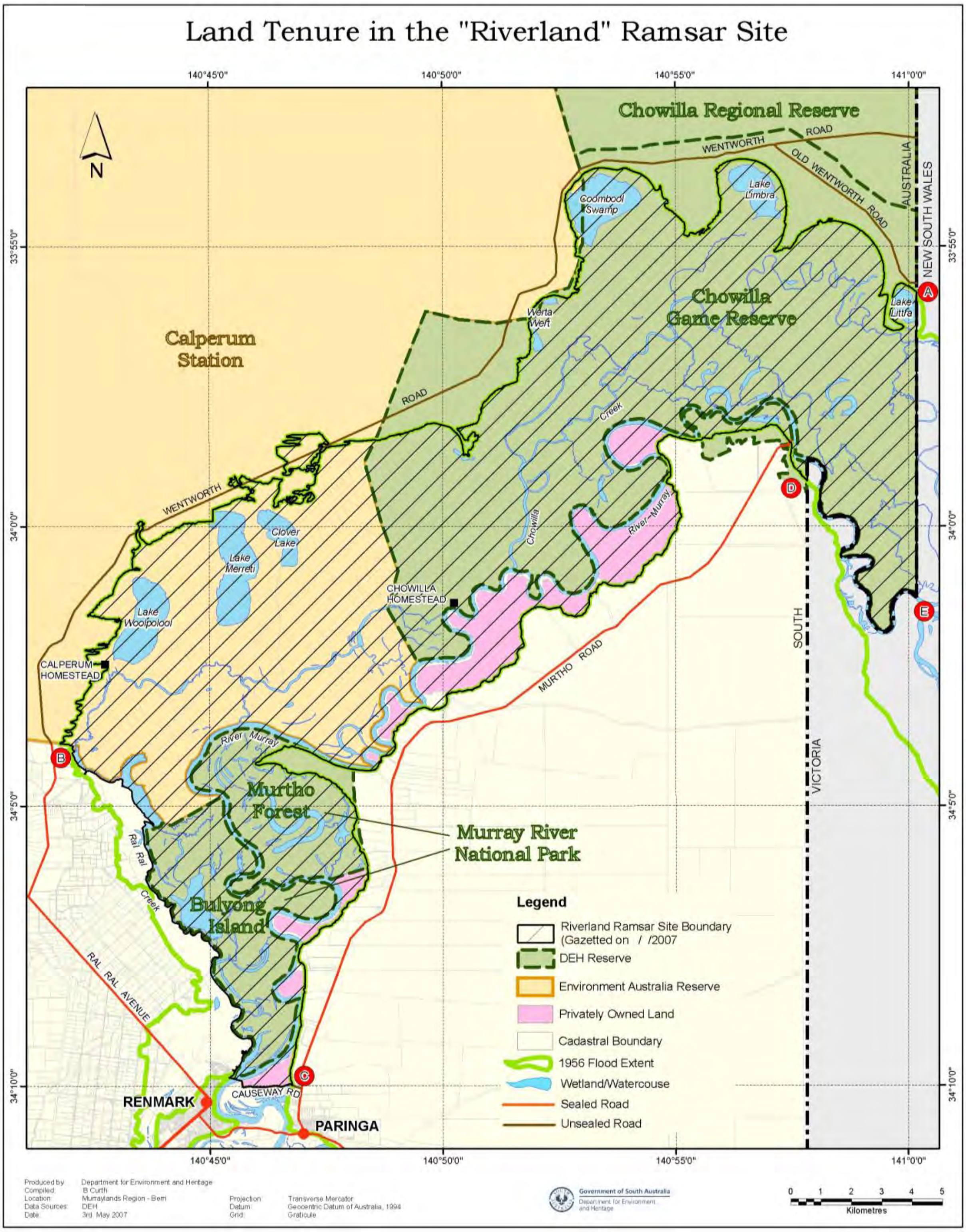
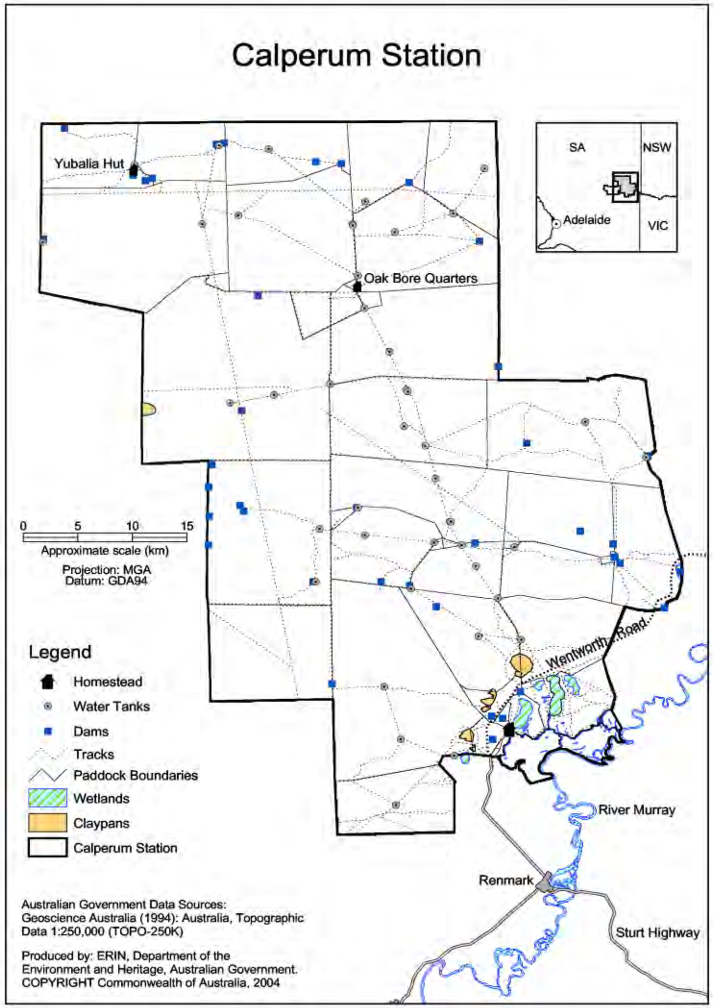


Figure 2.2: Land tenure at the Riverland Ramsar Site, shows the three main site blocks: Calperum, Chowilla and Murtho.



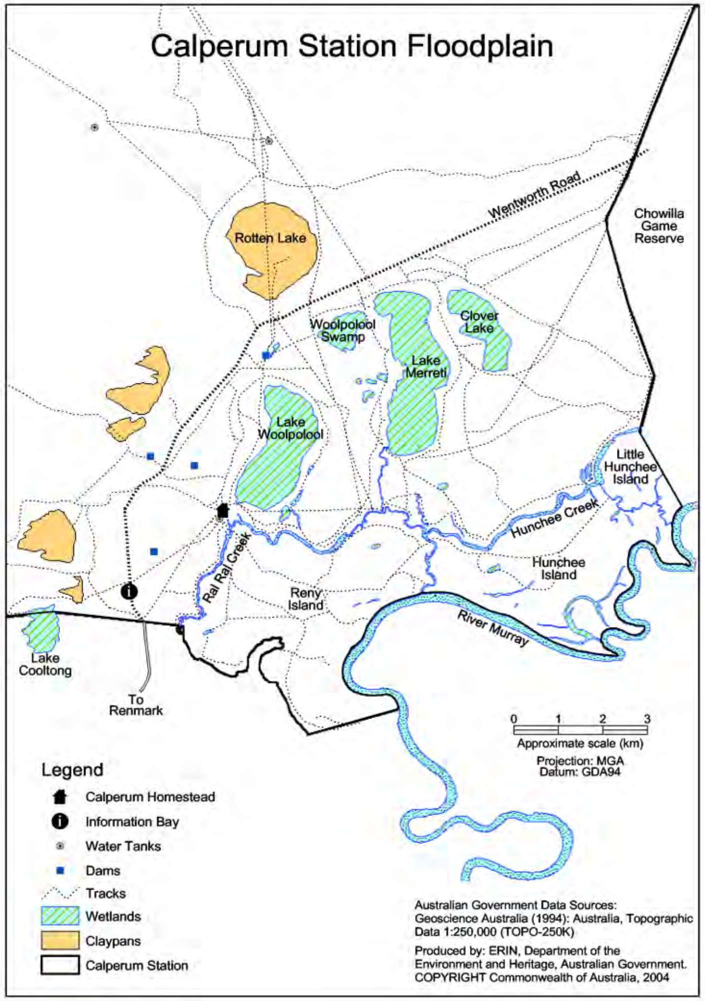


Figure 2.3: Calperum Station showing the floodplain habitat

2.3 Overview of Ramsar Site

The Site boundary follows the 1956 floodline west from the New South Wales border. It includes two major anabranch systems (Chowilla and Ral Ral Creeks) along an 80 km stretch of the River Murray, incorporating a series of creeks, channels, lagoons, billabongs, swamps and lakes. The total area is 30,615 hectares (Table 2.1, Figure 2.4).

Before construction of locks and weirs along the lower River Murray in 1922 to 1937, the River Murray in South Australia generally experienced highly variable flows. In spring and early summer the River was generally high, cool, turbid and fast flowing, gradually changing to become low, warm, clear and slow moving towards the end of summer. During drought, the flow would cease and saline pools would form through the interception of underlying saline groundwater (Sharley & Huggan 1995).

Since weir construction, the River and the main anabranch systems flow continuously and many wetlands are permanently inundated due to the river level having risen up to 3 m in the pools impounded by weirs at Locks 5 – 6. Regional saline groundwater (30,000 to 40,000 mg/L Total Dissolved Solids) now flows into the anabranch creeks. Up to 145 tonnes of salt per day can enter the Chowilla Anabranch system following a major flood compared to the steady background level of 43 tonnes per day, which is re-established after the effects of floods have passed (Sharley & Huggan 1995). Saline ground water mounds have formed beneath irrigated areas adjacent to the Riverland wetland e.g. the Renmark and Chaffey Irrigation Areas contribute approximately 34 tonnes of salt per day to the Ral Ral Anabranch (Woodward-Clyde 1999).

River regulation has greatly modified the frequency, height and duration of flows through the Riverland Site. Except in major floods, flow to South Australia is regulated through an agreement between the Murray-Darling Basin States/Territories and the Australian Government. Under the current water sharing rules, South Australia has a minimum 'entitlement' of 1,850 GL per year, although it did not receive entitlement flows in 2006, and did not receive full entitlement in 2007 or 2008 due to drought. Entitlement flows vary monthly, depending on demand for irrigation water and range from 7,000 ML/day or more in December-January to 3,000 ML/day in May-June. Significant overbank flow at the Site requires a flow greater than 50,000 ML/day. At least 80,000 ML/day is required to inundate half the floodplain and total inundation is achieved when flows reach 150,000 ML/day.

Wetland types and depths vary throughout the Site. Representative water depths are: main river 4-8 m; anabranch creeks 1-3 m; permanent wetlands <1-2 m and temporary wetlands 1-2 m. Since the construction of Locks 5-6 the river, main anabranches and many wetlands are permanently inundated, with little water fluctuation except during floods. For many temporary wetlands the reverse is true with areas receiving water less often and for less time than they did under unregulated conditions.

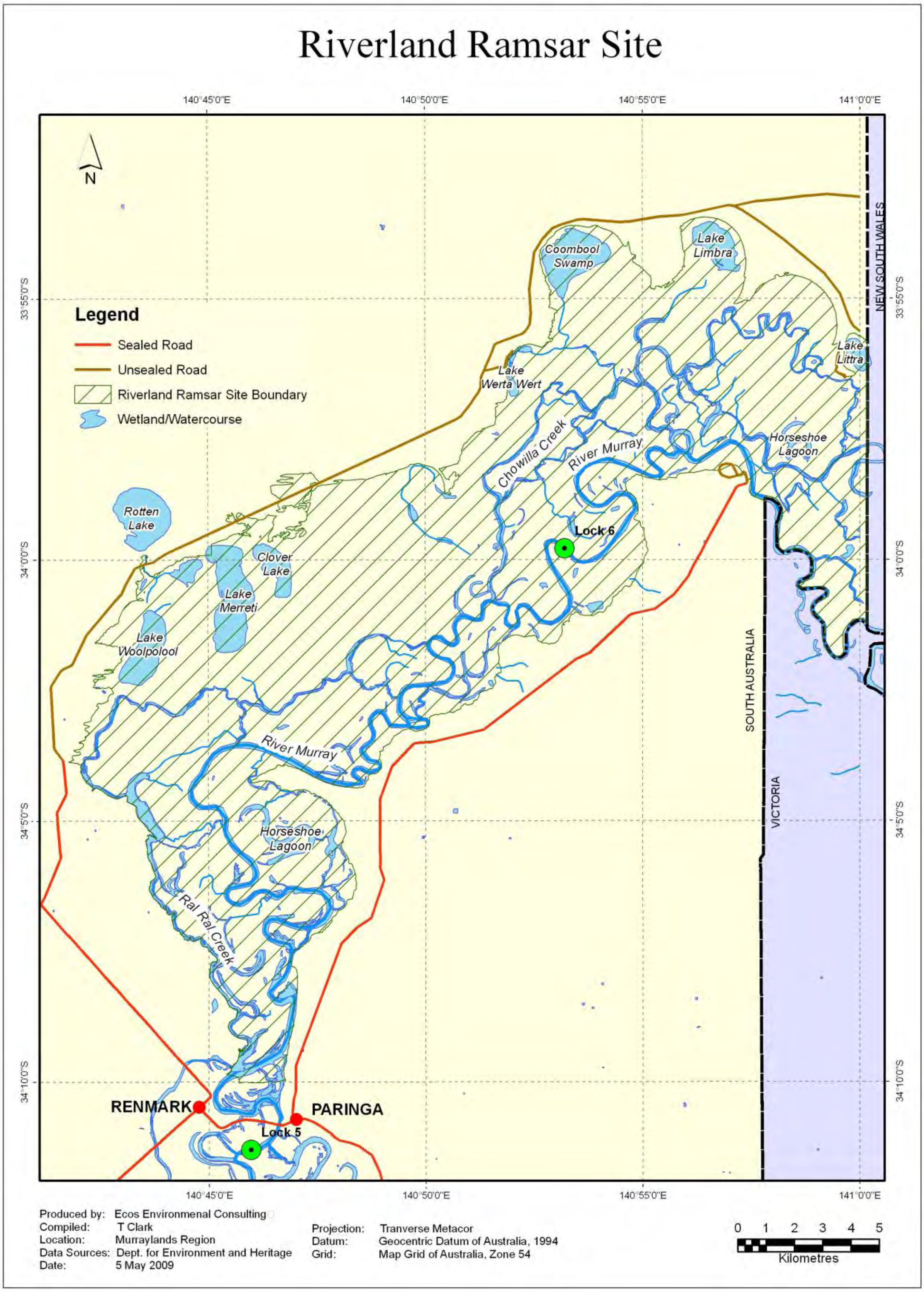


Figure 2.4: Map of major wetland sites within the Riverland Ramsar Site

In this overview section of the report, the Ramsar wetland types classification is used to identify and distinguish the types of wetland occurring in the Site. More locally-derived approaches of vegetation classification are presented in the section describing vegetation as a Site component (Section 3.2.6).

The Ramsar-defined wetland types that occur at the Site are displayed in Table 2.1, with associated landforms in the Riverland and some examples from within the Site. A map of these wetland types across the site is presented in Figure 2.5.

Table 2.1: Wetland types, areas, associated landforms and examples within the Riverland Ramsar Site

Code	Wetland Types	AREA (ha)	Associated Landforms	Examples within Riverland Ramsar Site
Xf	Freshwater, tree-dominated wetlands	4,032	scroll floodplain landform which supports River Redgum woodland	opposite Bunyip Reach and Nil Nil
M	Permanent rivers/streams/creeks	1,845	active floodplain channels	River Murray, Chowilla and Ral Ral Anabranch systems
P	Seasonal/intermittent freshwater lakes	770	(i) deflation basins; and (ii) lentic channels such as ancestral river oxbows	(i) Coombool Swamp and Lake Limbra; (ii) Punkah Island, Horseshoe Lagoon
O	Permanent freshwater lakes	535	(i) deflation basins; (ii) lentic channels such as ancestral river oxbows; and (iii) remnant channels	(i) Lake Merreti; (ii) Isle of Man; and (iii) Woolenook, Horseshoe Lagoon
Tp	Permanent freshwater marshes/pools	343	(i) scroll swales; (ii) slack water areas; (iii) discrete depositional basins; (iv) Interconnected depositional basin; (v) impounded wetlands; and (vi) miscellaneous floodplain depressions	(i) Nil Nil; (ii) Chowilla Anabranch; (iii) Pilby Creek complex; (iv) Bunyip Reach; (v) Whirlpool Corner; and (vi) Weila/Murtho Park
R	Seasonal saline/brackish lake	330	A deflation basin that was salinised in the 1950's due to land management practices	Lake Woolpolool
N	Seasonal/intermittent/irregular rivers/stream/creek	Not Available	lentic channels such as distributary channels and "crevasse" channels	Reny and Chowilla islands
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils	Not Available	(i) discrete depositional basins; (ii) lentic channels such as remnant channels; and (iii) miscellaneous floodplain depressions	(i) Longwang Island; (ii) Brandy Bottle Waterhole; and (iii) Gum Flat

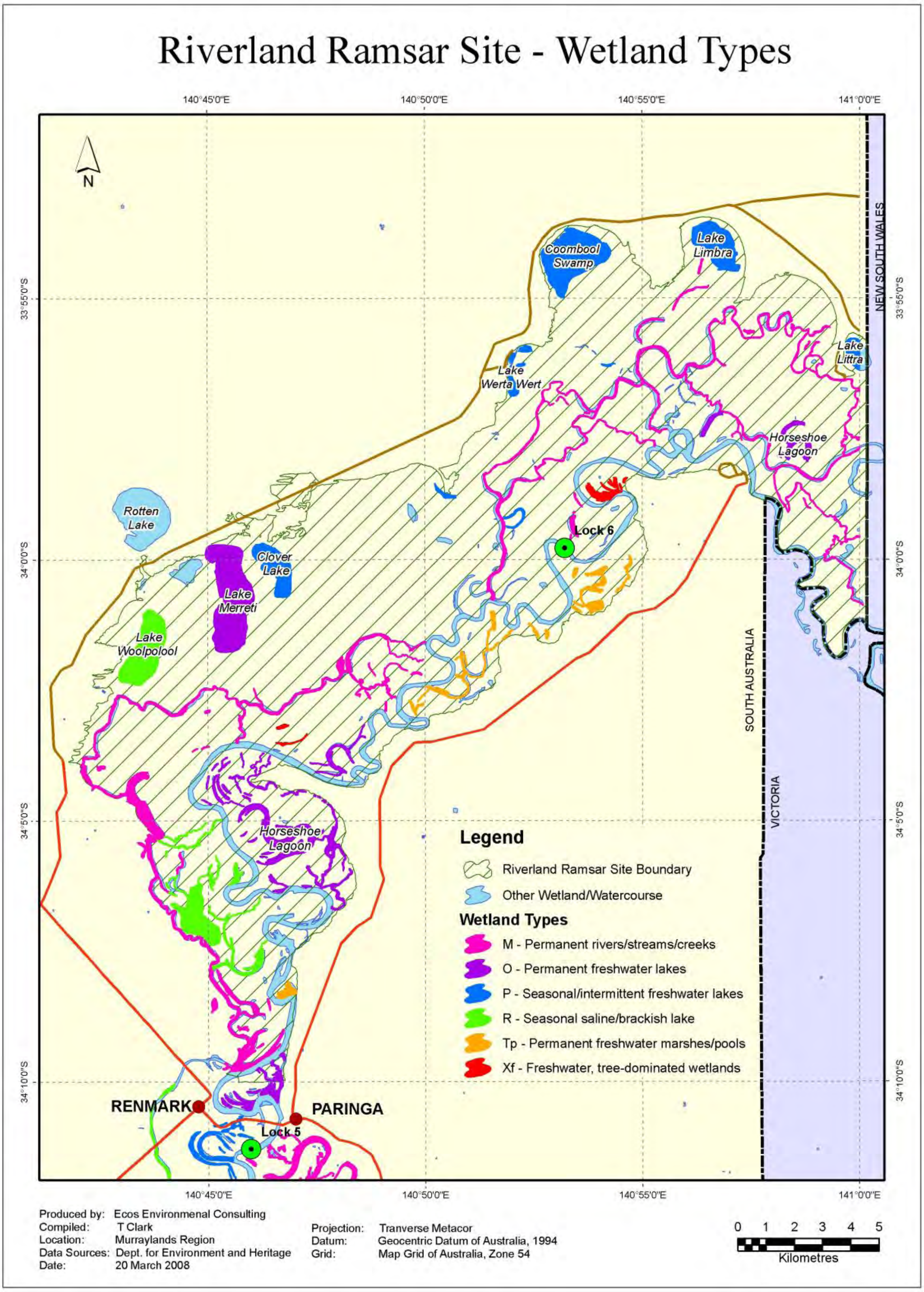


Figure 2.5: Wetland types within the Riverland Ramsar Site
(note: the main River Channel is also category M but is mapped light blue)

2.4 Ramsar Listing

The Site was originally listed in November 1987 against the (then) criteria 1(a), 1(b), 1(c), and 3(b), which states that "a wetland should be considered internationally important if:

1a – It is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region;

1b – It is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region;

1c – It is a particularly good representative example of a wetland, which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position

3b – it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity".

In 1999 the Ramsar criteria were revised and, in 2006, the RIS for the Riverland Site also was revised. The Site is now listed under criteria 1 to 8 (Table 2.2).

Table 2.2: Ramsar Citeria under which the Riverland Ramsar Site is Listed

Group A: Sites containing representative, rare or unique wetland types	
Criterion 1:	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion.
Group B: Sites of international importance for conserving biological diversity	
Criteria based on species and ecological communities	
Criterion 2:	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3:	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4:	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Specific criteria based on waterbirds	
Criterion 5:	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6:	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Specific criteria based on fish	
Criterion 7:	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8:	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Criterion 1 (representative/rare/unique wetland type in appropriate biogeographic region)

The Site is located in the lower River Murray basin of the Murray-Darling Division (http://www.bom.gov.au/hydro/wr/basins/index.shtml). At the time of listing, the Site contained one of the only parts of the lower River Murray floodplain not used for irrigation (within the Chowilla Floodplain), preserving much of its natural character. This has led to the Chowilla Floodplain being regarded as an 'icon site' by the Murray-Darling Basin Commission, one of six such sites in the basin (http://thelivingmurray.mdbc.gov.au/iconsites).

The Site has also been noted to contain excellent regional representative examples of a major floodplain system within the the lower River Murray floodplain. As such, the Site is representative of a floodplain system within the region, and also rare in that almost all of the other examples these wetland types in the region have been impacted by irrigation.

Criterion 2 (vulnerable/endangered/critically endangered species or ecological communities)

This criterion is focused on species and communities listed at the Commonwealth level, principally through the EPBC Act.

The Site supports the following taxa, listed as Vulnerable under section 179 of the EPBC Act:

- Regent Parrot (Eastern), *Polytelis anthopeplus monarchoides*;
- Southern Bell Frog, *Litoria raniformis*;
- Murray Cod, *Maccullochella peelii peelii; and,*
- Murray Hardyhead, *Craterocephalus fluviatilis.*

The Regent Parrot (eastern) is confined to the semi-arid interior of southeastern mainland Australia. It primarily inhabits riparian or littoral River Redgum (*Eucalyptus camaldulensis*) forests or woodlands and adjacent Black Box (*E. largiflorens*) woodlands, with nearby open mallee woodland or shrubland (DEWHA 2009b). In South Australia, the key breeding population occurs in the Murray-Mallee region, centred along the River Murray. Nesting typically occurs in River Redgum (*Eucalyptus camaldulensis*), and occasionally in Black Box (*E. largiflorens*), usually within 16 m of permanent water, or sometimes actually standing in water (DEWHA 2009b). Nest sites may sometimes occur near temporary water sources, such as ephemeral streams or seasonal billabongs, but these are usually within about 60 to 100 m of permanent water sites. These environmental conditions and tree species are provided by the Site.

The Southern Bell Frog (also known as the Growling Grass Frog) has declined dramatically across its range. Population studies have shown that Southern Bell Frog populations are positively influenced by permanent water, the extent of aquatic vegetation, extensive riparian or floodplain grasslands and the presence of other nearby Growling Grass Frog populations (Heard *et. al.* 2004). The species is dependent upon permanent freshwater lagoons for breeding. The ideal breeding habitat is the shallow part of still or slow-flowing lagoons, generally with a complex vegetation structure (DEWHA 2009b). Despite their requirement for permanent water for breeding, they also require terrestrial habitat (such as grasslands and forests), feeding mainly on terrestrial invertebrates such as beetles, termites, cockroaches, moths, butterflies and various insect larvae (DEWHA 2009b). The combined habitat requirements of permanent waters with still to slow-flowing areas and nearby forests and grasslands is provided by the Riverland Ramsar Site. Among the threats to the Southern Bell Frog, habitat loss through stock grazing and irrigation are considered major (DEWHA 2009b). Again, the Site provides some sanctuary form these impacts, making it a key refuge for this species within the region.

Murray Cod are found in a range of warm water habitats across the Murray-Darling Basin. The species is highly dependant on woody debris for habitat, using it to shelter from fast-flowing water and for spawning in lowland rivers (DEWHA 2009). Although the Riverland Ramsar Site offers substantial natural habitat in the form of deep pools and coarse woody debris, the Site also suffers from one of the major threats to the Murray Cod – altered hydrologic regime through the isntallation of locks and weirs. However, the large network of flowing anabranches within the Site provides valuable habitat for the Murray Cod, particularly as several of the anabranches are susceptible to flooding, connecting the channel to the floodplain. This attribute is relatively rare in the post-regulation River Murray and is largely restricted to this and other Ramsar sites.

The Murray Hardyhead is only known from the Murray-Darling River system and inhabits the margins of slow, lowland rivers, and lakes, billabongs and backwaters. It is found amongst aquatic plants and over gravel beds in both fresh and highly saline waters (DEWHA 2009). It has a short life history with fish typically only living for 15 months, so they do not persist in locations which do not provide the right conditions for the species. It is now found only in the lower southern part of the Basin, having suffered reductions in its distribution and abundance (Lintermans 2007). Causes of its decline are uncertain but are thought to include increasing salinisation, habitat degradation, altered flow regimes and impacts of alien species

(Lintermans 2007). The species is in dramatic decline and its presence at the Riverland Ramsar Site makes the Site a place of high importance for the species.

Criterion 3 (supports populations of plant and/or animals important for regional biodiversity)

This criterion includes species and communities listed at the State level. There are twenty-eight plant species listed at the State level under the National Parks and Wildlife Act 1972 that are found at the Site on a permanent or seasonal basis (Appendix 1.1). Twenty species are listed as rare and eight as vulnerable. The Site also contains animal species listed at the State level, including twenty-two State listed threatened species that inhabit the Site on a permanent or seasonal basis (Appendix 2.2). Fourteen of these species are listed as rare (two reptiles, twelve birds), seven as vulnerable (one reptile and six birds), and one (the Feather-tailed Glider, *Acrobates pygmaeus*) is listed as endangered.

This criterion also includes consideration of diversity within a bioregional context. As noted in the discussion for Criterion 1, the Site is located within the Murray River Drainage Division (AWRC 1975). This Drainage Division covers habitats which range from alpine meadows above the tree line, through wet montane forest, to arid lowlands in the continental interior. As described for Criterion 1 (above) the Site area overlaps with one of the only parts of the lower River Murray floodplain not used for irrigation, preserving much of its natural character. The full range of the riverine vegetation communities expected within this part of the lower River Murray floodplain is found within or near the Site (Margules et al. 1990). The Chowilla floodplain has a high diversity of both terrestrial and aquatic habitats, including fish breeding habitat and areas that support populations of breeding waterbirds (MDBC 2006). Significantly, the Chowilla floodplain contains the largest remaining area of natural River Redgum (*Eucalyptus camaldulensis)* forest in the lower River Murray (Sharley and Huggan, 1995).

Maintenance of remnant populations of endangered flora and fauna within the Site that are uncommon or extinct elsewhere in the lower River Murray has been acknowledged in numerous studies and has been attributed to unique flowing waters and habitat diversity in the Site's anabranch systems (O'Malley and Sheldon, 1990; Pierce, 1990; Sharley and Huggan, 1995; Zampatti *et al*, 2005). Recent fish investigations have provided further evidence of the Site's high conservation value (MDBC 2006). Fourteen species of freshwater fish have been recorded in sampling conducted during 2004 and 2005. The diversity of aquatic habitats within the Site's anabranch systems seems to benefit Murray Cod populations in particular, allowing different sized Murray Cod to exploit different habitats (Zampatti *et al*, 2005). Similarly, Carpenter (1990:64) noted that the Chowilla area is recognised as a site of high avian diversity and noted for the presence of species not readily found elsewhere in the State. Carpenter attributed this to regionally high habitat diversity and a relatively low level of disturbance, stating that it has "outstanding importance for bird fauna in South Australia. The woodland habitats support a high diversity of resident species, many of high conservation significance, as well as providing a corridor for bird movements interstate. The wetland habitats, particularly those prone to extensive periodic flooding, provide important breeding habitat for large numbers of breeding waterbirds."

Criterion 4 (supports species at critical stages or provides refuge in adverse conditions)

The Riverland wetland provides critical summer or stopover habitat for eight species of migratory birds listed under the JAMBA, CAMBA and ROKAMBA agreements. These are:

- Sharp-tailed Sandpiper (*Calidris acuminate*)
- Curlew Sandpiper (*Calidris ferruginea*)
- Red-necked Stint (*Calidris ruficollis*)
- Eastern (Great) Egret (*Ardea modesta*)
- White-bellied Sea-Eagle (*Haliaeetus leucogaster*)
- Caspian Tern (*Hydroprogne caspia*)
- Glossy Ibis (*Plegadis falcinellus*)
- Greenshank (*Tringa nebularia*)

These species and their listings are presented in Appendix 2.4. The Site is also important as habitat for nomadic waterbirds during times of drought in central and eastern Australia (Appendix 2.5) and for nomadic bush-bird species during the dry southern Australian summer (November to March), (Appendix 2.6).

During a 10-day bird survey of the Chowilla floodplain in 1988, Carpenter (1990) recorded a total of 30 breeding species. Of these, there were eight species of waterbird recorded breeding during the survey:

- Little-pied Cormorant (*P. melanoleucos*)
- Black Swan (*Cygnus atratus*)
- Australian Shelduck (*Tadorna tadornoides*)
- Pacific Blackduck (*Anas superciliosa*)
- Australian Grey Teal (*Anas gracilis*)
- Maned Duck (Wood Duck)(*Chenonetta jubata*)
- Masked Lapwing (*Vanellus miles*)
- Red-capped Plover (*Charadrius ruficapillus*)

Harper (2003) monitored waterbird breeding in Lake Merreti between 1987 and 1995. He noted that 9 species of colonial waterbirds had breeding events over those years (Table 2.3).

Table 2.3: Native Colonial Waterbird Species and Breeding Evenets at Lake Merreti between 1987 – 1995.

Species	Number of Breeding events in 9 years
Strawneck ibis	6
White ibis	6
Yellow-billed spoonbill	2
Royal spoonbill	1
Darter	5
Pied cormorant	1
Little black cormorant	4
Little pied cormorant	2
Black swan	1

Criterion 5 (providing habitat that regularly supports 20,000 or more waterbirds)

At the time of listing insufficient data were available to say the Site met criterion 5 (then criterion 3a), but more recent data indicates that the site supports 20,000 or more waterbirds involving fifty-nine species on a regular basis. A draft management plan for the Site (DEH undated) states "During 2002, 20,000 or more waterbirds involving fifty-five species were estimated by Goodfellow pers. com. (2003) and Harper pers. com. (2003) to be utilising the Ramsar Riverland Wetland" (p56) and "Due to the rehabilitation of a number of wetland sites within the Riverland Wetland, the area regularly supports 20,000 or more waterbirds" (p25).

The Ramsar Guidelines (Glossary) http://ramsar.org/key_guide_list2006_e.htm#E states: regularly (Criteria 5 & 6) - as in supports regularly - a wetland regularly supports a population of a given size if: i) the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or ii) the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).

In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. A difficulty with quantifying the waterbird numbers at the Riverland Ramsar Site is not only the paucity of data but also that information is generally available for individual wetlands rather than the whole-of-site. The data presented below has been used in support of this criterion. However, future monitoring will be required to confirm the validity of nomination under this criterion. Further, monitoring of sporadically-filled but nonetheless important wetlands will require consideration of the application and testing of the term 'reglularly'. In humid areas with consistent hydrologic regimes, 'regularly' may be able to measured as a percent of all years that have been monitored. Whereas in arid or semi-arid regions, 'regularly may' be more meaningful if based on whether or not the very high numbers recur (almost predictably) whenever a major inundation event occurs (albeit with a 10-year recurrence interval).

Some reported waterbird numbers and years are:

Site	Month & Year	Total Waterbird Count	Reference
Lake Merreti	Feb 2002	>23,000	Harper Unpub. Data
Lake Merreti	May 2001	>18,500	Harper Unpub. Data
Lake Merreti	March 2001	>19,000	Harper Unpub. Data
Lake Woolpolool	Feb 2002	>4,700	Harper Unpub. Data
Lake Woolpolool	January 2000	10,025	Harper 2003
Lake Woolpolool	May 2001	8,224	Harper 2003
Lake Woolpolool	October 2002	14,674	Harper 2003
Werta Wert	December 2005	3,066	Aldridge et al. 2006
Werta Wert	February 2006	3,161	Aldridge et al. 2006
Werta Wert	April 2006	2,350	Aldridge et al. 2006
Chowilla Floodplain (selected sites)	October 1988	> 5,000	Carpenter 1990

See Appendix 2.1 for a list of waterbird species recorded using the site.

Unpublished data from Harper (presented in Appendix 2.9), displays over 23,000 birds counted at Lake Merreti one day in February 2002, over 18,500 at the same site in May 2001 and over 19,000 in March 2001. As discussed above, these high numbers are from one site within the wetland – the 'whole-of-site' numbers are likely to be much larger but are not available. The same data set displays over 8,000 birds at Lake Woolpolool in May 2001 and over 4,700 in February 2002, on the same days as the high numbers were recorded at Lake Merreti.

Criterion 6 (providing habitat that regularly supports 1% of the global population of one species of waterbird)

At the time of listing insufficient data were available to say the Site met criterion 6 (then criterion 3c), but more recent data indicates that the site supports 1% of the population of three species on a regular basis. Similar to the previous criterion, there appears to be a paucity of quantitative data for supporting this criterion for the site – particularly over long periods. Therefore, although the data presented within this ECD supports this criterion, future monitoring will be required to confirm the validity of nomination under this criterion.

The following species have been recorded at the Site in numbers representing greater than 1% of their estimated global population:

- Freckled Duck, *Stictonetta naevosa*;
- Red-necked Avocets, *Recurvirostra novaehollandiae*; and
- Red-kneed Dotterel, *Erythrogonys cinctus*.

Freckled Duck: The IUCN redlist (Birdlife International 2008) estimates a global population of 20,000 Freckled Duck, and therefore 200 individuals would represent 1% of the global population. DEH (undated) states that the highest species count for Freckled Duck on the Site between 2000 and 2003 was 620 birds, recorded on Lake Merreti (Harper pers. com. 2003, in DEH undated). The data used by DEH (undated) are provided in Appendix 2.9 and show that between October 2000 and November 2002, the number of Freckled Duck on Lake Merreti exceeded 200 on three occasions (May 2001, February 2002 and November 2002).

Red-kneed Dotterel: The IUCN redlist (Birdlife International 2008) estimates a global population of 26,000 Red-kneed Dotterel, and therefore 260 individuals would represent 1% of the global population. DEH (undated) states that the highest species count for Red-kneed Dotterel on the Site between 2000 and 2003 was 277 birds, recorded on Lake Merreti (Harper pers. com. 2003, in DEH undated). The data in Appendix 2.9 show that this was in March 2002.

Red-necked Avocet: The IUCN redlist (Birdlife International 2008) estimates a global population of 110,000 Red-necked Avocet, and therefore 1,100 individuals would represent 1% of the global population.DEH (undated) noted that the highest species count for Red-necked Avocet (*Recurvirostra novaehollandiae*) on the Site between 2000 and 2003 was 3,600 birds, recorded on Lake Merreti (Harper pers. com. 2003, in DEH undated). In the Bird Atlas (Barrett et al., 2003) Red-necked Avocets were only confirmed in every 20th report from the Riverland and were not recorded to breed in the Riverland between 1998 and 2002. However the data provided in Appendix 2.9 displays Red-necked Avocets exceeding 1,100 at Lake Merreti on four occasions between February and May 2002, and again in October 2002. Also, the number of Red-necked Avocets at Lake Woolpolool exceeded 1,600 in January 2002, was over 6,000 in October 2002 and greater than 2,500 in November 2002. In February 2005 the number reached 1000 at Lake Littra.

All three species listed above have been used to support listing under criterion 6, with the recommendation that future monitoring be undertaken to confirm this listing.

Criterion 7 (supporting a significant proportion of indigenous fish taxa, life-history stages, species interactions or populations that are representative of wetland benefits and/or values)

The Site supports 16 species of freshwater native fish species within the Murray-Darling Basin, (Table 2.4). Nine family groups are represented within the 16 species. These fish have adapted to high variability in flow and water quality. This has resulted in the Site’s fish assemblage displaying a high biodisparity and five different reproductive styles.

This information is supported by studies undertaken within the Site. In the Murtho component of the Site (SKM 2005) eight native fish species were found across four sampled sites (Templeton, Weila, Murtho Park and Woolenook Bend). Similarly, surveys of the lakes and creeks on Calperum have recorded twelve species of native fish (Parks Australia 2005) and a survey in the Chowilla region near the time of Ramsar listing of the Site (Lloyd 1990) recorded eight native fish species.

Criterion 8 (supplying an important food source, spawning ground, nursery and/or migration path for fishes, on which fish stocks depend)

Golden Perch (*Macquaria ambigua*) and Silver Perch (*Bidyanus bidyanus*) undertake extensive migrations in fresh water (Reynolds, 1983; Mackay 1990). The Chowilla Anabranch within the Site is a pathway for these fish to migrate around Lock 6, which is a barrier at low-medium flows. Murray Cod and Australian Smelt also migrate through the anabranches undertaking moderate length migrations. All fish need to move around the Site to find mates, food and habitats as well as avoid predators. The Site provides habitat for breeding and a nursery for juvenile stages of Golden Perch (*Macquaria ambigua*) and Silver Perch (*Bidyanus bidyanus)*. Floods in spring and early summer ensure abundant plankton and other organisms as food for young fish (Lloyd 1990, Zampatti 2006b). Significant numbers of larvae of Australian smelt (*Retropinna semoni*) were recorded in the anabranches of the Site by Lloyd (1990), particularly in the slow-flowing anabranches where the slow currents keep the semi-bouyant developing eggs in suspension. The presence of larval and post larval stages is evidence of the Site providing a spawning ground/nursery for this species.

Other species have also been captured as larvae within the Site's waterways, including: Flatheaded Gudgeon (*Philypnodon grandiceps*); Carp gudgeon (*Hypseleotris* spp.); Bony Herring (*Nematalosa erebi*); Unspecked Hardyhead (*Craterocephalus stercusmuscarum fulvus*, a subspecies of the Flyspecked Hardyhead); Golden Perch (*Macquaria ambigua*); Murray Cod (*Maccullochella peelii peelii*) and Crimson-spotted Rainbowfish (*Melanotaenia fluviatilis*) (Zampatti 2006b).

Table 2.4: Native fish species found within the Riverland Ramsar Site (Lloyd 1990; Pierce 1990; Harper 2003; Zampatti et al. 2006a & 2006b; RIS in prep.)

Family	Species	Common Name	Reproductive Guild*
Clupeidae	*Nematalosa erebi*	Bony Herring	D2
Retropinnidae	*Retropinna semoni*	Australian Smelt	A
Plotosidae	*Tandanus tandanus*	Freshwater Catfish[E]	C2
Melanotaeniidae	*Melanotaenia fluviatilis*	Crimson-spotted Rainbowfish	A
Atherinidae	*Craterocephalus fluviatilis*	Murray Hardyhead[E*]	A
	Craterocephalus stercusmuscarum fulvus	Flyspecked Hardyhead[V]	A
Percichthyidae	*Maccullochella peelii peelii*	Murray Cod[V*]	C2
	Maccullochella macquariensis#	Trout Cod[E]	C2
	Macquaria ambigua	Golden Perch	D1
Teraponidae	*Bidyanus bidyanus*	Silver Perch[E]	D1
Kuhliidae	*Nannoperca australis#*	Southern Pigmy Perch[E]	B
Eleotridae	*Hypseleotris klunzingeri^*	Western Carp Gudgeon	C2
	Hypseleotris sp. A^	Midgley's Carp Gudgeon	C2
	Hypseleotris sp. B^	Lake's Carp Gudgeon	C2
	Philypnodon grandiceps	Flathead Gudgeon	C2
	Philypnodon sp. 2	Dwarf Flathead Gudgeon	C2

#Not recorded in recent surveys
^Regarded as a species complex with species A and B not formally described
[E]Regarded as endangered in SA (Hammer et al. 2007)
[V] Regarded as vulnerable in SA (Hammer et al. 2007)
[*] Listed under the EPBC Act
*according to Growns (2004):

Guild	Definition
A	Adhesive, demersal eggs with no parental care
B	Low fecundity, small non-adhesive demersal eggs with short incubation times
C2	Show parental care, including nest building and protection of young with species not generally undergo a spawning migration and typically have large eggs
D1	Single spawning species with high fecundity, non-adhesive eggs with no parental care with species undergoing a spawning migration
D2	Single spawning species with high fecundity, non-adhesive eggs with no parental care and display no spawning migration

2.5 Land Use and Tenure

Land uses, managers and areas at the Site are displayed in Table 2.5. Most land (27,213 ha) is allocated to biodiversity conservation under Australian, State and Local Government or private ownership. Stock grazing, predominantly by sheep, is the next largest land use, allocated 3,370 ha.

The Site supports a significant tourism industry that relies on the Site's inherent values. Tourism operators supply houseboat hire, nature-based boat and vehicle tours, pastoral industry tours and on-site accommodation. Recreational pursuits are centered on fishing, pleasure craft boating, bush camping, canoeing, waterfowl hunting, water-skiing and driving tours.

A few commercial fishers have been issued licenses to take Bony Herring (*Nematalosa erebi)* (a common native fish), European Carp (an exotic species) and other non-native species from the backwaters of the River Murray in South Australia using gill nets. A number of sites within the Site are available for commercial harvesting of these species.

Approximately 70 domestic or irrigation pumps take water from the River Murray channel, backwaters or anabranch creeks within the Riverland. Two small irrigation-based enterprises, a vineyard (32 ha) and an irrigated pasture (37 ha) exist within the Site.

Over the last 20 years extensive research and monitoring have been undertaken throughout the Site. Efforts have focused on ecosystem and threatening processes and the interactions of management (e.g. O'Malley and Sheldon 1990; Sharley and Huggan 1995; Overton et al. 2005).

Areas of land outside the Site are supplied irrigation water by pumps located in the Site. These include the Cooltong/Chaffey Irrigation Area (1,118 ha), private diversions from Ral Ral Anabranch and the Paringa/Murtho area (4,000 ha). The dominant horticultural enterprises involve vines and orchards with small areas of vegetables and sown pastures. Dryland farming also occurs to the south of the Site and involves cereal grain crops, pastures for hay and livestock. North of the Site is the Chowilla Regional Reserve, owned by the SA Department for Environment and Heritage, and the continuation of Calperum Station, a pastoral lease owned and managed by the Australian Government for biodiversity outcomes. Privately owned or local government (Renmark-Paringa District Council) land adjoins the remainder of the Site.

Table 2.5: Land uses, land managers and land areas in the Riverland Ramsar Site.

Land Use	**Land Owner/manager**	**Area (ha)**
Murtho Forest Reserve	Primary Industries and Resources SA, South Australian Government	1,709
River Murray National Park (Bulyong Island section)	Department for Environment and Heritage, South Australian Government	2,382
Chowilla Game Reserve (part)	Department for Environment and Heritage, South Australian Government (leased to Robertson-Chowilla Pty Ltd)	14,916
Calperum Station (part)	South Australian Government Pastoral Lease – invested in Director National Parks, Australian Government DEWHA	8,500
Crown land	South Australian Government - vested in the Minister for Environment and Conservation, River Murray channel, including the 150 link (30.18 metre) wide reserve for public use along the majority of the River's southern bank that became the practice to retain after 1898	793
Local Government	District Council of Renmark-Paringa	9
Privately owned	Companies, partnerships or individual owners	2,306
TOTAL		30,615

3. ECOLOGICAL CHARACTER OF THE RIVERLAND RAMSAR SITE

This chapter describes the components, processes and benefits/services of the Site and the linkages between them. Conceptual models of the ecosystem are then presented, followed by the limits of acceptable change to the key components, processes and benefits/services of the Site.

3.1 General Description

A representation of key components and processes occurring at the Site is displayed in Figure 3.1. The Riverland Ramsar Site is in a generally dry environment. Most of the water that fills the creeks and wetlands comes from remote catchments of the River Murray and its tributaries. The nature of the water regime — the magnitude, frequency, duration and seasonality of flows in the river, and the rate of rise and fall of the hydrograph — governs the ecological character of the wetland complex (see Section 3.5).

Another facet of the Site's water regime is water retention. This is affected by flows in the River Murray, and by local landforms (geomorphology), including localised depressions; abandoned channels and billabongs; linking channels; levees; larger deflation basins; and topography and elevation of the floodplain.

These geomorphic features also affect the components, processes and benefits and services of the Site. Water delivery will influence the geomorphic attributes of the Site, and conversely these will influence water delivery (e.g. rates, courses, and pooling). The vegetation and habitats are influenced by the hydrology and the geomorphology of the Site, with vegetation bands often delineating flooding regimes and the flooding regimes being products of topography and elevation.

Figure 3.1 displays several components and processes of the Site including climate, soils, vegetation, fauna, and water quality, all of which contribute to the ecological character of the Site. The principal component and process that drives the Site and system, however, is hydrology. This includes the surface water and groundwater regime. The range of components and processes is explored in following sections. Section 3.5 brings these elements together as conceptual models.

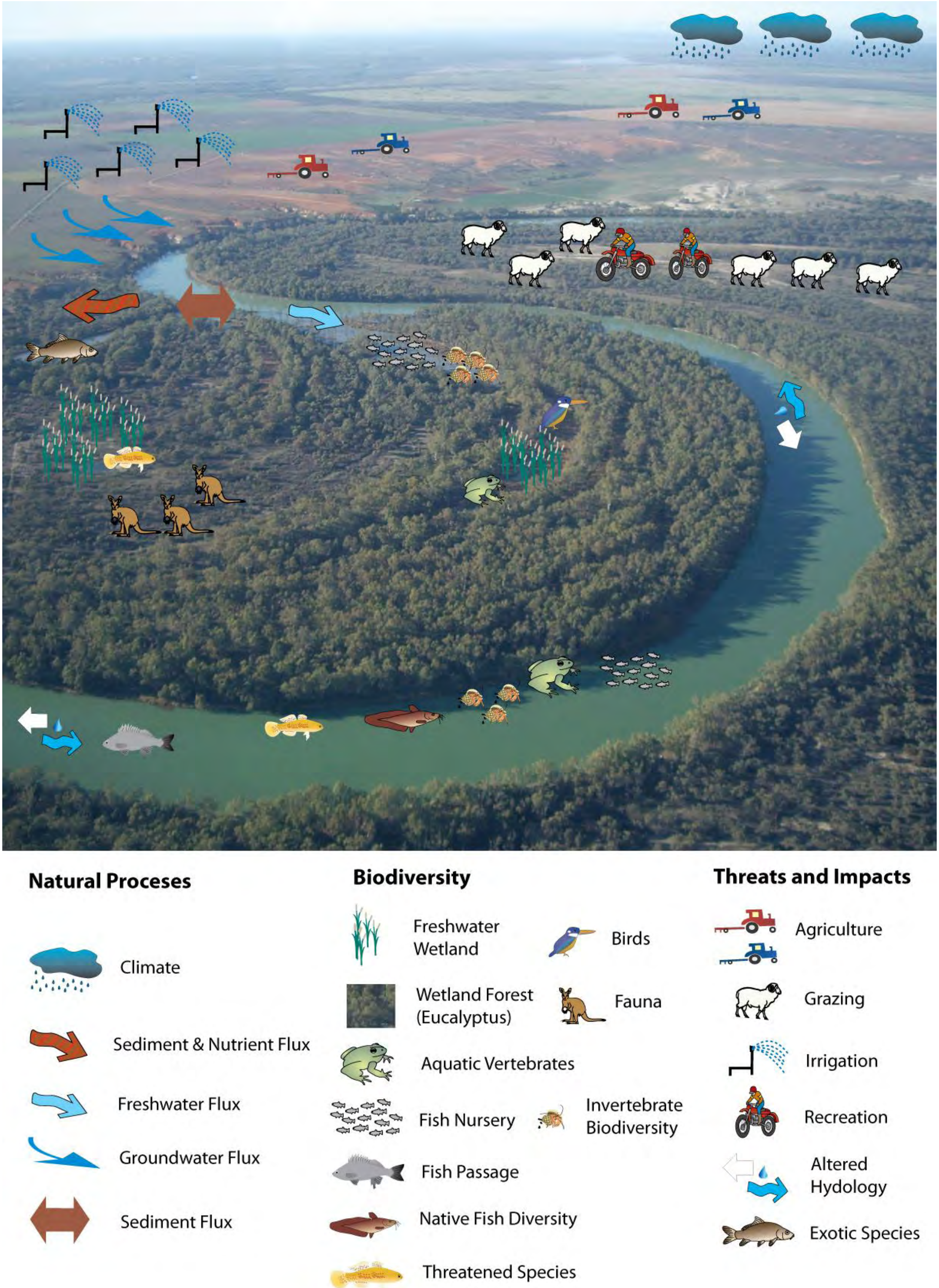


Figure 3.1: Riverland Ramsar Landscape showing components and processes

3.2 Components of the Site

The major components of the Site include:

- Climate;
- Geomorphology;
- Soils;
- Hydrology;
- Water quality;
- Vegetation & Habitat; and,
- Fauna.

Each component is discussed below.

3.2.1 Climate

The Riverland experiences features of a Mediterranean climate (temperate rainy climate with cool winters and dry, warm-to-hot summers) and also a dry subtropical climate (Steppe, climate hot) (Strahler and Strahler 1992). The Site is within the southern extension of Australia's central arid zone and temperatures can vary significantly diurnally and seasonally. At nearby Renmark (1 km from the southern Site boundary), the average summer temperature minima and maxima are 16°C and 31.6°C, respectively. In winter, the range is 5.5°C to 17°C.

Regional rainfall averages 260.5 mm per annum (data for Renmark, 1889-2002), with a poorly-defined peak in winter-spring (Figure 3.2). Annual evaporation is 1960 mm (RIS in prep.).

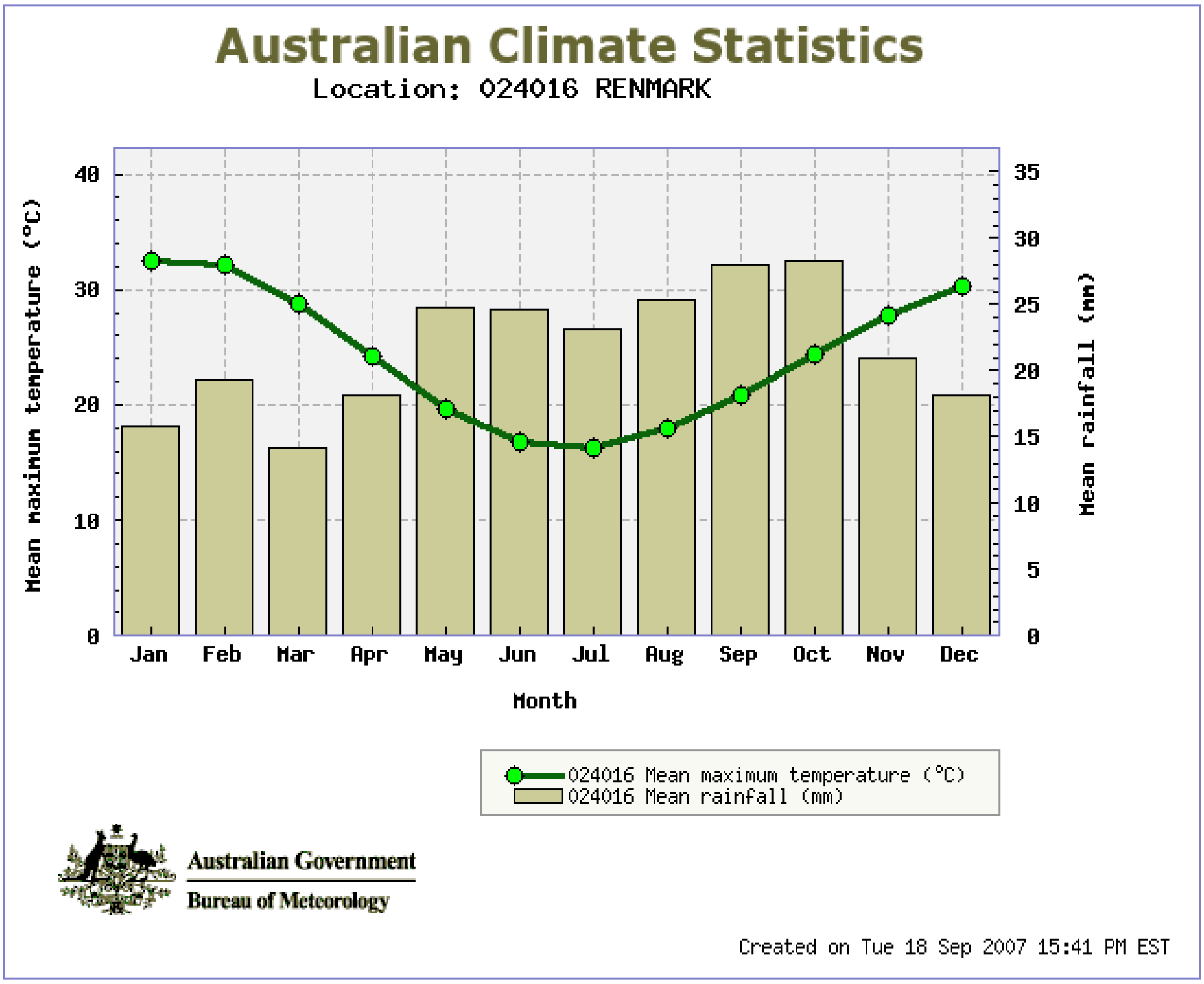


Figure 3.2: Climograph for Renmark, 1957-2007 (Temperature) and 1889-2002 (Rainfall). Source :
http ://www.bom.gov.au/climate/averages/tables/cw_024016.shtml

Rainfall is highly variable, with recorded annual extremes of 89.5 mm and 517.0 mm. The 10th and 90th percentiles for rainfall for each month are displayed in Figure 3.3. Drought occurs frequently, but there is no clear pattern in occurrence of wet and dry years (RIS in prep.). Historically, ENSO (El Niño) has an approximate 5-year return period. In general the River Murray crosses longitudes and is less susceptible to ENSO than the Darling River, which crosses latitudes. The River Murray's contribution is roughly 90 percent of the total, and it is more reliable than that of the Darling. The late 1980s (i.e. prior to and during the Site's listing) was a dry period and most of the water in the Lower River Murray was from the Darling River, stored in Lake Victoria for release during the irrigation season.

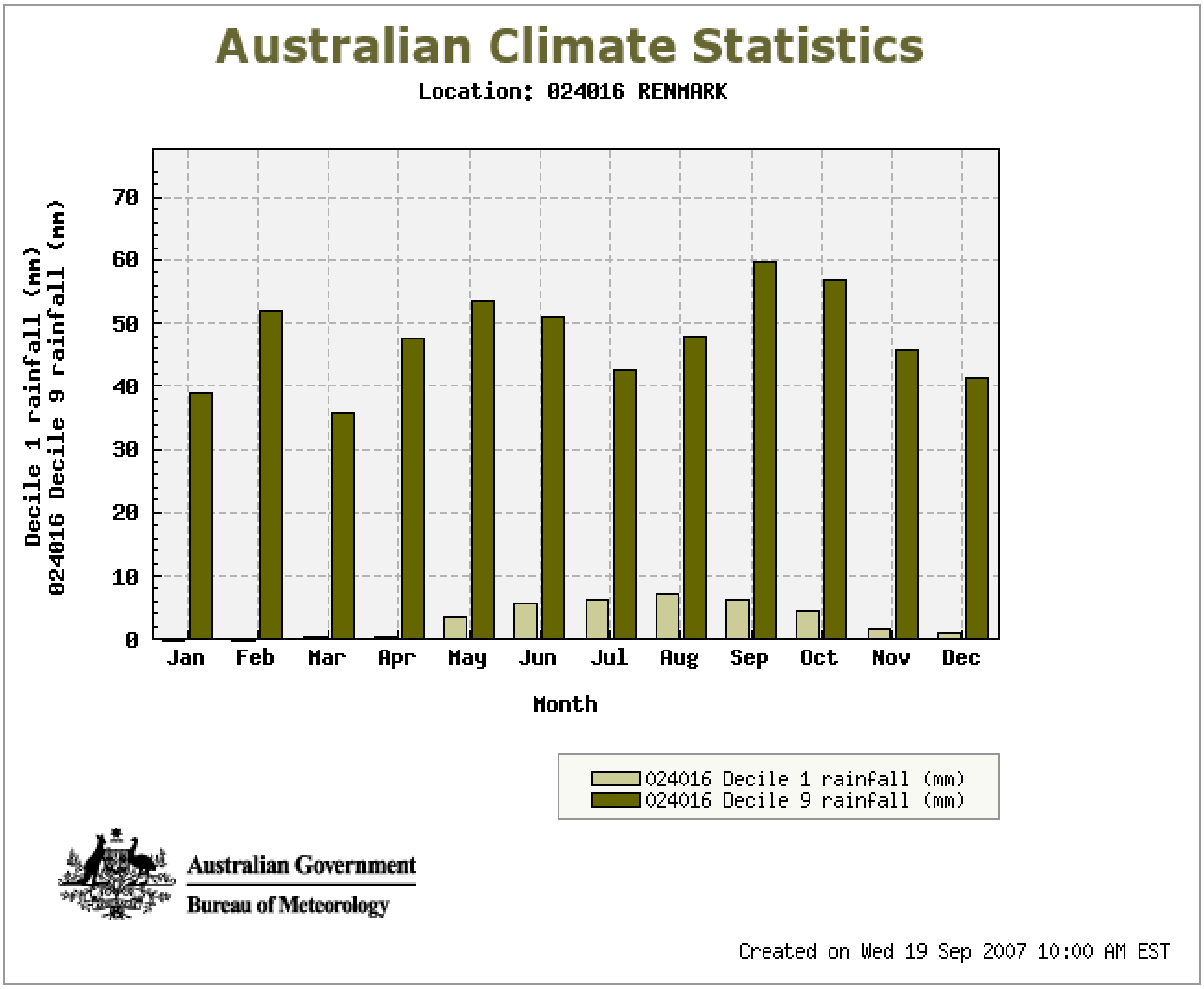


Figure 3.3: Graph of 10th percentile (Decile 1) and 90th percentile (Decile 9) for Renmark, 1889 – 2002. Source :
http ://www.bom.gov.au/climate/averages/tables/cw_024016.shtml

In the context of this ECD, the key features of climate are floods and droughts and the future impacts of climate change. Although climate change was not recognized as an issue at the time of listing (1987), it clearly warrants consideration in the following sections describing changes and threats to the Site.

3.2.2 Geomorphology

In this section, geomorphology is treated as a component (i.e. in terms of landforms) rather than a process, although both roles apply. Through differential retention of water and variations in depth, surface area and elevation, local landforms are responsible for the mosaic of habitats at the Site. They also influence the dynamics of wetting and drying phases.

This section describes wetland habitat types based on geomorphology whereas the Ramsar Convention uses wetland types that are defined by water regime, salinity and vegetation cover and a description of these wetland types is found in section 2.4.

There are six major landform-based habitat types at Chowilla (Sheldon & Lloyd 1990):

1. River channel:	Large, wide channels of the River Murray
2. Anabranches:	Much narrower channels with a variety of flow regimes, usually remaining connected to the main channel
3. Backwaters:	Waterbodies connected to the main channel at normal pool level
4. Billabongs:	Mostly still, isolated water bodies connected to the main channel only at times of flood
5. Swamps:	Wetland areas with shallow basins and little free water but highly saturated soils
6. Floodplain:	"Terrestrial" areas subject to occasional flooding episodes and free draining, retaining water during flood

The River Murray channel (Plate 3.1) attains depths of 5-6 metres and is wide in this stretch of the river, confined on one side by cliffs and spilling over into the floodplain on the other as it meanders across the floodplain. The waters of the main channel are characteristically turbid but well oxygenated. The river has a variety of habitat types with different substrate types (sand and clay), woody debris, deep pools and vegetated margins.

Plate 3.1: River Murray Channel (Wetland Type M) Overlooking Cliffs (Lance Lloyd, June 2007)

Anabranches (Plate 3.2) have variable depths, depending on flow in the main channel, and provide a variety of habitat types. The faster-flowing anabranches have narrow channels and are prime habitat for riverine species including Murray Cod, Murray Crayfish and River Mussels. In contrast, the slower-flowing anabranches are much wider, providing shallow, warm and slow-to-still water habitats that encourage large invertebrate and plant populations.

Anabranches have been identified as a unique habitat on the River Murray floodplain (Sheldon & Lloyd 1990, Lloyd 1990, Lloyd and Boulton 1990, Boulton and Lloyd 1991, Whiterod et al. 2004, McCarthy 2005). Anabranches are known to have specific water requirements based on the requirements of a suite of distinctive flora and fauna which depend upon these habitats. Both fast and slow flowing anabranches are present within the Riverland Ramsar Site.

Permanently flowing water provides an essential habitat component for a number of River Murray fauna. Prior to the construction of the weirs, flowing water habitat was available in both the river and the anabranches, but now only occurs in some anabranch sections. The fast flowing anabranches are generally deeply incised and subject to rapid changes in level according to river flow. They are therefore lined by a narrow zone of emergent plants. Groundwater discharge from the creeks contributes to relatively shallow and low-salinity groundwater beneath the adjacent floodplain, which promotes the growth of trees in the fringing Redgum woodland.

Fast Anabranches represent a contrasting flowing, relatively well-oxygenated aquatic habitat to the River Murray and to floodplain wetlands. The flow of water also reduces the potential for high water temperatures which can occur in shallow standing water in wetlands. Anabranches provide potential habitat for the locally extinct River Murray Crayfish (*Euastacus armatus*) which grazes on epiphytes and other organic debris and preys on aquatic invertebrates. Deep holes in the main channel and larger anabranches which have cooler water provide habitat for Murray Cod. Other species which are favoured by flowing water include the River Snail (*Notopala hanleyi*), the Freshwater Shrimp (*Macrobrachium australiense*) and River Mussel (*Alathyria jacksoni*).

Slow flowing anabranches are generally wider and shallower than fast flowing anabranches and they also tend to become dry at low river levels (Plate 3.3). These anabranches provide relatively shallow, warm and still habitat for the establishment of large aquatic invertebrate and plant communities.

Anabranches provide passage for fish between river reaches (and around locks and other barriers) and are particularly important for the migratory species Silver Perch, Golden Perch and, to some extent, Murray Cod. Flowing water provides an important breeding habitat for Australian Smelt.

Plate 3.2: Pipeclay Creek – a fast flowing anabranch of the River Murray in the Riverland Ramsar Site (Wetland Type M) (Lance Lloyd, June 2007)

Plate 3.3: A slow-flowing anabranch in the Riverland Ramsar Site during a dry phase (Wetland Type N) (Lance Lloyd, June 2007)

Backwaters (Plate 3.4) are less common, with variable depth and generally slow flow and a permanent or semi-permanent connection to the main channel (Sheldon and Lloyd, 1990). Where conditions allow, backwaters may thermally stratify, forming a cool, saline, hypoxic (oxygen deficient) bottom layer (hypolimnion).

Plate 3.4: River Murray Backwater (Wetland Type Tp) (Photo: Lance Lloyd, June 2007)

Billabongs (oxbows; Plate 3.5) are more common locally than elsewhere along the River Murray in South Australia. Disconnection from the main channel often causes billabongs to dry, allowing herbaceous vegetation to grow on the nutrient-rich sediment. This provides food for aquatic animals following inundation (Sheldon and Lloyd, 1990).

Plate 3.5: Pilby Creek Wetland, a River Murray Billabong (Wetland Type O) (Photo: Anne Jensen)

The shallow waters and gently-sloping banks of billabongs provide a habitat for aquatic macrophytes, which in turn harbour many forms of aquatic and terrestrial fauna. Water quality varies with the frequency of inundation, period of time since inundation and the extent of macrophyte growth and decay. The dry phase can be greatly extended as a result of river regulation, where flooding frequency is reduced. This is discussed in the sections on hydrology and threats.

Calperum contains a similar suite of landforms to the Chowilla block, with its most readily identified landforms being the 5 major wetland depressions - Lake Merreti, Lake Woolpolool, Clover Lake, Woolpolool Swamp and Rotten Lake - and the Ral Ral anabranch system. The five wetland depressions encompass an area of approximately 1,100 ha (Rotten Lake is not within the Site), with approximately 3,200 ha of floodplain directly associated with the depressions (Parks Australia 2005).

The landforms of the **Murtho** block contain a lower percentage of the drier floodplain areas and a relatively larger proportion of lentic channel forms, active channels, backwaters and miscellaneous floodplain depressions.

3.2.3 Soils

Soil type varies across the Site, but grey self-mulching cracking clays, brown siliceous sands and firm grey siliceous sands are dominant at the Site (Laut et al. 1977). Elevated areas typically have the sandy soils, often associated with stands of Murray Pine, *Callitris preisii*.

The Atlas of South Australia (www.atlas.sa.gov.au/go/resources/atlas-of-south-australia-1986/environment-resources/soils) identified two broad soil groups within the Site: self-mulching cracking clays; and crusty red duplex soils. The website provides the following general descriptions of the soil types:

> **Self-mulching cracking clays** occur on the alluvium of the River Murray valley. They typically have uniform fine-textured profiles with significant cracks when dry, although the cracks are not always apparent at the surface. Most of the clays are moderately fertile in their natural state. In the higher rainfall areas these soils support cereals and improved pastures. In the interior, the natural pastures on the clay soil floodplains provided fodder for the flocks of the early pastoralists.
>
> **Crusty red duplex soils** occur in arid regions, usually on tablelands and stony plains, and are often associated with red cracking clays in saucer-like depressions. A surface pavement of gravels is often partly embedded in the loamy brown surface soil. There is an abrupt boundary to the red clay subsoil. Through overgrazing, large areas have lost the sparse shrubland that once provided grazing for sheep and cattle, although ephemeral herbs may provide excellent feed following heavy rains.

Soil descriptions for the Murtho block (SKM 2005) and the Calperum block (Parks Australia 2005) indicate that the soil profiles of the site broadly consist of inter-bedded layers of sand and clay with some silt content at the surface. In general the profiles showed soils with higher clay content underlain by sandy soils.

3.2.4 Hydrology

Hydrology is simultaneously a component and a process. It governs the seasonality, magnitude, frequency, duration and rate of water delivery, and many biotic responses that include seed germination (including species favoured by the hydrologic regime), triggers for breeding (birds, fish, frogs), breeding success and provision of food. The season of delivery, period of inundation for ephemeral wetlands (or water level rises for permanent wetlands), fluctuations in water level and inter-annual flow variations all are influential.

The inundation levels at the Site are shown in Figure 3.4. These levels show the significant flow bands across the site as predicted by the Floodplain Inundation Model (FIM; Overton et al. 2006b).

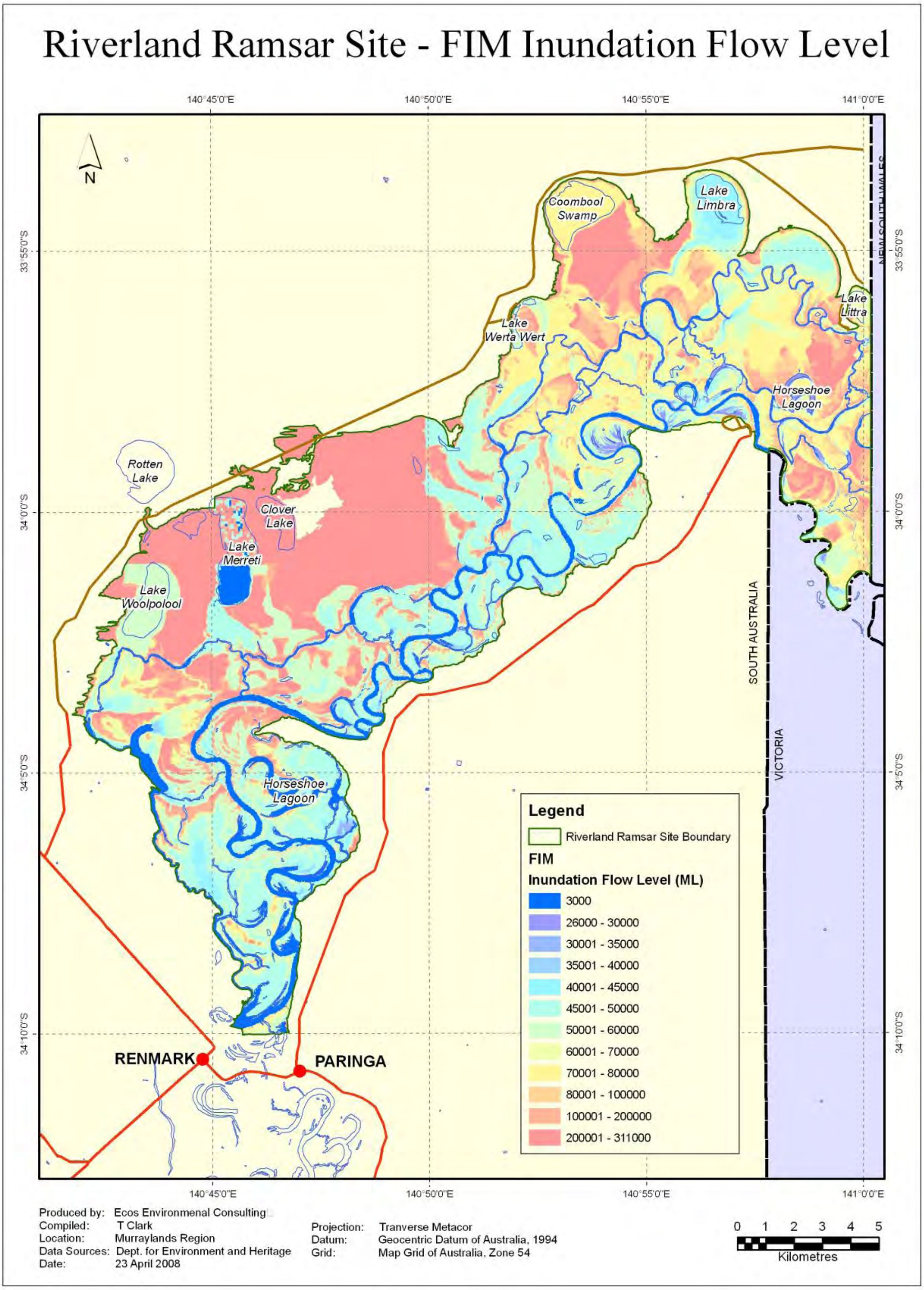


Figure 3.4: Inundation levels at the Site as predicted by the Floodplain Inundation Model (FIM; Overton et al. 2006b).

The hydrological regime is dominated by regulation of the River Murray. The impacts of regulation were evident in 1987. The River Murray's annual hydrograph (1922-2006) shows a high degree of inter-annual variability, typical of rivers in dry regions throughout the world (Figure 3.5).

An understanding of the post regulation hydrology is assisted by consideration of the pre-regulation hydrology. Prior to regulation, the River Murray experienced seasons with highly variable flows. Although there was marked variation between years, in spring and early summer the River Murray was generally high, cool, turbid and fast flowing. Towards the end of summer, flows in the River Murray gradually changed to become low, warm, clear and slow moving (MDBC 1991). During times of droughts, the flow would cease completely and the river would contract to saline pools fed by saline groundwater from the Pliocene Sands aquifer incised in the Coonambidgal and Monoman Formations (Sharley & Huggan 1995).

The demand for water from the Murray-Darling Basin has increased steadily since 1922 (when the first weir was built on the river in South Australia). The trend was interrupted in 1974-75, when there was a major flood, and again from the late 1990s to the present, when there has been a significant decline in rainfall, hence streamflow.

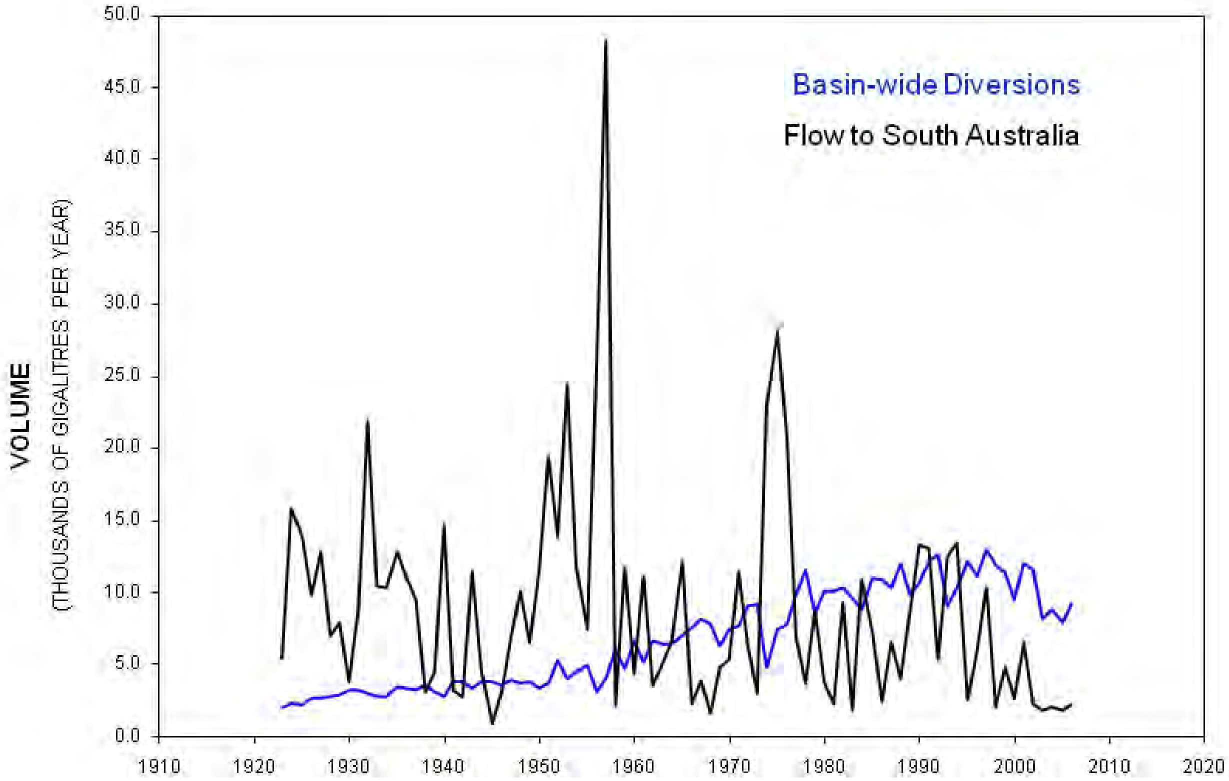


Figure 3.5: River Murray Hydrology 1922 to 2006 (Source: Murray Darling Basin Commission Flow database).

There is some hydrological persistence in the hydrograph, in that wet and dry years often occur in sequences. For example, the decade of the 1940s was very dry, and the 1950s was very wet.

This is partly related to ENSO (El Niño has a 5-year return interval), and depends somewhat on the inflow from the Darling. The River Murray crosses 13 degrees of longitude; its headwaters are in areas dominated by winter-spring rainfall, and it is less affected by ENSO. The Darling crosses 13 degrees of latitude; its headwaters are in areas where peak flows are from erratic summer monsoonal systems, and it is more affected by ENSO.

The degree of variability means that the background variation in the hydrograph is difficult to predict, and difficult to describe statistically. In statistical terms, it could take many years to detect statistically significant trends in annual flow (and other hydrological parameters). The problem is difficult enough when the baseline (the regional climate) is stable, but this is not so for the River Murray—long-term shifts in rainfall mean that it is of dubious value to compare long-term averages. This is strikingly shown in the hydrograph. The downturn in streamflow over the last 10-15 years has few if any historical precedents, and its impact has been intensified by the high level of demand for water.

In historical terms, the flood of 1974-75 is regarded as a 1 in 10 year event, but no comparable flood has occurred now for nearly 30 years. The hydrological changes imposed by regulation at the Site affect the smaller floods to a greater degree than larger ones. Regulation has significantly changed the frequency distributions of small to moderate sized floods, particularly over-bank flows.

The local anabranches formerly flowed only during floods (MDBC 2006) or high flows. The extent of floodplain inundation, hence the refilling of disconnected wetlands, was determined by flood magnitude, proximity to the river channel and local topography.

The infrastructure that has altered the hydrology of the Site includes dams in upstream catchments, Locks 5-6 on the River Murray channel, weirs and banks across the anabranches and hydrological structures on wetland sites. Lock 6 is downstream of the Chowilla anabranch inlet and 8 km upstream of the anabranch outlet. It has raised the river level by 3 m, banking water up into the anabranch system. Several banks and weirs on the anabranches restrict the volume of water that can by-pass Lock 6.

Lock 5 is downstream of the Ral Ral anabranch outlet (Figure 2.4) and, like Lock 6, raises the river level by 3 m, backing water into the anabranch system. The elevated water levels enhance water extraction and navigation of the main channel and also minimise saline inflows from the banks and wetlands directly connected to the River (RIS in prep.).

The ecological impacts of regulation include:

- permanent inundation of some ephemeral wetlands, hence loss of a summer drying phase;
- loss of in-stream habitat diversity necessary to maintain biological diversity;
- loss of flow dependent native fauna – for example, river mussels, Murray Crayfish and river snails;
- reduced range of bank habitats;
- reduced exchange of organic material, carbon, nutrients and sediment between floodplain and river;
- barriers to fish passage;
- declines in native fish abundance –floods promote reproduction in most native species, but stable flows may favour alien species, notably European Carp;
- reduced diversity and biomass of invertebrates in annually-flooded areas;
- reduced recharge of local groundwater ('freshwater lens') in semi-permanent wetlands, leaving insufficient water for trees;
- reduced diversity of waterbirds and terrestrial native fauna;
- degradation of natural low-flow channel;
- thermal stratification creating hypoxic bottom water and favouring blue-green algae;
- raised saline groundwater levels into the root zone of floodplain vegetation, causing dieback and soil scalding; and,
- natural ecological processes disrupted by unnatural constant flow for sustained periods, unseasonable flow and increased minimum flow (MDBC 2006).

The impacts of flow regulation from upstream in the River Murray system are most evident through the reduction in the moderate sized overbank flow events that covered large portions of the Site. Table 3.1 compares flood frequency data for pre- and post-regulation conditions at the Site. It shows that the effect of flow regulation and diversions on the floodplain has been to reduce flood frequency for all flood volumes displayed. For example, under natural conditions, a flood of 80,000 ML/day (covering nearly 50% of the floodplain) happened almost every 2 years (45 years out of 100) for an average period of 3.2 months. Under regulation, it occurs once every eight years for an average 2.6 months (MDBC 2006).

Table 3.1: Flooding extent, frequency, and duration under natural and regulated conditions at the Site (Source: Sharley and Huggan 1995).

River Murray flow (ML/day)	Area inundated (ha)	% Area of Chowilla floodplain inundated	Return period (Number of times peak flows occur in 100 years)		Duration (Number of months flow is exceeded)	
			Natural	Regulated	Natural	Regulated
5,000	-	-	100	100	11.4	9.5
10,000	-	-	100	94	10.1	4.6
20,000	-	-	99	63	7.8	4.6
40,000	1,400	8.0	91	40	4.9	3.3
50,000	2,200	12.4	79	30	3.9	2.7
60,000	4,000	22.6	59	21	3.9	2.5
70,000	5,600	37.6	49	15	3.6	2.9
80,000	8,200	46.3	45	12	3.2	2.6
90,000	11,100	62.7	37	11	3.1	2.1
100,000	13,200	74.6	32	9	2.9	2.0
140,000	16,800	94.9	14	4	2.1	2.5
200,000	17,700	100	3	1	2.0	2.0
300,000	17,700	100	1	0	2.0	-

Groundwater also is a critical aspect of the Site's hydrology. Prior to flow regulation, the main channel of the River Murray intercepted and drained regional saline groundwater at the Site, with the groundwater flowing under the anabranches. This left the anabranches dry between floods (MDBC 1991).

Post-regulation, the increased elevation of the water surface created by Lock 6 has resulted in the anabranches being filled by the impounded water and has also created a back-pressure on the adjacent groundwater, with it subsequently flowing into the now inundated anabranches. This saline groundwater now reaches the River Murray downstream of Lock 6, via the anabranch system (MDBC 1991).

The back pressure on the groundwater is also leading to rising water tables on the floodplain creating salinity stress for the tree cover. Overton et al. (2006) have reported severe declines in tree health on the floodplains of the Site, and have found the primary cause to be salinisation of the floodplain soils caused by increased groundwater discharge and hence increased movement of salt up into the plant root zone. The reduced frequency and duration of medium-sized floods adds to the pressure created on the groundwater through the elevation of the surface water. Under natural conditions, the medium-sized floods leach salt from the plant root zone and supply fresh water for transpiration. The marked reduction in these floods further exacerbates the salinity stress on the floodplain vegetation.

Areas where the groundwater has been flushed have low salinity groundwater that supports a healthy tree cover, whereas the remaining areas have a raised water table with high salinities which creates a stressed tree cover.

In a hydrogeological benchmark assessment for salt accessions to the River Murray between Wentworth and Renmark, REM (2003) assigned the Chowilla floodplain and the Murtho irrigation area as first and second priority 'hotspots' respectively, for management intervention and monitoring. The hot-spots were rated using semi-quantitative criteria based on current and future impacts, and the capacity to be able to manage the problem. Chowilla achieved the highest ranking primarily due to high (measured) salt accession to the River. Murtho received second ranking based on the potential for future salt accessions to become high.

Within Chowilla, the key process for the discharge of salt during low to medium river flow was identified as direct groundwater discharge (REM 2003). During higher river flows (when over-bank flow occurs), salt is discharged from the floodplain sediments by:

- flushing of stagnant pools of saline water;
- wash-off of salt from the floodplain surface; and/or,
- flood water recharging the floodplain aquifer and creating a groundwater pressure gradient back to the River channel. This is a major process influencing the discharge of salt from anabranch systems found in Chowilla.

Within Murtho, the presence of small groundwater mounds in the region has accelerated discharge of salt to the River and floodplain by displacing naturally saline groundwater (at 10,000 to 30,000 mg/L) from the Channel Sands aquifer to the River. Modelling has indicated that, within 50 to 100 years, the groundwater mounds could increase salt accessions to the River by more than three times the current load of 30 T/day. Much of this increase is due to historic irrigation that was less efficient than current operations (REM 2003).

Discussing limitations of the data, REM (2003) state that their findings should be considered as preliminary only and strongly recommend additional sampling for verification. However, they did note that indicators of salinity (e.g. samphire growth, salt scalding and groundwater seepage) were high in four of their delineated sub-regions, three of which (Murtho, Ral Ral, and Chowilla) are located within the Site. Sub-regions that showed greater evidence of salinity also showed higher levels of tree stress, with highly affected sub-regions showing tree stress levels often above 70 percent (REM 2003).

3.2.5 Water Quality

The main issues with water quality at the Site are turbidity, eutrophication and salinity. A water quality report published by the Murray-Darling Basin Commission in 1988 provides information on a range of water quality indicators relevant to the Site in the decade immediately before its Ramsar designation.

Turbidity in this reach of the River Murray is dominated by the effects of the Darling River, which carries large quantities of fine clays (mean particle diameter 2 µm) (Mackay 1988). Turbidity monitoring in the River Murray in 1978-1986 showed a doubling of turbidity above and below the Darling River confluence (median 23 NTU at Merbein; 46 NTU at Lock 9), with the Darling River at the confluence having a median 76 NTU (Mackay 1988). At Lock 5, near the Riverland Ramsar Site, the median turbidity over the 9-year sampling period was even higher than Lock 9, at 65 NTU, probably reflecting inputs from Lake Victoria, which at that time was used to store water from the Darling River. Water quality is highly variable in space and time and is affected by flow conditions. However, the increased turbidity values downstream of the Darling confluence were a consistent feature of the monitoring results. Some of the suspended clay settles during periods of low flow, and this may be increased by flocculation caused by high salinity.

Nutrients were also typically high in the River Murray downstream of the Darling confluence, with median total phosphorus concentrations increasing from 0.068 mgL^{-1} at Merbein, to 0.112 mgL^{-1} at Lock 9 over the sampling period. The median total phosphorus concentration at the Darling River site over the sampling period was very high at 0.310 mgL^{-1}. Similar to turbidity results, the median total phosphorus concentration showed further increases from Lock 9, reaching 0.129 mgL^{-1} at Lock 5 (Mackay 1988). A similar pattern was observed for filterable reactive phosphorus (0.010 mgL^{-1} at Merbein; 0.024 mgL^{-1} at Lock 9; 0.175 mgL^{-1} in the Darling River; and 0.027 mgL^{-1} at Lock 5).

High nutrient concentrations in the River Murray within this reach typically do not result in high phytoplankton biomass (algal blooms) due to the light reduction caused by the high turbidity. However, the potential for algal blooms remains high, and can occur when flows are low enough to allow a settling of the fine clays (Mackay 1988). An aspect of the typically high turbidity is that it favours blue-green algal species that can regulate their own buoyancy and therefore remain near the water surface. Therefore, when flows diminish and turbidity reduces, these species are available to take advantage of the improved light environment and high nutrient concentrations, and flourish, causing algal blooms. Blue-green algae (Cyanoprokaryotes) include some species which are toxic to humans, mammals and fish.

Median salinity in the reach of the River Murray at Lock 5 between 1978 and 1986 was 494 EC (Electrical Conductivity units at 25°: EC-25) (Mackay 1988). Within the South Australian section of the River Murray, much of the natural groundwater flow is towards the River and has been increased by:

- vegetation clearance (increasing accessions);
- irrigation causing groundwater mounding; and,
- groundwater displacement by weirs.

These changes have increased the accession of salt to the River.

There is a strong relationship between river flow and many measures of water quality, including salinity. In simple terms, the relationship between flow and salinity is an inverse one (i.e. increased flows result in lower salinities – although a flood after a dry spell may cause a sharp temporary increase in river salinity).

Prior to regulation the River Murray would cease to flow during droughts and salinity in the remnant pools could rise to 10,000 EC within the South Australian reaches. The effect of regulation has been to maintain flows through the drier periods, and as a result, river salinities rarely reached 1,500 EC during the sampling period, even during droughts (Mackay 1988). Although this simple inverse relationship is generally correct, the situation is more complex in practice, and salinity reduction measures such as dilution flows and revised water allocations require computer modelling for management of flows and salinity.

In a study of water quality of eight River Murray floodplain wetlands in South Australia (Suter et al. 1993) three wetlands within the Riverland site were sampled between May 1990 and February 1992. The three wetlands were Clover Lake, Lake Merreti and Lake Woolpolool. Salinity and its variability ranged between the wetlands. Total dissolved solids (TDS) in Clover Lake ranged from 3,210 mg/L at the end of a long drying phase, down to 334 mg/L one month later when floodwaters replenished water in the system. In contrast, Lake Merreti displayed a much smaller range, from a high of 532 mg/L down to 207 mg/L. Lake Woolpolool recorded the highest salinity reading for the entire study, 44,000 mg/L, after a comparatively low reading of 1,710 mg/L a few months earlier, giving it a seasonal fluctuation of 2,470% (Suter et al. 1993). Clover Lake and Lake Merreti both displayed a comparatively uniform salinity across the water bodies during each sampling event, whereas Lake Woolpolool was noted as displaying a distinct difference between the northern and southern sections due to more regular inputs of freshwater from Ral Ral Creek at the southern end of the lake.

Turbidity was highly variable in the three lakes, with each ranging an order of magnitude from maximum to minimum readings. Lake Merreti recorded the highest mean turbidity during the study (210 NTU), Lake Woolpolool the lowest of the three (40 NTU) and Clover Lake had a mean of 110 NTU (Suter et al. 1993). The authors noted that turbidity readings were generally influenced by salinity, with high salinities (exceeding 3,000 mg/L) reducing turbidity.

The above section on water quality focuses on the Site at the time of Ramsar listing. In the last decade, major reductions in rainfall across the Murray Darling Basin have led to diminished flow in the River Murray. If this weather pattern persists, water quality at the Site will alter. The effects are likely to include increased salinities and increased algal blooms.

3.2.6 Vegetation and Habitat

Vegetation is a key component of the Site, contributing substantially to its ecological character and providing the habitat and landscape that form the basis of the Site's ecological services.

Vegetation of the Site encompasses a diversity of terrestrial and aquatic plant communities, from stands of *Callitris* pines on raised dunes to permanent wetlands. The vegetation has been surveyed on several occasions (e.g. O'Malley 1990, Margules et al. 1990, DEH 2002). Variations in sampling and descriptive approaches have led to different classifications. Although some vegetation communities/classes are comparable between studies, others are not.

The DEH survey produced a comprehensive baseline for the Site (Figure 3.7). This survey recognised the following wetland and floodplain vegetation communities which include arid and semi-arid hummock community, Black Box woodland, chenopod shrubland, fringing aquatic reed/sedge, herbfield, Lignum shrubland, low chenopod shrubland, *Melaleuca* forest/woodland, River Cooba shrubland, River Redgum woodland, River Redgum forest, river saltbush chenopod shrubland, and samphire low shrubland.

O'Malley's 1990 study covered a large part of the Site and provides a description and classification of vegetation as sampled from May 1988 to January 1989 – mostly within a year of the Site being Ramsar listed. The study identified six major community types: floodplain Black Box ± River Redgum ± Lignum ± River Cooba; blackbush/hopbush sand-based communities; lakebed herbfield; River Redgum forest communities; weedy lagoon communities; and aquatic herbfield.

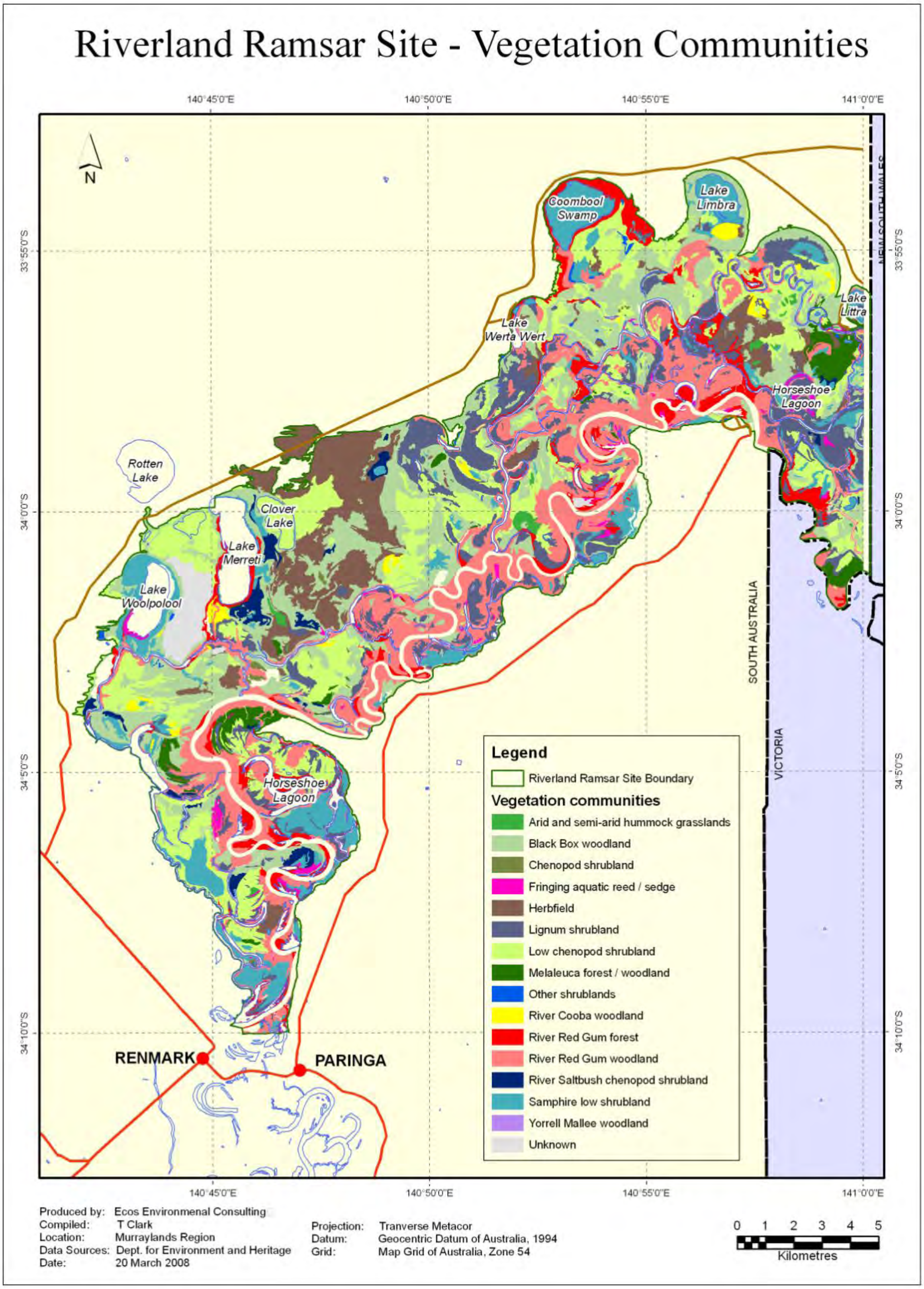


Figure 3.7: Vegetation Communitiues based on 2002 DEH Survey

The vegetation communities identified by Margules et al. (1990) and O'Malley (1990), both of which were close to the time of Ramsar listing, and the DEH (2002) survey (see Figure 3.7) are all broadly similar and the following vegetation communities are recognised:

River Redgum *Eucalyptus camaldulensis* forest/woodland over low open shrubs of Ruby Saltbush *Enchylaena tomentosa*, Nitre Goosefoot *Chenopodium nitrariaceum* or Spreading Emu-bush *Eremophila divaricata* or with forb ± sedge ± grass understorey or floating freshwater herbland (Plate 3.6). The primary distinction between the 'forest' and woodland classifications is that the River Redgum forest communities have a denser growth of trees than the woodland. The denser growth of trees is associated with greater water availability, as displayed by the distributions of the two community types in Figure 3.8. The River Redgum forest communities are typically found closer to permanent water courses and wetlands within the Site.

Plate 3.6: River Redgum (*Eucalyptus camaldulensis*) forest/woodland (Wetland Type Xf) (Photo: Anne Jensen)

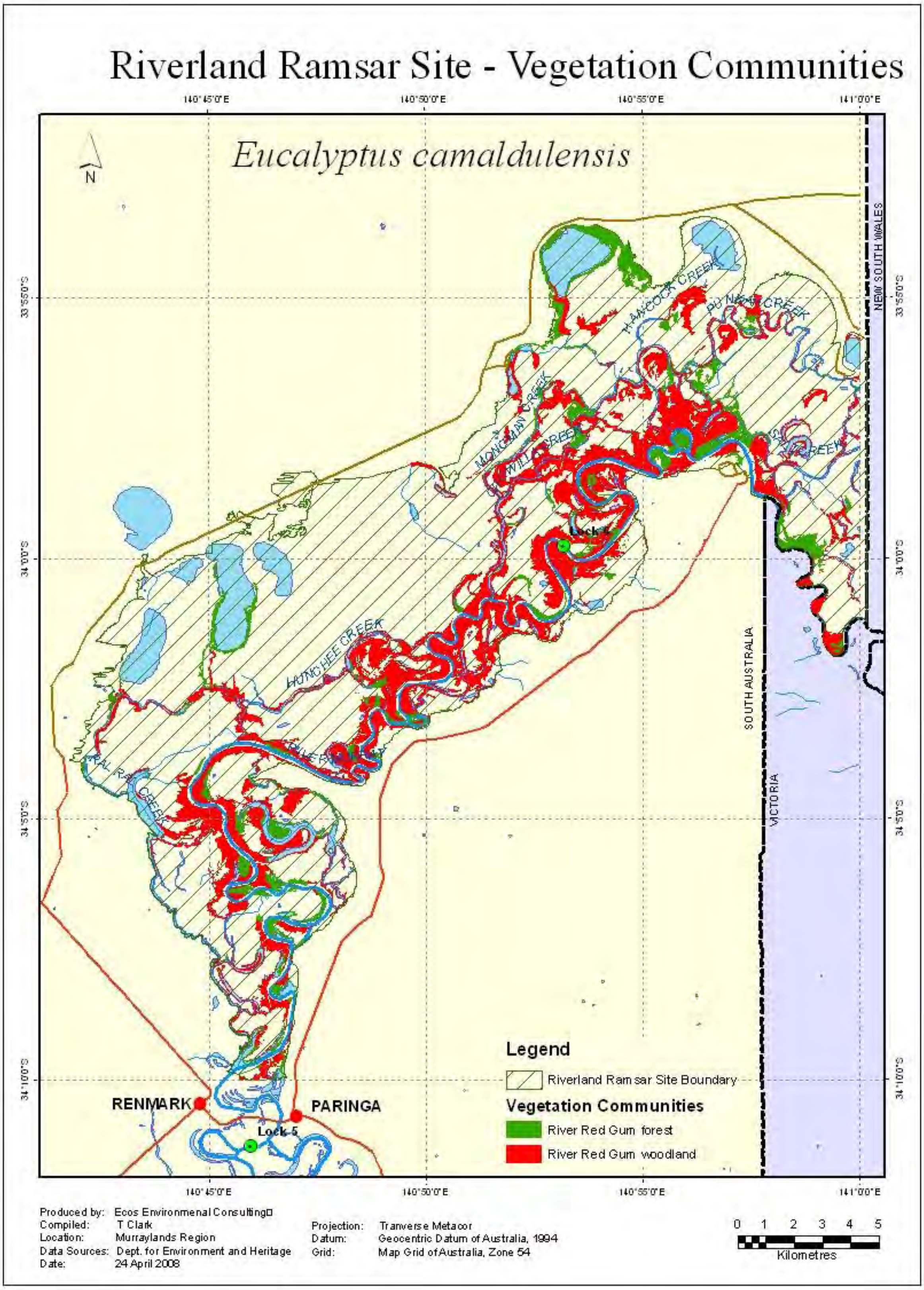


Figure 3.8: Distribution of River Redgum forest and woodland communities over the Riverland Ramsar Site, 2002.

Black Box (*Eucalyptus largiflorens)* woodland with either ephemeral forb/grass, chenopod shrubland dominated by *Atriplex* and *Sclerolaena* spp. or Pigface *Disphyma clavellatum* understorey (Plate 3.7). The Black Box woodland community is typically associated with higher elevations than the River Redgum communities, at greater distances from the watercourses and permanent wetlands (Figure 3.9).

Plate 3.7: Black Box (*Eucalyptus largiflorens*) woodland (Wetland Type Xf) (Photo: Anne Jensen)

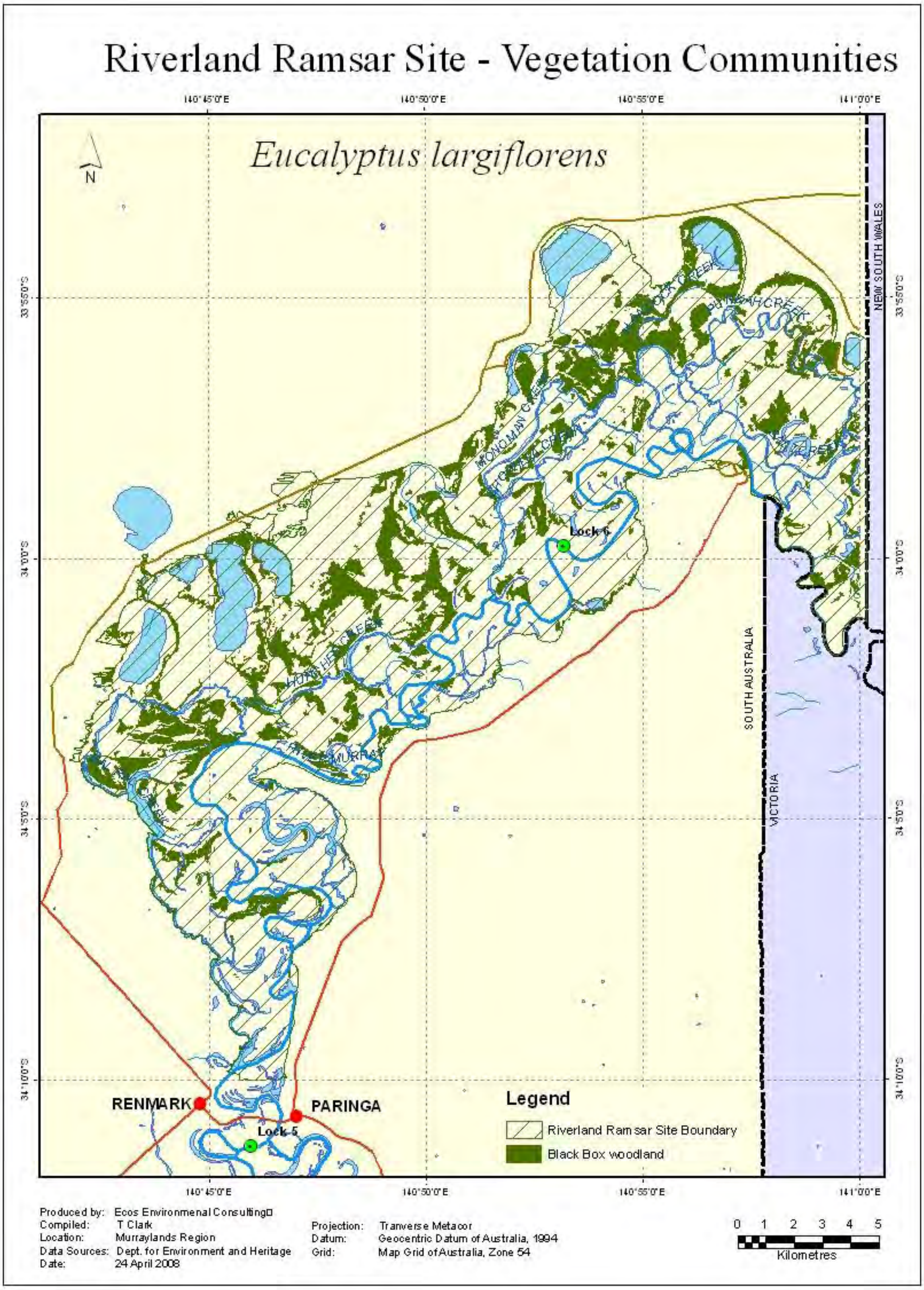


Figure 3.9: Distribution of Black Box woodland communities over the Riverland Ramsar Site, 2002.

Lignum (*Muehlenbeckia florulenta)* shrubland +/- River Redgum, Black Box and River Cooba *Acacia stenophylla* and/or an understorey of herbland or grassland (Plate 3.8). Although the lignum shrubland communities are defined and typified by the lignum shrub layer, they are occasionally associated with a sparse tree layer of River Redgum, Black Box and River Cooba. Similar to the Black Box woodland communities, the Lignum shrubland communities are typically associated with higher elevations, at greater distances from the watercourses and permanent wetlands (Figure 3.10).

Plate 3.8: Lignum (*Muehlenbeckia florulenta*) shrubland (Wetland Type R) (Photo: Anne Jensen)

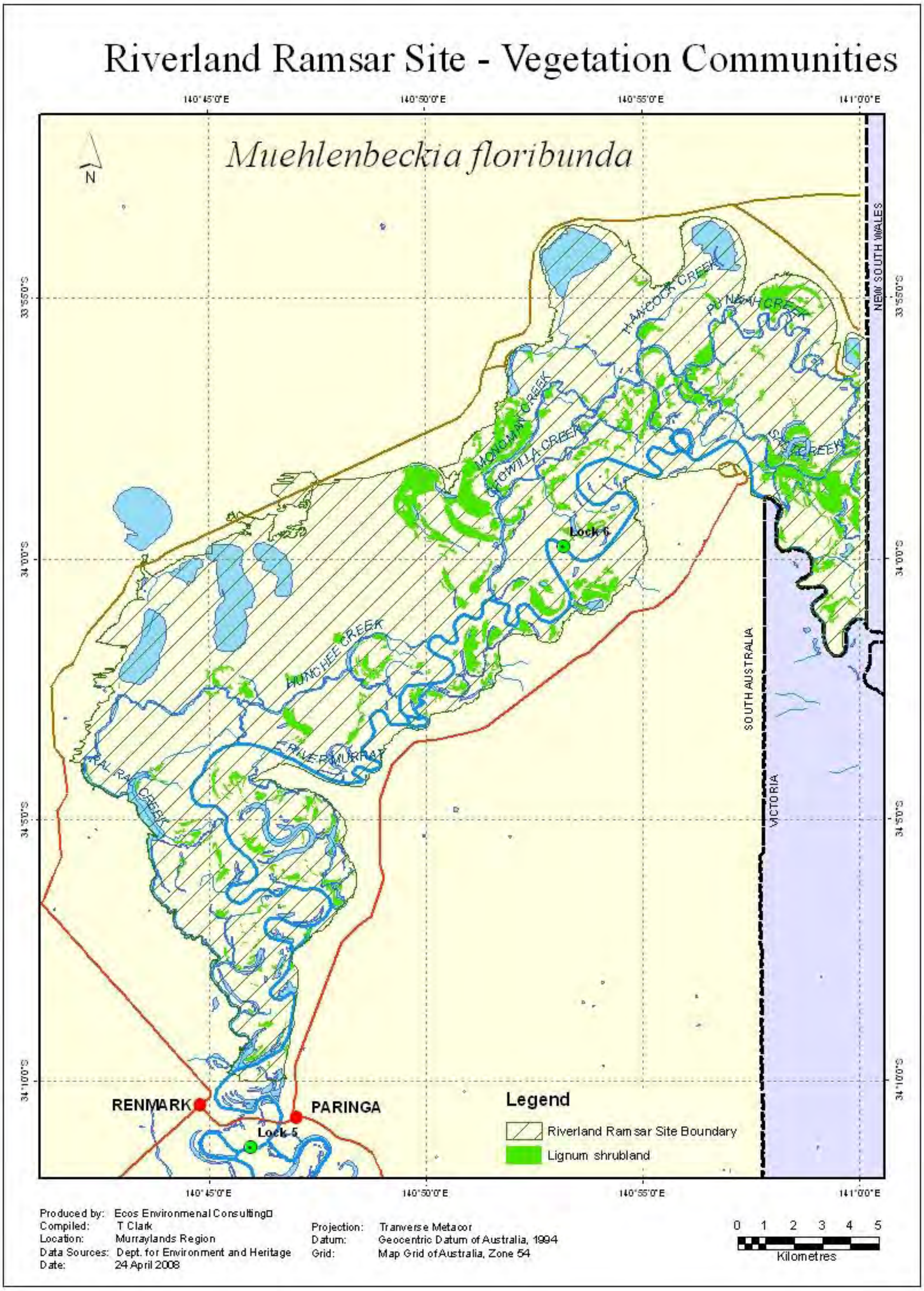


Figure 3.10: Distribution of lignum shrubland communities over the Riverland Ramsar Site, 2002.

River saltbush (*Atriplex rhagodioides)* chenopod shrubland (Plate 3.9).

Plate 3.9: River saltbush (*Atriplex rhagodioides*) chenopod shrubland (Wetland Type R) (Photo: Anne Jensen)

Low chenopod shrubland dominated by *Atriplex* and *Sclerolaena* spp. (Plate 3.10).

Plate 3.10: Low chenopod shrubland (Wetland Type R) (Photo: Mike Harper)

Samphire low shrubland dominated by *Halosarcia indica, H. pergranulata* and *Pachycornia triandra* (Plate 3.11).

Plate 3.11: Samphire low shrubland (Wetland Type R) (Photo: Anne Jensen)

Herbfield dominated by *Calocephalus sonderi, Plantago cunninghamii* and *Lepidium* spp., or grassland dominated *Bromus rubens* and *Vulpia* spp. and /or *Sporobolus mitchellii* (Plate 3.12).

Plate 3.12: Herbfield/grassland (Wetland Type Ts) (Photo: Peter Newall)

The above classification focuses mainly on the vegetation communities during the drier phases of the Site, although creeks and billabongs are often fringed by Common Reed (*Phragmites australis)*, Spiny Sedge (*Cyperus gymnocaulos)* and Cumbungi (*Typha domingensis*)*.* There are also aquatic areas containing submergent vegetation such as Red Milfoil (*Myriophyllum verrucosum)* and Ribbonweed (*Vallisneria americana*), these areas expand during large floods. The Margules et al. (1990) classification has also been more widely used within management plans for the region and a previous RIS for the Site. This ECD identifies two more groups described but not classified by Margules et al. (1990):

Fringing aquatic reed & sedge (Plate 1.13) is typified by Common Reed (*Phragmites australis*), Spiny Sedge (*Cyperus gymnocaulos*) and Cumbungi (*Typha* spp.); and,

Aquatic (permanent and semi-permanent) (Plate 1.13) containing submergent vegetation such as Red Milfoil (*Myriophyllum* spp.) and Ribbonweed (*Vallisneria Americana)*, emergent species such as Spiny Sedge, Cumbungi, and Lignum, and also free-floating species such as *Azolla* spp.

Plate 3.13: Riparian and aquatic vegetation habitat (Wetland Type M) (Photo: Anne Jensen)

A study of the aquatic macrophyte communities within the Site (Roberts and Ludwig 1990) identified four distinct communities, two of which contained an overstorey of River Redgum (redgum + reed; redgum + sedge-rush) and two without a tree overstorey (Spiny Sedge + grass; riparian grasses). The communities were associated with different flow regimes and bank steepness measures, with 'redgum + reed' community mainly found at sites on the main river channel whereas the 'redgum + sedge-rush' community was restricted to billabongs and backwaters. 'Spiny sedge + grass' communities were restricted to backwaters and slow anabranches, whereas the 'riparian grasses' community type was limited to slow and fast flowing anabranches.

A description of vegetation within the Calperum block (Parks Australia 2005) notes "The River Murray floodplains at the southernmost portion of Calperum represent a small but significant vegetation community, dominated by Red Rivergum *(Eucalyptus camaldulensis*), Black Box *(E. largiflorens),* River Cooba *(Acacia stenophylla)* and Lignum (*Muehlenbeckia florulenta*)". This focus on the drier vegetation units reflects the substantially greater percentage of cover by these communities. However, aquatic and semi aquatic habitats are also represented within Calperum. For example, Suter et al. (1993, in Harper 2003) noted a suite of aquatic and semi-aquatic species, including Spike Rush, Waterbuttons and Spiny Sedge.

Landform (including elevation) and hydrology are strong determinants of vegetation distribution across the site. Table 3.2 presents the key geomorphic and hydrologic features associated with the vegetation communities described above and displayed in Figure 3.11. This figure represents a diagrammatic cross-section of the landscape where the placement of the vegetation communities displays the basic relationships of hydrology, landscape and vegetation community at the Site. Table 3.2 does not represent all combinations, but does present important hydrological features, including flooding regime and duration.

Environmental flow programs often do not have defined targets, and their effects may not be measured other than by casual observations. Yet there are profound differences in the strategies needed for, say, *ad hoc* flow allocations meant to arrest the rate of mortality in River Redgums and programmed flow regimes designed to have sustained effects on entire floodplain communities.

As a rule, animals and plants require water for *survival*, more water for *growth* and still more water for *reproduction*.

Even reproduction may not be a sufficient response, if the goal is to maintain populations over the long term. For example, localized flooding may encourage seeds to germinate, but the seedlings must grow to maturity before they become potentially reproductive. In the case of River Redgums, it takes 2-3 years for the young trees to develop a sinker root that confers some independence of moisture at the soil surface. Until then, the saplings may require a second flooding, especially in the following summer, to maintain soil moisture near the surface and ensure survival. Serial floods, rather than isolated events, are associated with the major cohorts of River Redgums over the last century (Dexter 1967).

The process of *recruitment* (the accrual of potentially reproductive individuals to populations) therefore, is the key to effective management. Recruitment requires more water, delivered at critical times in the life cycle. If the target is a community, rather than individual species, the water regime may need to be diversified, in space and time, to meet the requirements of a diverse suite of organisms. From a manager's viewpoint, it may be necessary to select key species to represent different sections of the community with similar water-regime needs.

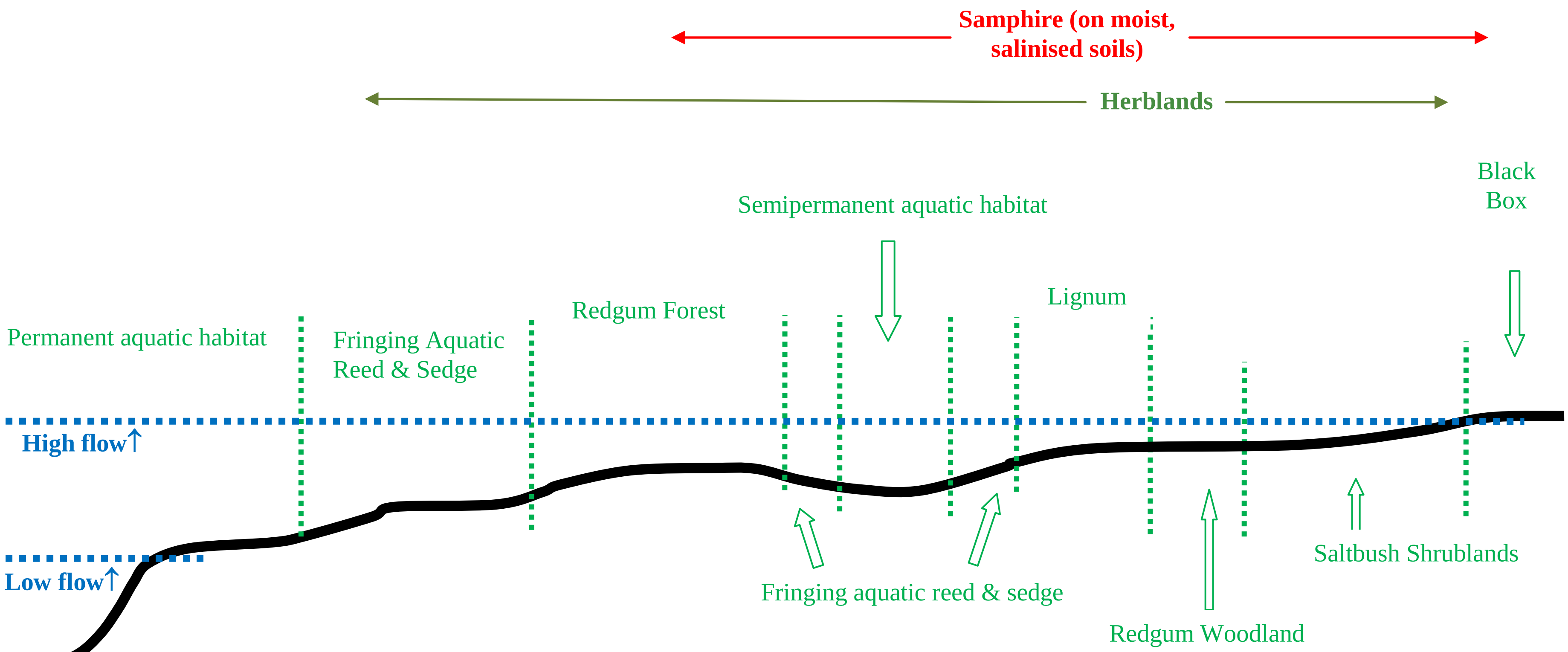
Landform, hydrology and vegetation of the Site combine to form the habitat-types. The wetland types, as presented on the RIS (in prep.), also describe the types of habitat found within the Site (Table 2.1).

Table 3.2: Vegetation communities and their associated landforms and hydrology in the Riverland Ramsar Site

Vegetation Community*		Associated landforms/landscape# (AMP = active meander plain; LRMP = low relict meander plain; HRMP = high relict meander plain)	Associated hydrologic regime‡		
			Flow (GL/day)	Recurrence interval	Duration
Aquatic	Permanent	Channels; Billabongs; swamps	5 – 40 40 – 50	1 in 2 years 1 in 2 years	Permanent
	Semi-permanent	AMP: Floodouts; backplains. LRMP: channels; swamps; backplains	50 – 60 60 – 70	1 in 2 years 1 in 3 years	Long duration,. frequently not drying out at all
Fringing aquatic reed & sedge		AMP: Floodouts; backplains. LRMP: channels; swamps; backplains	50 – 60 60 – 70	1 in 2 years 1 in 3 years	3 months (summer) or 6 months (winter), to enable seedlings to establish
Herbfield		AMP: scroll plains; floodouts. LRMP: channels; floodouts; depressions	5 – 40 50 – 60 60 – 70 70 – 80 80 – 90	1 in 2 years 1 in 2 years 1 in 3 years 1 in 4 years 1 in 4 years	Highly variable dependent upon floodplain elevation
River Redgum Forest		AMP: scroll plains.	5 – 40 40 – 50	1 in 2 years 1 in 2 years	3 months
Lignum shrubland		AMP: backplains, floodouts; LRMP: depressions; levees; scrolls; backplains; floodouts .	40 – 50 50 – 60 60 – 70 70 – 80	1 in 2 years 1 in 2 years 1 in 3 years 1 in 4 years	3 months
River Redgum woodland		AMP: scroll plains. LRMP: channel.	50 – 60 60 – 70	1 in 2 years 1 in 3 years	3 months
River Saltbush chenopod shrubland		LRMP: Lunette. HRMP: depressions. Terraces. Upland Rises	70 – 80	1 in 4 years	Long enough to saturate surface soil, with slow recession (at least 2-4

Vegetation Community*	Associated landforms/landscape# (AMP = active meander plain; LRMP = low relict meander plain; HRMP = high relict meander plain)	Associated hydrologic regime‡		
		Flow (GL/day)	Recurrence interval	Duration
				months)
Low chenopod shrubland	LRMP: Lunette. HRMP: depressions. Terraces. Upland Rises	70 – 80	1 in 4 years	Long enough to saturate surface soil, with slow recession (at least 2-4 months)
Samphire low shrubland	LRMP: Lunette. HRMP: depressions. Terraces. Upland Rises (in moist, salinised areas)	70 – 80	1 in 4 years	3 months
Black Box woodland	AMP: scroll plains; levees. LRMP: channel; levees; scrolls; lunettes. HRMP: depressions; levees; prior streams.	70 – 80 80 – 90 90 – 140	1 in 4 years 1 in 4 years 1 in 8 years	Long enough to saturate surface soil, with slow recession (at least 2-4 months)

*Largely derived from RIS (in prep.); #Largely derived from MDBC (1991) Fact Sheet 14; ‡Largely derived from MDBC (2006) – Icon site EMP



Samphire (on moist, salinised soils)
Herblands
Black Box
Semipermanent aquatic habitat
Lignum
Redgum Forest
Permanent aquatic habitat
Fringing Aquatic Reed & Sedge
High flow↑
Low flow↑
Fringing aquatic reed & sedge
Saltbush Shrublands
Redgum Woodland

Figure 3.11: Characterisation of vegetation zones of the Site (after MDBC 1991 – Fact Sheet 6).

As is well-known, the hydrological changes imposed by regulation within the site have more to do with smaller floods than big ones. Regulation has changed the frequency distributions of small-to-moderate-sized floods, particularly over-bank flows. In ecological terms, these smaller floods promote recruitment in some sectors of the river-floodplain community and provide low-level 'bridging' recruitment in populations of longer-lived species (e.g. fish, trees).

The term recruitment here refers to the accrual of potentially reproductive individuals to populations. That is, newly germinated seedlings, or newly-spawned fish, are not recruits until they have attained maturity and are able to contribute their own progeny. As a guide, for River Redgums there needs to be substantial recruitment at least once in a decade, and for Murray Cod the interval should not be longer than about seven years.

If recruitment does not occur within these intervals, the populations will decline. As older individuals die, they will not be replaced by others and, over time, the population age profile will change.

A flood may promote reproduction among plants and animals, but for some species at least, it does not ensure recruitment. Judging from historical events, River Redgums may require a second, follow-up flood, perhaps a year after the first, to ensure that soil moisture is maintained for seedlings that have not yet developed sinker roots (and some independence from conditions at the soil surface).

3.2.7 Vegetation and Inundation Level

The dependence of plant distributions upon hydrologic regime at the Site is displayed in Figures 3.12 to 3.14, which show the distributions of three major species (River Redgum, Black Box and Lignum) across the site, in relation to floodplain inundation categories. Note that the areal coverage presented in these figures is different to the coverage presented in Figures 3.8 to 3.10, as Figures 3.8 to 3.10 display vegetation *community* coverage (e.g. River Redgum *forest*, Black Box *woodland*), whereas Figures 3.12 to 3.14 display coverage by the individuals of each species, regardless of community type. Many of the River Redgum trees are not located within River Redgum forests or woodlands. Similarly, a large percentage of the Black Box trees are not located within Black Box woodland (compare Figure 3.9 with Figure 3.13). Despite the larger area covered by the individual trees in comparison to associated vegetation communities, the distributions are generally similar.

The distribution of River Redgum across inundation flow categories within the Site (Figure 3.12) shows a very clear predominance of trees at sites inundated by flows from 45,000 to 80,000 ML day^{-1} (45 – 80 GL day^{-1}), with more than half the tree cover from this species being located in the 45 – 50 and 50 – 60 GL day^{-1} categories. This is supported by the vegetation community data presented in Table 3.3, which shows that the River Redgum forest and woodland communities similarly show a strong preference for these flow categories. Although less widely distributed than the River Redgums, Lignum shows a similar distribution pattern, peaking in abundance at the sites inundated by flows of 45 – 50 and 50 – 60 GL day^{-1} (Figure 3.14) and the lignum shrubland community distribution shows a similar pattern (Table 3.3).

In contrast, the Black Box distribution is negligible below 50 GL day^{-1}, gradually increases with increasing inundating flow volumes and peaking at the highest category of 200 to 311 GL day^{-1}. Again, the distribution of the Black Box woodland community reflects the distributions of the Black Box trees. The distribution of River Saltbush chenopod shrubland similarly shows a strong peak in the drier areas of the Site (Table 3.3). In contrast, the distributions of permanent and semipermanent aquatic communities (Table 3.3) are generally restricted to areas that only require 3 GL day^{-1} for inundation, with a smaller peak in areas inundated flow volumes of 45 – 60 GL day^{-1} associated with the larger wetlands that retain water and soil moisture between large events.

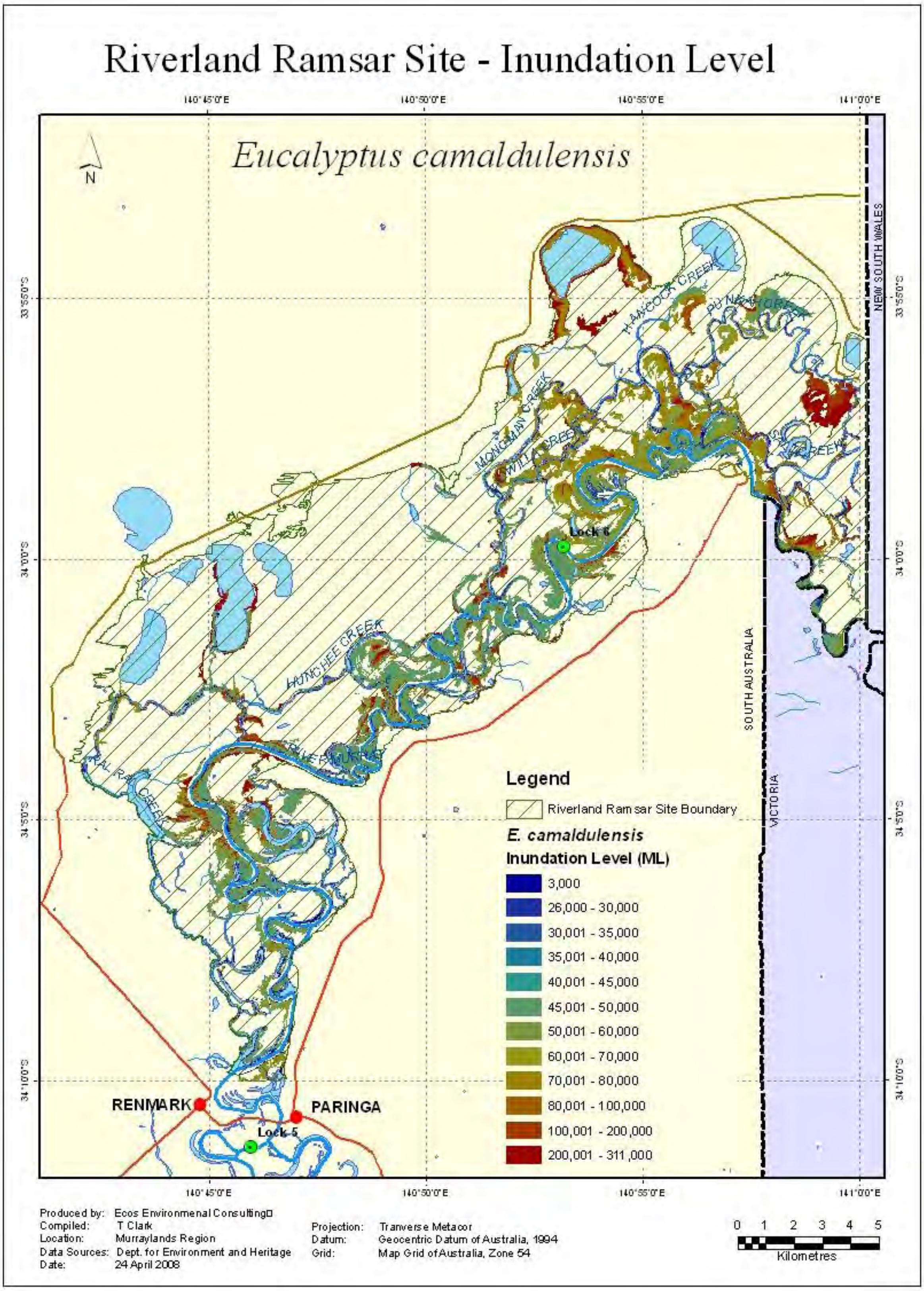


Figure 3.12: Distribution of River Redgum grouped by inundation levels over the Riverland Ramsar Site, 2002.

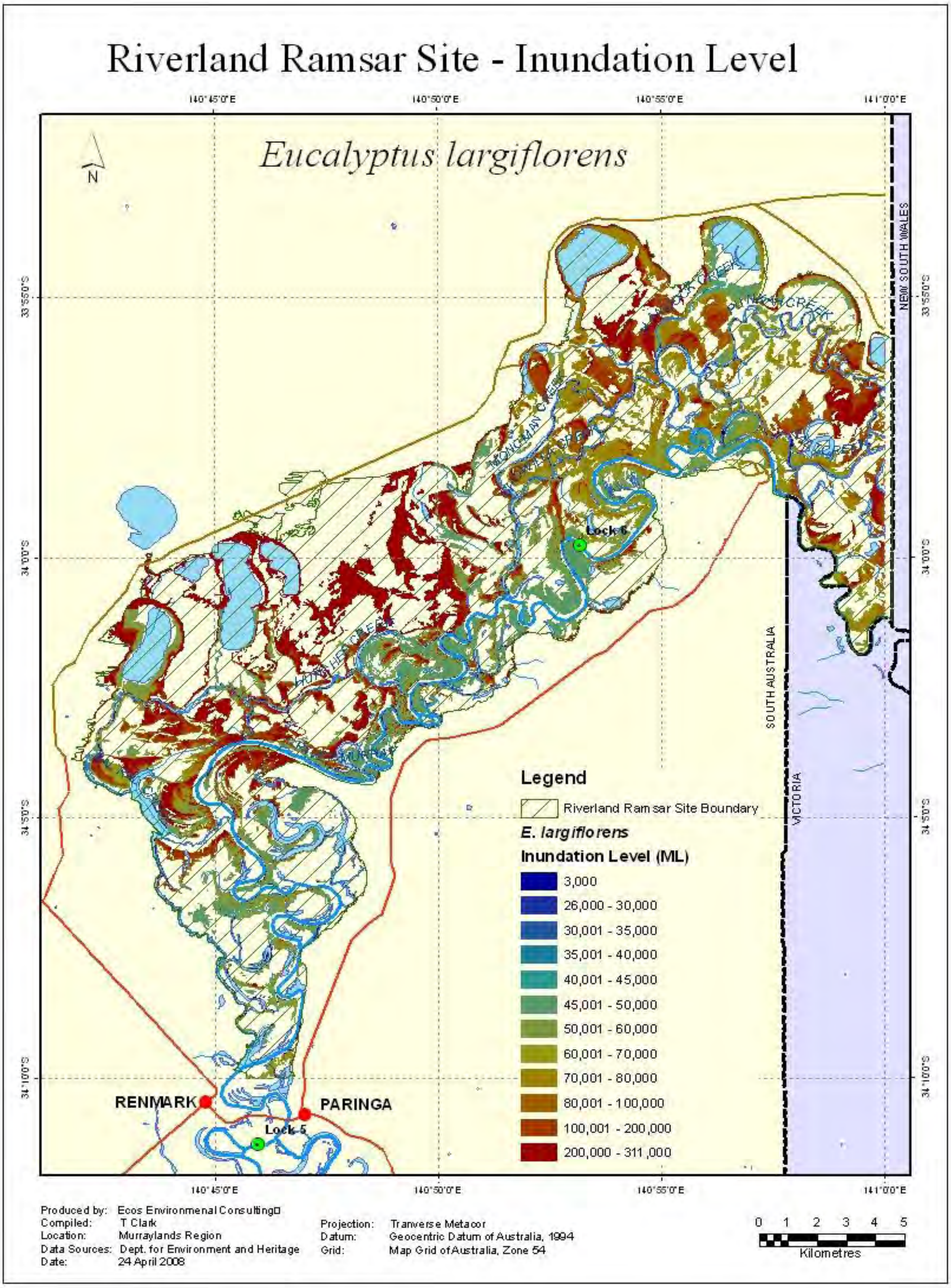


Figure 3.13: Distribution of Black Box grouped by inundation levels over the Riverland Ramsar Site, 2002.

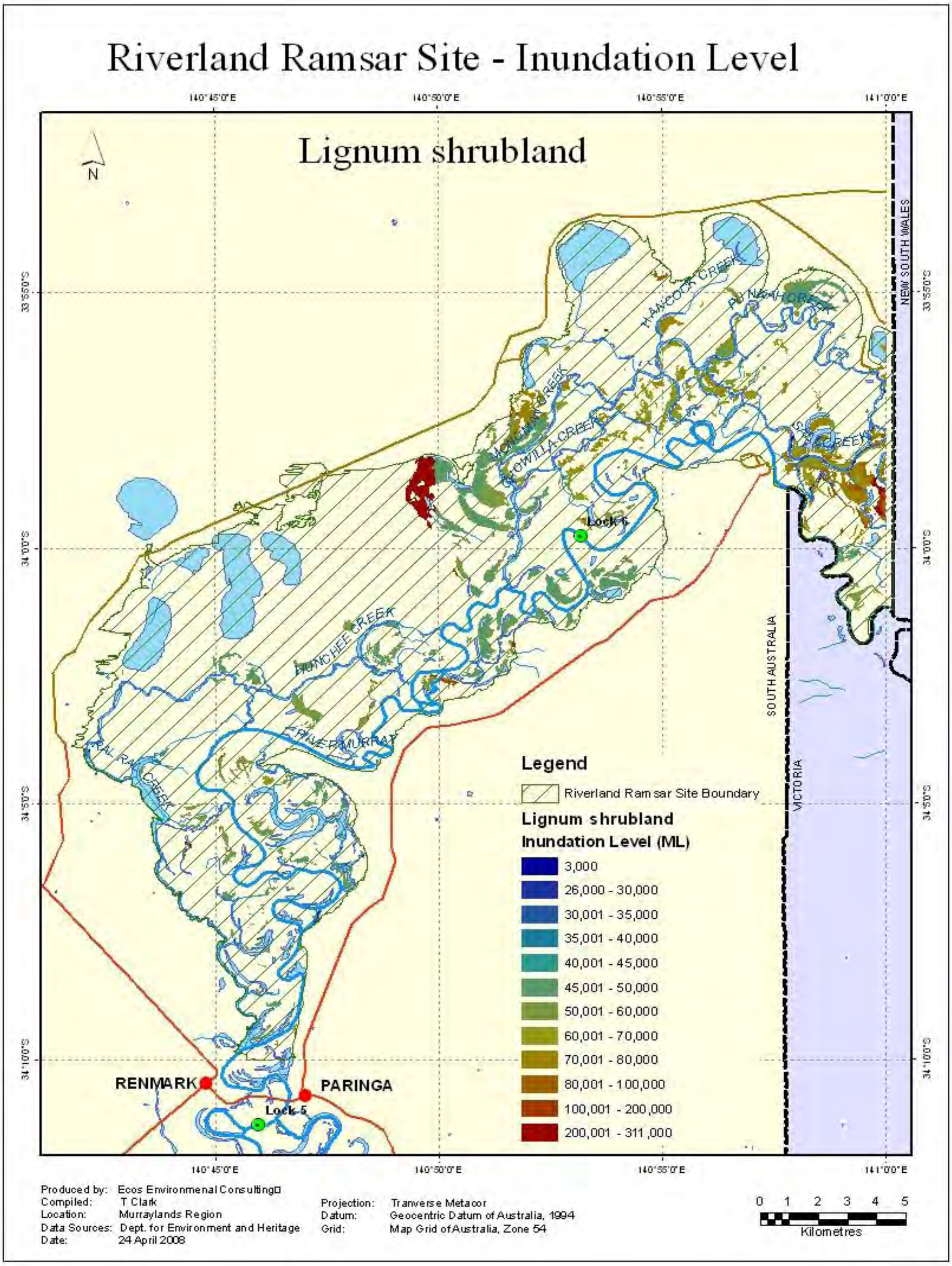


Figure 3.14: Distribution of Lignum grouped by inundation levels over the Riverland Ramsar Site, 2002.

Table 3.3: Area and degree of Vegetation community inundated under various flow ranges (from River Murray FIM)

			Flood inundation range (GL day^{-1})											
Vegetation Community	Hectares	Gap in FIM layer	3	26-30	31-35	36-40	41-45	46-50	51-60	61-70	71-80	81-100	101-200	201-311
Arid and semi-arid hummock grasslands	122.33						0.1	44.4	24.4	1.2	28.5	0.5	1.0	
Black Box woodland	5838.36	0.0	0.4	0.2	0.0	0.1	0.2	5.6	10.4	4.8	9.3	10.1	22.0	36.8
Chenopod shrubland	46.27	0.0	0.0	0.0	0.0	0.0	0.0	1.3	44.8	3.8	4.7	10.8	15.0	19.5
Fringing aquatic reed / sedge	275.16	0.0	4.5	25.1	1.1	3.5	5.1	28.5	21.4	2.6	2.7	2.5	1.1	1.9
Herbfield	2322.50	0.1	0.0	0.0	0.0	0.3	0.3	5.1	13.1	3.7	8.4	1.8	1.8	65.4
Lignum shrubland	2945.32	0.0	0.6	0.5	0.1	0.3	0.9	35.2	23.2	11.8	16.7	3.3	1.8	5.7
Low chenopod shrubland	4834.11	4.4	0.1	0.1	0.0	0.0	0.7	14.1	21.9	7.8	14.0	4.4	4.4	28.0
Melaleuca forest / woodland	586.21	0.0	0.3	0.8	0.1	0.0	0.1	1.0	7.0	4.8	8.7	4.5	26.4	46.2
Other shrublands	63.62	1.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.3	2.3	2.3	3.5	90.2
River Cooba woodland	230.86	0.0	0.0	0.1	0.0	0.0	18.1	25.2	23.1	9.8	7.5	0.3	2.2	13.6
River Redgum forest	1550.21	0.0	6.1	2.6	0.8	1.2	3.3	23.4	16.1	6.9	17.0	6.4	5.4	10.6
River Redgum woodland	5305.03	0.0	3.8	2.3	0.5	0.8	2.2	24.6	25.4	10.4	13.6	4.4	7.1	4.9
River Saltbush chenopod shrubland	350.29	0.0	0.1	0.0	0.0	0.2	1.0	16.9	8.4	0.4	2.4	0.8	6.1	63.8
Samphire low shrubland	2485.17	0.0	0.4	0.7	0.7	0.8	13.1	24.5	19.5	5.5	16.8	2.7	4.5	10.7
Unknown	425.56	0.2	1.6	0.1	0.0	0.0	0.0	1.4	5.0	0.2	0.2	0.2	0.4	90.8
Yorrell Mallee woodland	0.78	11.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0	0.3	1.8	85.2
Permanent and Semi-permanent aquatic communities	3254.88	0.0	57.5	3.6	0.4	0.3	0.9	7.3	13.7	2.5	2.4	3.1	3.2	5.0
Hectares per inundation category		219	2244	403	76	120	664	4940	5444	2038	3513	1487	2465	7026
% of Total Area Inudated per category		0.7	7.3	1.1	0.2	0.4	2.2	16.1	17.8	6.7	11.5	4.9	8.0	22.9

3.2.8 Fauna

While there is good information about the species occurrences of birds, mammals, reptiles and amphibians, aquatic macroinvertebrates, molluscs and crustaceans and fish there is poor if any information on the populations of these fauna through time. Some snapshots exist for some fauna but these have been undertaken during the current drought period and are unlikely to be representative of the time of listing (e.g. Harper 2003; Zampatti et al. 2006b).

Avifauna The vegetation communities and habitats described in the previous sections sustain diverse bird assemblages, including wetland, woodland, shrubland and grassland species, and species not found elsewhere in South Australia. This reflects the habitat diversity of the Site, its relatively low disturbance and its remoteness from human population centres (Carpenter 1990). The Site also provides a corridor for bird movements between regions.

Carpenter (1990) recorded 134 species at Chowilla, including 30 breeding species, and noted that 170 species had been recorded in that area. A total of 165 native bird species have been recorded across the Calperum and neighbouring Taylorville stations, including wetland, migratory and mallee-dependent species (Parks Australia, 2005), and 53 species of waterbirds and two wetland raptors were recorded at Lake Woolpolool alone (Jensen 2000; Harper 2003). The most recent RIS (in prep.) reported 179 species for the whole site, including 63 wetland-dependent species (Appendix 2.1). As noted in Section 2 of this report, the Site supports 18 State-listed threatened bird species (Appendix 2.3), eight species listed under international agreements (Appendix 2.4), and one species listed nationally as 'vulnerable' under the EPBC Act. A list of all bird species recorded as part of a DEH survey in 2003 is presented in Appendix 2.2

Mammals In a survey near the time of Ramsar listing (Brandle and Bird 1990), 25 species of mammals were recorded at Chowilla, including 17 native species. The native species included eight species of bat, three species of dasyurid (two dunnart species and a planigale), two species of kangaroo (Western Grey and the Red), a species of native mouse, the native water rat, the Short-beaked Echidna and the Brush-tailed Possum. The introduced species were sheep, cattle, the rabbit, brown hare, feral pig, feral goat, House Mouse and Red Fox.

A total of 25 native mammal species have been recorded across the Calperum and neighbouring Taylorville stations (although the majority of these species were from mallee not floodplain habitat) of which the Western Grey Kangaroo and Red Kangaroo are the most abundant (Parks Australia 2005). About half of these 25 species recorded are bats.

A list of all mammal species recorded as part of a DEH survey in 2003 is presented in Appendix 2.8.

Although not recorded during the 1988 Chowilla survey (Brandle and Bird 1990), the Feather-tailed Glider is a State-listed species, endangered in South Australia, and has been recorded within the Site (RIS in prep.).

Brandle and Bird's (1990) data were limited, but some conclusions could be drawn:

- the Site contains a species assemblage that is surprisingly diverse and unique to the riverine corridor of the upper River Murray in South Australia;
- the Site has not escaped the widespread, devastating changes to the Australian semi-arid and arid zones, including extinctions to almost all the medium-sized species of rodents, small macropods, bandicoots, and dasyurids;
- several habitat types are important to the mammal fauna, especially the low flood plain areas subject to frequent inundation; and,
- feral animals present particular problems for the Site's fauna, in particular, rabbits, feral goats, feral pigs and foxes either directly or indirectly contribute pressure on the native fauna.

Reptiles and Amphibians Thirty-eight species of reptiles have been recorded at the Site (RIS in prep.). These include three turtle species, lizards such as gecko, dragon, monitor and skink species and six species of snake.

Bird and Armstrong (1990) surveyed the Chowilla block of the Site in October 1988 and recorded:

- seven species of frog (including the Southern Bell Frog, *Litoria raniformis*, listed as endangered under the EPBC Act);
- eighteen species of lizard, comprising;
  - nine skinks (each from a different genus);
  - five geckoes;
  - two goannas (including the Lace Monitor, *Varanus varius*, listed as Rare in South Australia); and,
  - two species of dragons;
- one turtle (Eastern Long-necked Turtle, *Chelodina longicollis*); and,
- five snakes.

As in the mammal survey by Brandle and Bird (1990), Bird and Armstrong (1990) stated that their sampling was limited and indicative only, and cited several species of herpetofauna that were not found during the survey but had been recorded at the Site on other occasions. These included two species of turtle (the Broad Shelled Turtle *Chelodina expansa*, listed as Vulnerable in South Australia and the Murray

River Turtle *Emydura macquarii*) a gecko and the carpet python (*Morelia spilota variegata*, listed as Rare in South Australia). Additionally, there are other species that have been found in similar habitats and may occur on the Site, but have not been recorded. A survey of the site by DEH in 2003 found twenty-seven species of reptiles, and is presented in Appendix 2.7.

The RIS (in prep.) noted eight species of frog have been recorded at the site. The survey by Bird and Armstrong found seven species, which covered the list of frog species known for the Chowilla region:

- Peron's Tree Frog (*Litoria peronii*);
- Southern Bell Frog (*Litoria raniformis*);
- Eastern Sign Bearing Froglet (*Crinia parinsignifera*);
- Bull Frog (*Limnodynastes dumerilii*);
- Long-thumbed Frog (*Limnodynastes fletcheri*);
- Spotted Grass Frog (*Limnodynastes tasmaniensis*); and,
- Sudell's Frog (*Neobatrachus sudelli*).

A species of frog not found in Chowilla – the Common Eastern Froglet (*Crinia signifera*) - was recorded at Woolpolool (Harper 2003), Whirlpool Corner and also Woolenook in the Murtho block (SKM 2005). The updated RIS (in prep.) had not included the Common Eastern Froglet in its list of eight amphibians, instead noting the presence of the Painted Frog (*Neobatrachis pictus)*. Therefore, the total number of frogs recorded at the site is nine.

Aquatic Macroinvertebrates The aquatic habitats on the River Murray floodplain at the Site support a diverse assemblage of macroinvertebrates, with a total of 96 taxa being recorded during a survey of the Chowilla section of the Site in October 1988 (Lloyd and Boulton 1990). The main channel sites within the survey recorded 27 taxa, indicating that the floodplain habitats harbour a rich faunal diversity compared to the channel, reflecting its high habitat diversity.

The Lloyd and Boulton (1990) survey demonstrated that many macroinvertebrate taxa display specific habitat requirements. The functional feeding groups (e.g. predators, detritivores) also showed significant differences in habitat distributions, emphasizing the need for a broad range of habitat types within the floodplain. In particular, flow regimes and vegetation structural complexity separated many taxa and functional feeding groups (Boulton and Lloyd 1991). For example, there was little faunal overlap between billabongs and the main river channel.

Within the Murtho block, macroinvertebrate sampling at Woolenook, Weila and Murtho Park yielded 41, 42 and 40 taxa, respectively (SKM 2005). A detailed study of the macroinvertebrates of Clover Lake, Lake Merreti and Lake Woolpolool (Suter et al. 1993) resulted in 86, 121 and 106 taxa being identified in the three wetlands, respectively. The study by Suter et al. (1993) examined eight wetlands in the South Australian floodplain of the River Murray and noted that all wetlands in the study had high species richness, although the 86 taxa at Clover Lake was the equal lowest richness of the eight wetlands. The lower number of taxa at Clover Lake was related to a trend of increasing richness at permanently inundated wetlands and at low salinity wetlands (Suter et al. 1993).

As the fauna of the floodplain is the most diverse and the floodplain habitat is potentially the most threatened by alteration of the flooding regime, the wetland macroinvertebrate fauna is particularly vulnerable to the effects of river regulation.

Molluscs & Macrocrustaceans Two species of freshwater mussel occur in the wetland complex. The river mussel *Alathyria jacksoni* is typical of moderate- to fast-flowing channels, including the River Murray channel and the larger anabranches. The floodplain mussel *Velesunio ambiguus* prefers slow-flowing and still-water habitats, including billabongs, backwaters and impounded areas of the main channels.

The river snail *Notopala hanleyi* was formerly common in flowing-water habitats within the site prior to listing in pre-regulation times, but has virtually disappeared in South Australia except for populations surviving in a few irrigation pipeline systems, where they are an occasional pest. In the last 10-15 years (pre-2007) efforts have been made to establish snail populations in some regional wetlands. The species is declared endangered in New South Wales.

The Murray crayfish *Euastacus armatus* was formerly common in flowing-water habitats within the site prior to listing in pre-regulation times, but now is virtually extinct in South Australia. This may be due to river regulation causing a substantial reduction in its preferred running water habitats. The smaller yabbie (*Cherax destructor*) is common throughout the Site's wetlands, except in fast-flowing water.

Atkins and Musgrove (1990) indicated that the freshwater shrimp (*Macrobrachium australiense*) occurs in a range of lotic habitats within the Site.

Fish As noted in Section 2.2 of this report, the Site supports 16 native fish species within the Murray-Darling Basin (Table 3.4). In the Murtho block of the Site (SKM 2005) eight native fish species were found across four sampled sites (Templeton, Weila, Murtho Park and Woolenook Bend). In the Calperum block twelve native fish species have been recorded (Parks Australia 2005).

In a survey within the Chowilla block in 1988, Lloyd (1990) collected eleven species of fish, three of which were exotic. Lloyd noted that the species caught were those known to be common in the area, and that the brief sampling event was unlikely to find locally rare species. The study revealed that, although similar to fish faunal assemblages at other sites on the River Murray, the fish at the Site displayed clear habitat differentiation, due to the extensive development of floodplain macrohabitats at the Site (Lloyd 1990). This supports the suggestion that maintenance of the Site's fish diversity is dependent upon maintenance of habitat diversity.

In surveys conducted in 2005 and 2006, Zampatti et al. (2006a and 2006b) reported 13 species of fish (which included 3 exotic species). These studies showed that fish larvae for most native fish were present for much longer periods during the year in which a spring flow event was observed. The same studies showed significant associations between fish numbers with particular habitats such as large woody debris, emergent and riparian vegetation for the larger bodied fish (Callop and Silver Perch) and Australian Smelt. Bony Herring and Murray Rainbowfish were positively correlated with open water (near vegetation beds) and the gudgeon species associated with submerged or floating-leaved vegetation.

Although there are no fish species listed under the National Parks and Wildlife Act (1972), a recent review has highlighted that Freshwater Catfish, Murray Hardyhead, Silver Perch, Trout Cod and Southern Pigmy Perch should be regarded as endangered in SA whereas Flyspecked Hardyhead and Murray Cod should be regarded as vulnerable (Hammer et al 2007).

Significant populations of exotic fish are also present within the Riverland Ramsar Site and these species include Eastern Gambusia, European Carp and Golfish. Redfin and other exotic species maybe expected in the region but have not been recorded in published reports.

Findings of the Site's Faunal Studies The information available for the Riverland Site at the time of Ramsar listing reveals a diverse fauna. The studies undertaken for the NCSSA report (O'Malley and Sheldon 1990) strongly suggest that the basis of the faunal diversity is the habitat diversity and that this is dependent upon a water regime that includes natural flow variations including regular flooding and drying sequences.

3.2.9 Critical components of the Site

Each of the components described in the sections above contribute to the status of the ecological character of the Site. However, the role of the vegetation in providing the habitat template, and the influence of the hydrologic regime upon the vegetation structure and dynamics, highlight the vegetation and hydrology as the primary critical components of the Site. Accordingly, these components and their interactions are the focus of the conceptual models later in this document (Section 3.5).

3.3 Processes of the Site

Ecosystem processes are "the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological" in nature (Ramsar Convention 1996 Resolution, in DEWHA 2008). They include all those processes that occur between organisms, and within and between populations and communities, including interactions with the non-living environment, which results in existing ecosystems and brings about changes in ecosystems over time (Australian Heritage Commission 2002, in DEWHA 2008).

The key ecosystem process that occurs within the Riverland Site is hydrological: the inundation and replenishment of various forms of wetland habitat. This process is essentially the driver of the Site's ecological character, maintaining connectivity and enabling a range of subsequent processes, including:

- Vegetation growth, providing a mosaic of habitat types for fauna;
- Survival, growth, reproduction, and recruitment of a range of biological communities; of particular importance are:
  - River Redgum forests/woodlands;
  - Black Box woodlands;
  - Lignum, chenopod and samphire shrublands;
  - Herbfields;
  - Billabongs, anabranches and basins;
- Freshwater recharge of saline groundwater systems, including freshwater lenses under temporary wetlands;
- Storage and diversion of high flow waters, providing water supplies for humans, stock and wildlife;
- Flushing of salt from floodplain soils, reducing salinity impacts;
- Energy and nutrient processing, providing a base for ecosystems;
- Deposition of fine sediments and nutrients, enhancing water quality of the main channel;
- Breeding and recruitment of the broad range of life forms at the Site; and,
- Dispersal of flora and fauna.

The influence of higher flood waters can also result in the formation and erosion of geomorphic features, ranging from the formation of natural levees, to the filling of depressions with sediment deposits.

The ecological processes listed above are summarised in Tables 3.4 and 3.5. Section 3.5 also provides conceptual models of these processes and interactions at the Site. The pre- and post-regulation hydrologic regime at the Site has been described in Section 3.2.4 of the report, as have the ecological impacts of river regulation.

3.4 Benefits and Services of the Site

Benefits and services of Ramsar listed sites include:

- benefits to humans derived from the site; and,
- non-anthropocentric ecosystem services derived from the site (DEWHA 2008).

Benefits to humans derived from the Site include:

- Cultural heritage (indigenous and European);
- Tourism/recreation;
- Drinking water for livestock;
- Water for irrigated agriculture;
- Livestock fodder;
- Flood retardation;
- Pollutant reduction, including nutrient inputs to the River Murray;
- Sediment trapping;
- Educational and scientific values, including studies on groundwater; and,
- Greenhouse gas offset.

The non-anthropocentric ecosystem services provided by the Site include:

- Wetlands of International Significance;
- Unique occurrence of wetlands in the normally semi-dry lower River Murray floodplain environment;
- Part of the Riverland Biosphere Reserve;
- One of the only parts of the lower River Murray floodplain not irrigated, retaining much of its natural character; hence natural heritage;
- A highly diverse mosaic of both terrestrial and aquatic habitats; probably the highest biodiversity of any site along the Lower River Murray;
- Supports populations of rare, endangered and nationally threatened species;
- Supports populations of rare, endangered and threatened species and communities in South Australia;
- The site has:
  - 28 plant species of state significance;
  - 4 animal species of national significance;

- ❖ Southern Bell Frog (*Litoria raniformis*);
- ❖ Regent Parrot (*Polytelis anthopeplus monarchoides*);
- ❖ Murray Cod (*Maccullochella peelii peelii*);
- ❖ Murray Hardyhead (*Craterocephalus fluviatilis*);

– 23 animal species of state significance;

- o Diverse and abundant waterbirds;
- o Diverse fish fauna (including nationally significant species); and,
- o Diverse invertebrate fauna.

The benefits to humans are displayed in Table 3.4 and the ecosystem services provided by the site are shown in Table 3.5. Both tables present the primary processes contributing to the services and the key components at the source of those processes.

Table 3.4: Benefits provided by the Riverland Ramsar Site with relevant processes and components

Benefits provided	Ecological Processes Creating/Supporting the Service	Key Components
Cultural heritage (indigenous and European)	Maintenance of current landform integrity to meet cultural and spiritual values	Geomorphology
	Maintenance of habitat quality and integrity to meet cultural and spiritual values	Hydrology, Water Quality
	Maintenance of ecosystem, biotic communities, and species populations to meet cultural and spiritual values	Hydrology, Water Quality, Vegetation & Habitat
	Preservation of artefacts, including: middens; burial sites; scarred trees; and campsites	Geomorphology
Tourism/recreation	Provision of water regime to meet tourism/recreation needs, including: boating; house-boating; fishing; camping; and aesthetic enjoyment	Hydrology
	Provision of water quality to meet tourism/recreation needs, including: boating; house-boating; fishing; camping; and aesthetic enjoyment	Water Quality
	Maintenance of biotic communities and species populations to meet tourism/recreation needs for fishing, birdwatching, and waterfowl hunting.	Hydrology, Water Quality, Vegetation & Habitat
Drinking water and fodder for livestock	Provision of water to meet stock watering requirements	Hydrology
	Provision of water to sustain plants for stock fodder	Hydrology
	Maintenance of water quality to meet stock watering requirements, including acceptable salinities and algal concentrations	Water Quality

Benefits provided	Ecological Processes Creating/Supporting the Service	Key Components
Water for irrigated agriculture	Provision of water to meet irrigation water quantity requirements	Hydrology
	Provision of water to meet irrigation water quality requirements, particularly of salinity	Water Quality
Flood retardation	Maintenance of depressions and other landforms that capture and retard overbank flows	Geomorphology
	Maintenance of vegetation cover that contributes to surface roughness and impedes flood flows	Hydrology, Vegetation & Habitat
Pollutant reduction, including nutrient inputs to the River Murray	Maintenance of depressions and other landforms that capture and retard overbank flows, enabling trapping of nutrients and organics in swamps and billabongs	Geomorphology
	Maintenance of vegetation for uptake of nutrients and organics in swamps and billabongs	Hydrology, Vegetation & Habitat
Sediment trapping	Maintenance of depressions and other landforms that capture and retard overbank flows, promoting sediment deposition	Geomorphology
	Maintenance of vegetation cover that contributes to surface roughness and impedes flood flows, promoting sediment deposition	Hydrology, Vegetation & Habitat
Educational and scientific values, including studies on groundwater	Maintenance of current landform quality and integrity to meet scientific and educational study requirements	Geomorphology
	Maintenance of habitat quality and integrity to meet scientific and educational study requirements	Hydrology, Water Quality
	Maintenance of ecosystem, biotic communities, and species populations to meet scientific and educational study requirements	Hydrology, Water Quality, Vegetation & Habitat

Human benefits from the Site include indigenous and European **cultural heritage**. The Riverland has a rich Aboriginal history of some 12,000 years and nearly 180 years of European occupation. Numerous Aboriginal and European heritage sites are located throughout the Ramsar Site.

The Maraura, Ngintait and Erawirung Aboriginal peoples occupied the area. Burnt clay and "middens" of mussel shells mark old campsites. There are also burial sites, scarred trees and isolated artefacts. The people made baskets and nets to catch fish and waterfowl and possums, kangaroos, mussels, yabbies and turtles were also eaten. They made canoes from the bark of River Redgum trees and used possum skins as cloaks. Plants like Cumbungi (*Typha* spp.) produced edible tubers and seeds that were ground into flour.

The first pastoral lease over the region north of the river, known as Chowilla Station, was issued in 1851. In 1864, the lease was assumed by the Robertson family, forebears of the present day lessees. The first owner of the area south of the river between Renmark and the Victorian border was E.M. Bagot. In 1887, the Government set aside 30,000 acres (= 12,141 ha) at the downstream end of Chowilla, then known as Bookmark, for an irrigation area. The town of Renmark was laid out on this land in 1886. The Robertson partnership was dissolved in 1896 and the Chowilla/Bookmark property was split to create Chowilla and Calperum Stations.

In 1871, "Littra House" was built near the NSW border on the northern side of the river to house the Stock Inspector, whose job was to prevent entry of the sheep disease Scabby Mouth into South Australia. The house later became a Customs House, and remains today as a ruin. On the south side of the river a Customs House was established at Border Cliffs in 1884, adjacent to the Victorian border, to monitor river trade between States. The house remains, although modified, and is still occupied.

In the 1880s, Longwang Island, and part of Bulyong Island on the Ral Ral Anabranch, became a community commonage for the settlement of Renmark. At the end of World War I, the commonage was leased to the Returned Servicemens League for horse agistment. In 1967, an evaporation basin was established on Bulyong Island to receive drainage water from local irrigation areas, but this was decommissioned in 1989, after a flood breached the embankment. The islands now are part of the River Murray National Park.

From May 1942 to May 1945, there was a Prisoner of War wood-cutting camp at Woolenook Bend in the Murtho Forest Reserve. Black Box densities were reduced to 1-2 trees per acre (PIRSA 1997), but these trees have a remarkable capacity to re-sprout. Many of the trees harvested during this period remain alive, and can be identified by multiple stems and scarred trunks. The timber was used for fences, buildings and vineyard trellises, and as fuel for irrigation pumps, electricity generators, domestic needs and steamboats.

Other human benefits of the Site include its economic contribution to the region. The water in this section of the River Murray has been the catalyst for the region's economic development. This ranges from early development of the pastoral industry through provision of **water and fodder for livestock**, through the riverboat trade during the late 1800s, to the **irrigation** industry of the present day. In addition to other forms of industry, the Site has been a major contributor to the region's **tourism and recreation** values. Recreational fishing of native and introduced fish along the River Murray and backwaters within the Site is a long-established use of the Site. The area provides a range of tourist activities such as bush camping, fishing, boating, house boating and accommodation in shearers' quarters. It is reputedly the most valuable area in South Australia for the canoeing component of outdoor educational programs for secondary schools, tertiary educational classes and youth agencies.

The Site has also been the focus of significant **environmental scientific research**, particularly over the last two decades. Key programs have included the *Chowilla Floodplain Integrated Natural Resource Management Program* in the early 1990's, the *Riverland Biosphere Reserve Program*, and more recent activities associated with Chowilla being declared an *Icon Site* and *Significant Ecological Asset* under the Murray-Darling Basin Commission's program, *The Living Murray*.

Channel maintenance and water quality maintenance for the River Murray, **flood retardation** and **floodwater storage** for use in salt dilution are important ecosystem services. The Site is likely to reduce the input of sediment to the River Murray through **sediment trapping** within aquatic-vegetated backwaters adjacent to the main river channel. Similarly, these communities **trap pollutants** including nutrients, reducing the risk of eutrophication and algal blooms further downstream.

Within the Site there are also large, often dry wetlands such as Coombool Swamp and Lakes Limbra and Littra that retain large volumes of flood water. This slows the rate at which floodwaters rise, thereby reducing flood peaks. Similarly, Lake Merreti stores floodwaters which, through agreement with local irrigators and water managers, are released to dilute high-salinity flows in Ral Ral Creek following the flood recession.

Table 3.5: Ecosystem services provided by the Riverland Ramsar Site with relevant processes and components

Ecosystem Services	Ecological Processes Creating/Supporting the Service	Key Components
Wetlands of International Significance Incorporated into the Riverland Biosphere Reserve	Provision of water volumes for ecosystem requirements (including groundwater replenishment & salt flushing)	Hydrology
	Water delivery regime supporting wetland mosaic/diversity	Hydrology
	Maintenance of landform variation	Geomorphology
	Providing aquatic habitat medium to meet species requirements, including salinity, nutrients, and algal concentrations	Water Quality
Unique occurrence of wetlands in the normally semi-dry lower River Murray floodplain environment	Water delivery regime, including variations in flooding magnitude, frequency, duration, seasonality	Hydrology
	Landform processes creating depressions, basins, channels for water retention	Geomorphology
Provision of remnant lower River Murray floodplain habitat and species (not impacted by human irrigation)	Hydrologic regime, including variations in flooding magnitude, frequency, duration, seasonality	Hydrology
	Landform processes creating depressions, basins, and channels for water retention	Geomorphology
	Growth and establishment of plant species and communities	Vegetation and Habitat
High diversity and mosaic of both terrestrial and aquatic habitats	Maintenance of landform variation	Geomorphology
	Water delivery regime supporting wetland mosaic/diversity (including flood-recurrence variations, contributing to vegetation bandings)	Hydrology

Ecosystem Services	Ecological Processes Creating/Supporting the Service	Key Components
	Provision of nutrients and growth surfaces	Substrate
Supports populations of rare, endangered and threatened species (State & National)	Provision of required physical, chemical and biotic environment	Vegetation and Habitat
Diverse and abundant waterbirds	Provision of water volumes for ecosystem requirements	Hydrology
	Water delivery regime supporting wetland mosaic/diversity	Hydrology
	Provision of shelter	Vegetation and Habitat
	Provision of required physical, chemical and biotic environment	Vegetation and Habitat
Diverse fish and invertebrate fauna	Provision of water volumes for ecosystem requirements	Hydrology
	Water delivery regime supporting wetland mosaic/diversity	Hydrology
	Provision of shelter	Vegetation and Habitat
	Provision of required physical, chemical and biotic environment	Vegetation and Habitat
	Providing aquatic habitat medium to meet species requirements	Water Quality

3.5 Conceptual Models of the Site

Conceptual models draw on scientific information to describe the processes that govern ecosystem health. An ecosystem is 'healthy' when its character (its native flora and fauna, for example) is sustained over time, notwithstanding disturbances due to human activities or events like droughts and floods. In these circumstances, the ecosystem is resilient enough to withstand disturbances, maintain processes and supply resources. Its resilience depends, of course, on the degree and nature of exploitation or change. A model can describe a 'healthy' ecosystem that meets the management objective and can also include known impacts and show how they reduce health or biodiversity.

Conceptual models are "a generalised description or representation of the structure and function of a complex system". They are constructed from a series of hypotheses that:

- represent processes known to degrade ecosystems;
- identify processes which can be managed to restore ecosystem function; and,
- inform scientific investigation and monitor management actions.

3.5.1 Landscape conceptual models

The landscape models below build upon Figure 3.1 (presented at the start of Section 3) and show key components and processes, and their interactions, of the Riverland Site at a landscape scale under two sets of conditions:

- **Low water levels** with the water mainly confined to within the river channel; and (Figure 3.15); and,
- **Flood conditions** when water spills through the anabranches and across the floodplain and wetlands (Figure 3.16).

Low Water Conditions

Under low water conditions (Figure 3.15) water is retained mainly within the main channel and the rainfall (1) is not sufficient to maintain the wetlands on the floodplain. During this time, evaporation and salt concentration (5 & 6) become important processes. Some aquatic flora and fauna lay dessicant resistant eggs or seeds to hatch or germinate on the next flood. Groundwater inflows occur along the river channel and floodplain in this reach from natural sources (2) and as a result to perched water tables from local irrigation (7). Freshwater flows (4) occur from the remote, wetter catchments upstream and are altered by river regulation (3) resulting from upstream weirs and storages as well as weirs and river abstraction in this reach. Local impacts are also evident through land cleareance and soil disturbance from irrigation (7), dryland agriculture (8), grazing (9) and recreation activities (10).

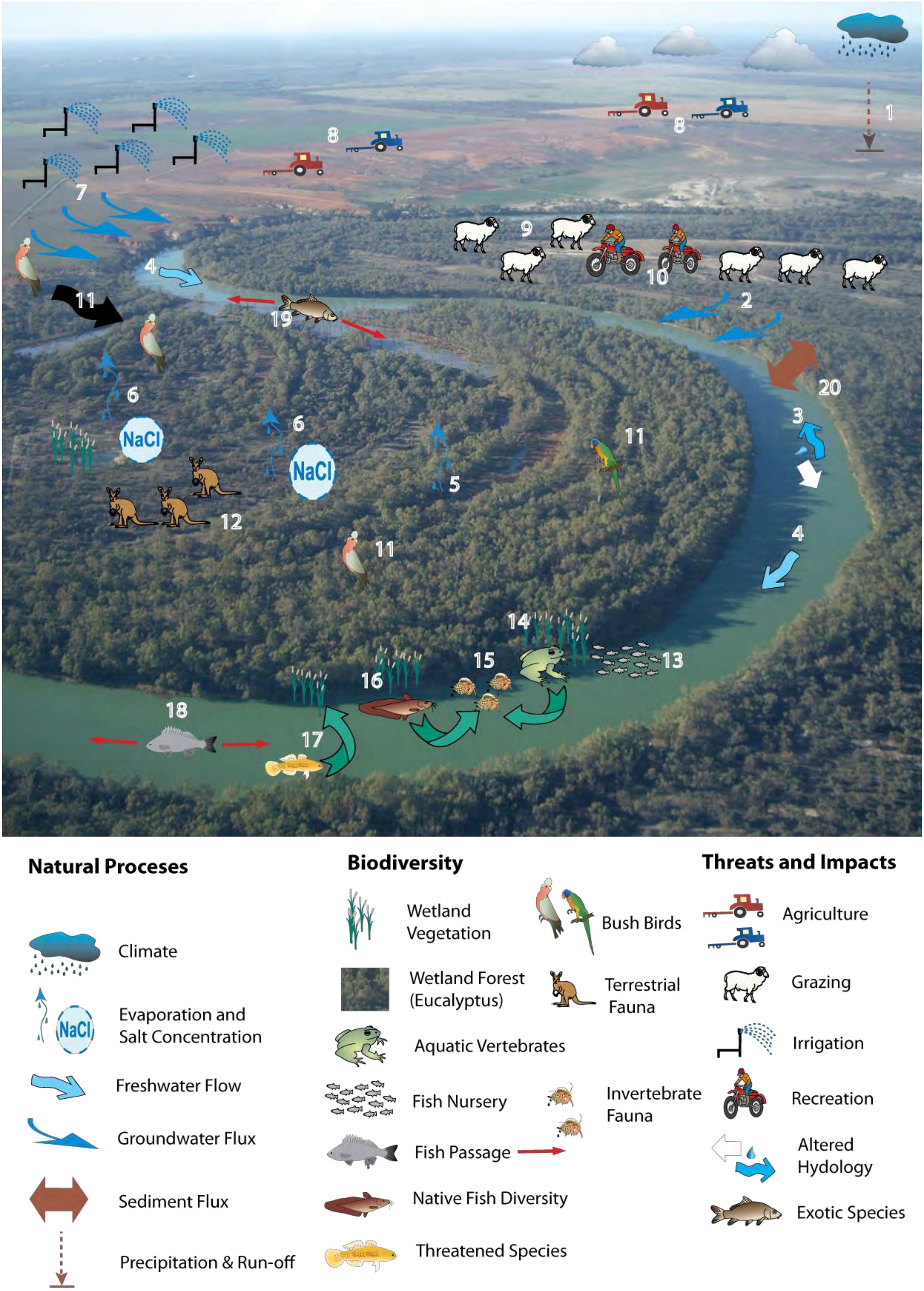

NaCl
Natural Proceses
Climate
Evaporation and Salt Concentration
Freshwater Flow
Groundwater Flux
Sediment Flux
Precipitation & Run-off
Biodiversity
Wetland Vegetation
Wetland Forest (Eucalyptus)
Aquatic Vertebrates
Fish Nursery
Fish Passage
Native Fish Diversity
Threatened Species
Bush Birds
Terrestrial Fauna
Invertebrate Fauna
Threats and Impacts
Agriculture
Grazing
Irrigation
Recreation
Altered Hydology
Exotic Species

Figure 3.15: Riverland Ramsar Landscape under low water levels (numbers in text refer to this diagram)

In the dry phase, the floodplain becomes a haven for bush birds (11) and terrestrial fauna (12), which move onto the floodplain and are able to exploit the abundant resources of the drying floodplain. The river channel is the main aquatic habitat during this period with with fish larvae (13), reptiles and frogs (14), macroinvertebrates (15) and fish (16) depending upon this vital habitat which includes riparian reeds, macrophtes and woody debris making up the majority of habitat. Fish, reptiles, and frogs all depend upon macroinvertebrate populations in the river at this time. Threatened species (17) also depend upon riparian and other habitat. The lack of high flows mean that fish undergo short, local movements both up- and down-stream (18).

Flood Conditions

Under flood conditions (Figure 3.16) water spills out of the main channel and the local rainfall (1) assists in maintaining the wetlands on the floodplain. Groundwater inflows occur along the river channel and floodplain in this reach from natural sources (2) and as a result to perched water tables from local irrigation (14). Freshwater flows (4) increases from upstream sources, however these are still altered by river regulation (3) resulting from upstream weirs and storages as well as weirs and river abstraction in this reach but flood waters inundated wetlands and the floodplain (5). Local impacts from land cleareance and soil disturbance from irrigation (14), dryland agriculture (15), grazing (16) and recreation activities (17) still occur as well as sediment fluxes from local run-off (18) from cleared or grazed lands.

As the floodplain is inundated, bush birds and terrestrial fauna (13) move from the floodplain but some species are still able to exploit the floodplain. As flows increase migratory fish make short and long upstream migrations to find additional habitat and breeding (7), native and exotic fish colonise floodplain wetlands as connections are made between the River and floodplain habitats with increasing water levels (8). As wetlands are inundated aquatic vegetation expands and creates aquatic habitat (6) including for threatened species which colonise these habitats (8). Some aquatic flora and fauna which have laid dessicant resistant eggs or seeds hatch or germinate. Fauna also colonise the inundated floodplain habitats to breed and proliferate (9), fish spawning producing larvae (10) which eventually move back to the main channel (11) as they grow. The reptiles, frogs, macroinvertebrates and fish (10) inhabiting the river channel are triggered to move onto the floodplain as water levels rise to expoit the abundant food resources, these populations increase and their condition improves before they migrate back to the main channel as water levels fall (12).

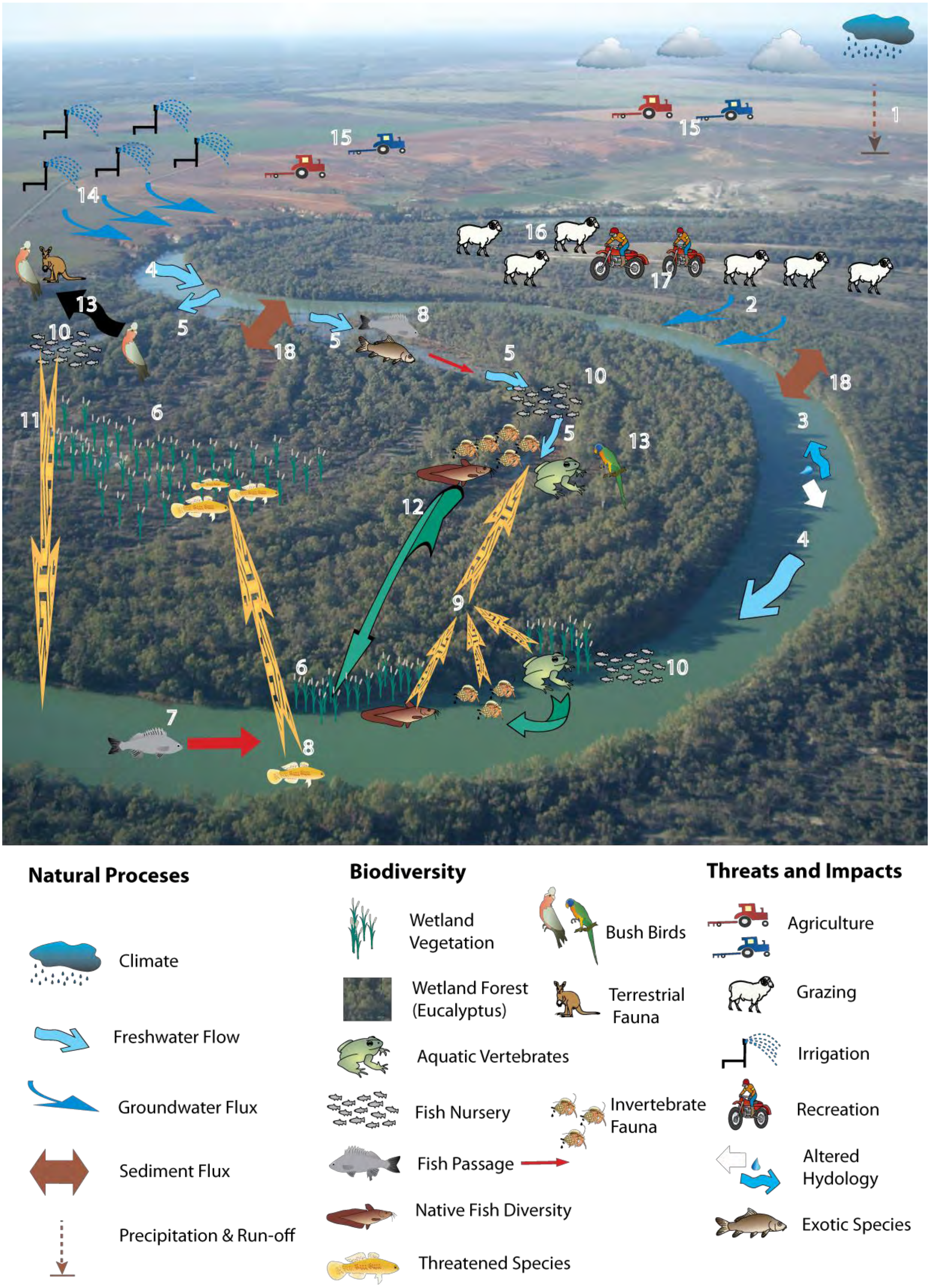


Figure 3.16: Riverland Ramsar Landscape under flood conditions (numbers in text refer to this diagram)

3.5.2 Flood levels and vegetation communities

Complementary models (Figure 3.17) represent interactions between vegetation and flooding regimes, presented as duration, frequency and extent. The visual aids for the model include:

i. floodplain cross-sections incorporating landforms, vegetation and flood levels;

ii. inundation maps for discharges that correspond with the cross-sections; and

iii. pie charts displaying duration and recurrence intervals for the specific discharges. All hydrological data used in the pie charts for Figure 3.17 were sourced from Sharley and Huggan (1995).

The following caveats apply:

- The vegetation bands are based on generalisations from the literature and personal observations. The presence of a plant community at one point in the landscape does not preclude it from occurring elsewhere. For example, lignum shrubland is shown at a lower elevation than River Redgum woodland vegetation, yet there are many places where lignum occurs as an understorey to River Redgum;

- The hydrological information presented in Figure 3.17 for 'regulated' conditions refers to modelled outputs based on data gathered since regulation and up to 1995 (and therefore approximates conditions up to the time of listing of the Site in 1987). Since then, the regional climate has been comparatively dry, with less rainfall and higher evaporation.

Figure 3.17(a) displays the flood extent at flows of 5,000 ML day^{-1}. This level of discharge maintains the water in the main channel, anabranches and creek systems without causing overbank flow. Accordingly, as displayed on the cross-section of Figure 3.17 (a), this rate of flow inundates the permanent aquatic vegetation associated with these systems. This includes habitats with River Redgum as riparian overstorey and also the habitats dominated by submerged, emergent and free-floating aquatic macrophytes. Permanent aquatic habitats disconnected from the main channel, such as billabongs and relict channels, would not be replenished from flows of this magnitude.

The permanent aquatic habitats (Plates 3.1) are significant for conservation, particularly the anabranches (Plates 3.2) which are rare on the River Murray in South Australia and resemble the channel of the River Murray prior to regulation (Sheldon and Lloyd 1990). The diversity of aquatic habitats is rated as high by Sheldon and Lloyd (1990) and is reflected in the variety of physical environments present. The anabranch creeks are important breeding areas for native fish species and refugia for declining aquatic species.

Flows of 5,000 ML day^{-1} would be exceeded 11.4 months of the year under natural (unregulated) conditions and, under regulation, are exceeded for 9.5 months of the year (Sharley and Huggan 1995). This flow was exceeded every year (displayed as 100% of years) under natural conditions and was also exceeded every year at the time of Ramsar listing [described as 'regulated' in Figure 3.17 (a) and in the paragraphs below].

As discharge increases to 40,000 ML day^{-1} [Figure 3.17 (b)], water breaches the banks of the channels and anabranches, reaching areas occupied by the fringing reed and sedge, flows into the semi-permanent aquatic habitats, and replenishes permanent aquatic habitats such as billabongs and relict channels (Plates 3.2 – 3.5). Areas of 'island' River Redgum forest are inundated by this level of discharge and some areas of herbland and samphire shrublands are also inundated [refer also to Figure 3.17 (d)]. These wetlands in the floodplain provide seasonal habitat for migratory birds listed under international agreements such as JAMBA, CAMBA and ROKAMBA.

As displayed in Figure 3.17 (b), flows of 40,000 ML day^{-1} would be exceeded for over one-third of the year (nearly five months) under natural conditions but under regulation are exceeded approximately one-quarter of the year (just over three months) (Sharley and Huggan 1995). The decreased duration is due to the highly regulated flow in the River Murray, controlled by the dams and weirs upstream of the site. This flow was exceeded in just over 90% of years under natural (unregulated) conditions and, under regulation, is exceeded for 40% of the years.

Discharges of 60,000 ML day^{-1} [Figure 3.17 (c)] occurred approximately 59% of years under natural conditions and, under regulation, occur approximately 21% of years. On average, flows of this magnitude would have been exceeded four months of each year, and under regulation are exceeded two and one-half months of each year. At this level of discharge, the Lignum Shrublands are inundated, as are more zones of Herbland and Samphire Shrubland [refer also to Figure 3.17 (d)].

Discharges of 80,000 ML day^{-1} [Figure 3.17 (d)] inundate the River Redgum Woodlands and reach the Saltbush (chenopod) Shrublands. Under natural conditions, this level of discharge occurred in 45% of years and was exceeded, on average, for just more than three months every year. Under regulation, these flows have markedly reduced, occurring on average 12% of years and are exceeded for an average of 2.6 months per year.

At discharges of 100,000 ML day^{-1} [Figure 3.17 (e)] the Black Box woodland is inundated. Pre-regulation, these flows occurred just over 30% of years and now occur in less than 10% of years. Under natural conditions this level of flooding occurs for an average of nearly three months per year, whereas under regulation flooding occurs for an average of two months per year.

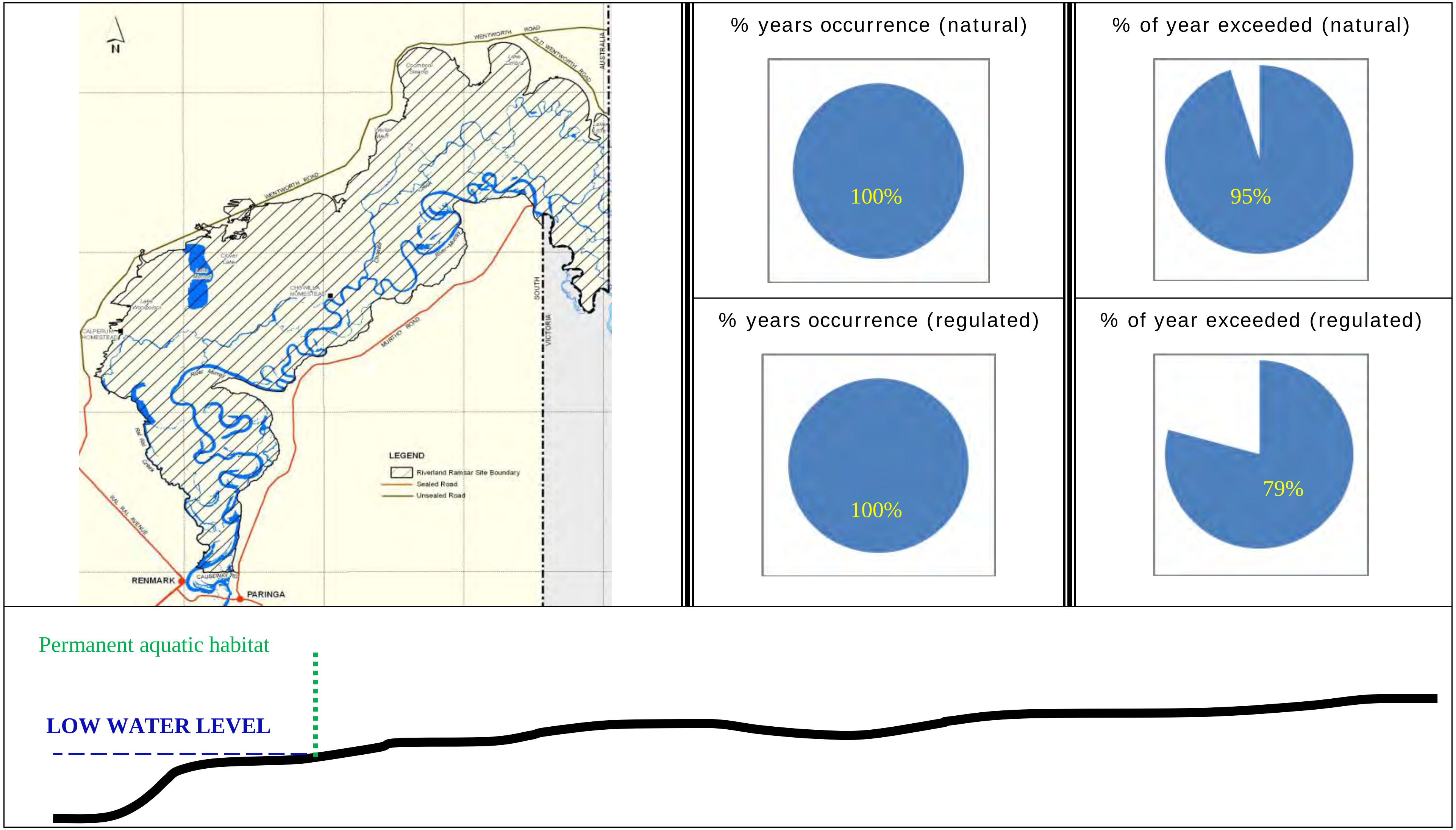
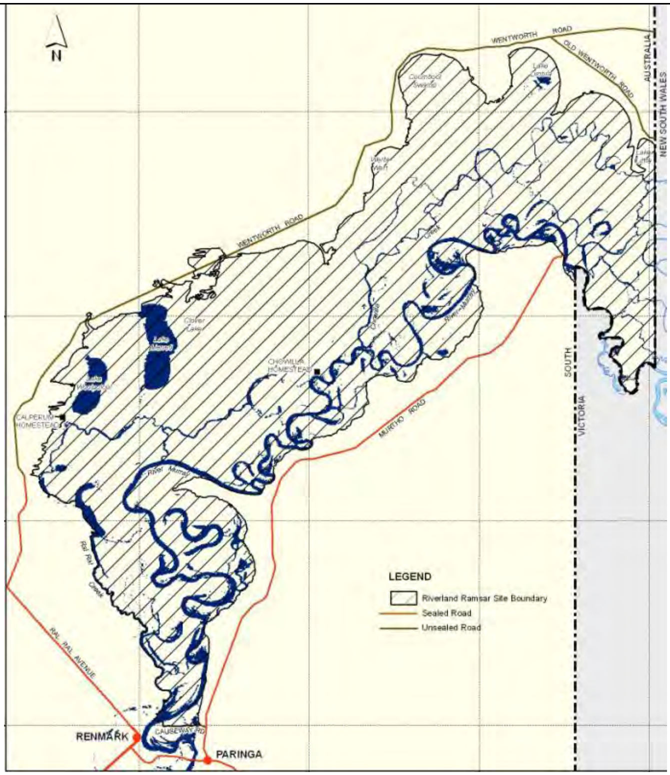
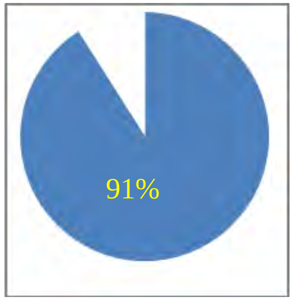


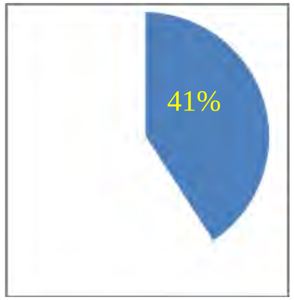
Figure 3.17 (a) Hydrological Conceptual Model 5,000 ML day-1 (= 5 GL day-1)



% years occurrence (natural)



% of year exceeded (natural)



% years occurrence (regulated)

% of year exceeded (regulated)

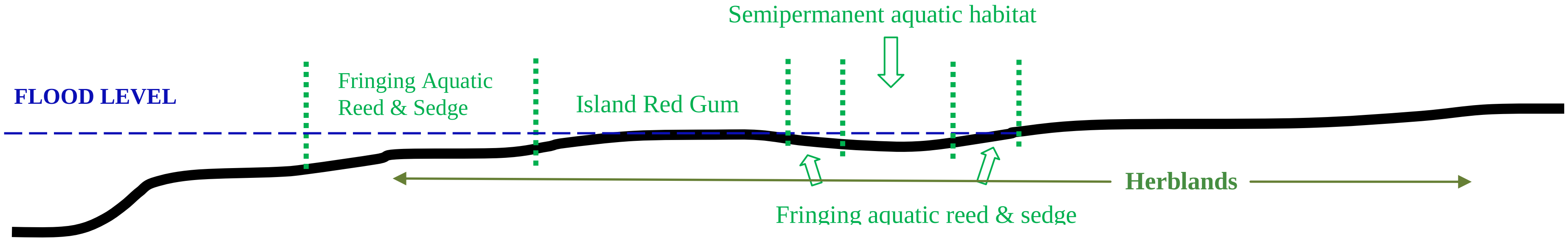


Figure 3.17 (b) Hydrological Conceptual Model 40,000 ML day-1 (=40 GL day-1)

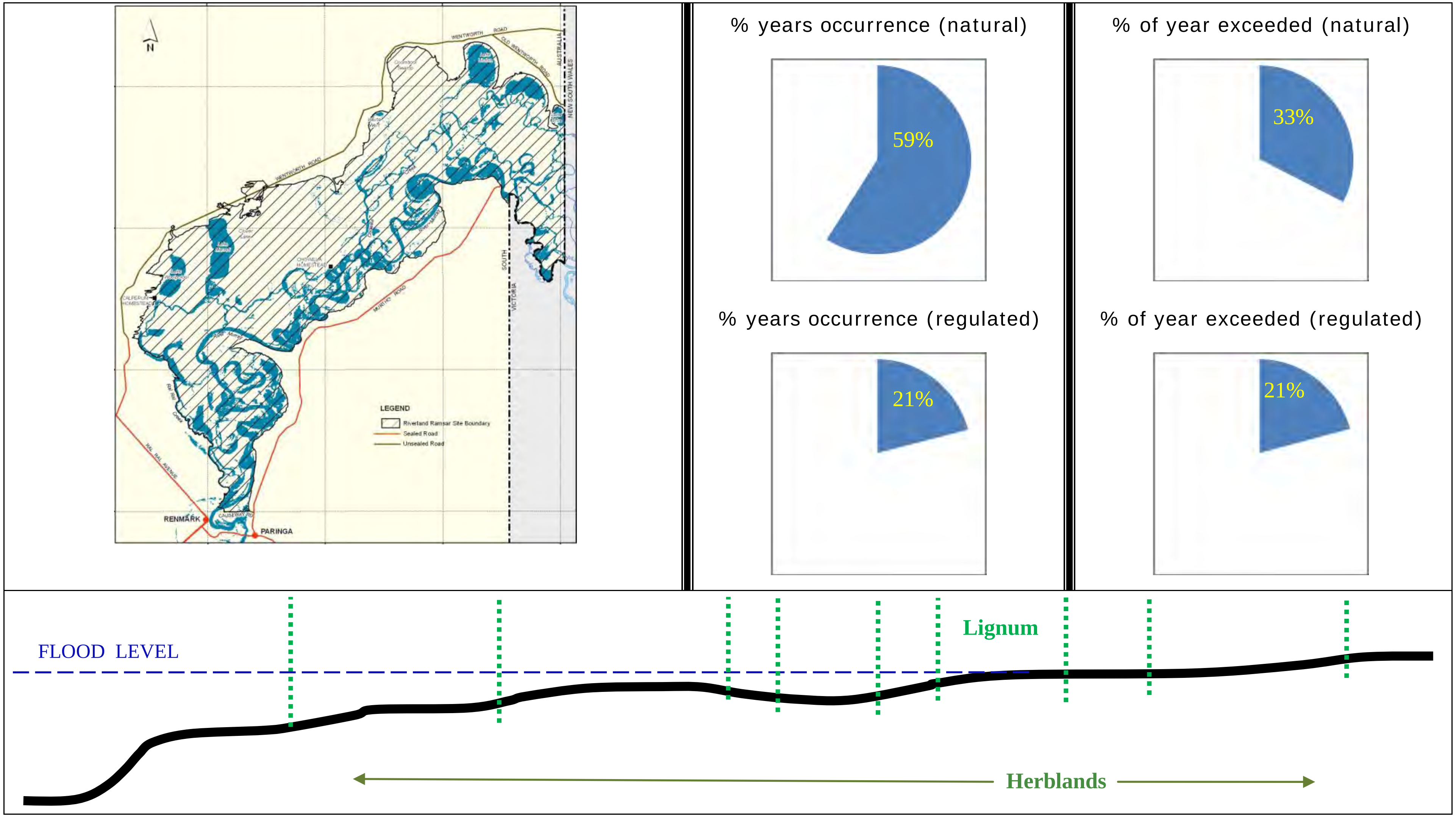


Figure 3.17 (c) Hydrological Conceptual Model 60,000 ML day-1 (=60 GL day-1)

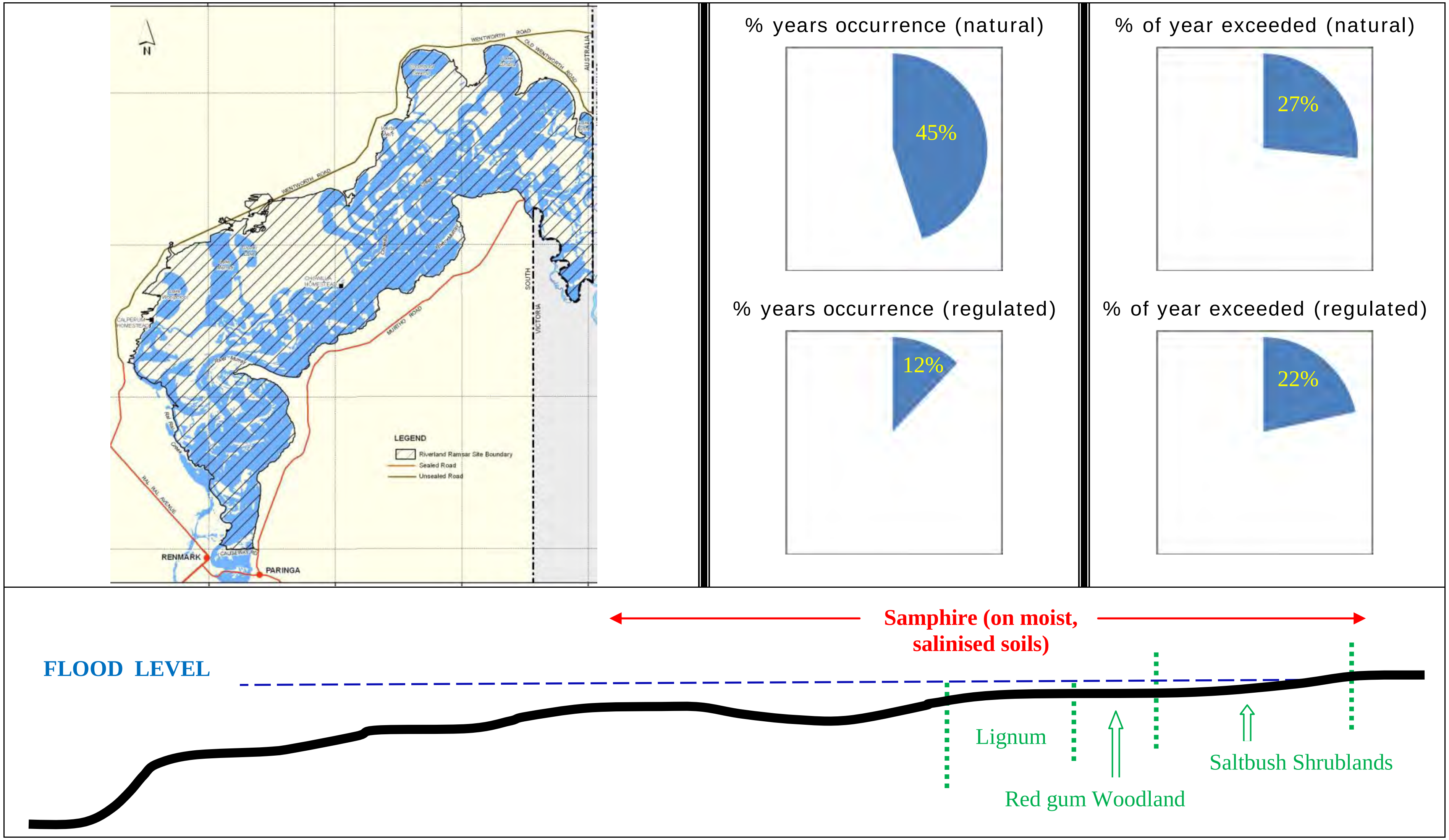
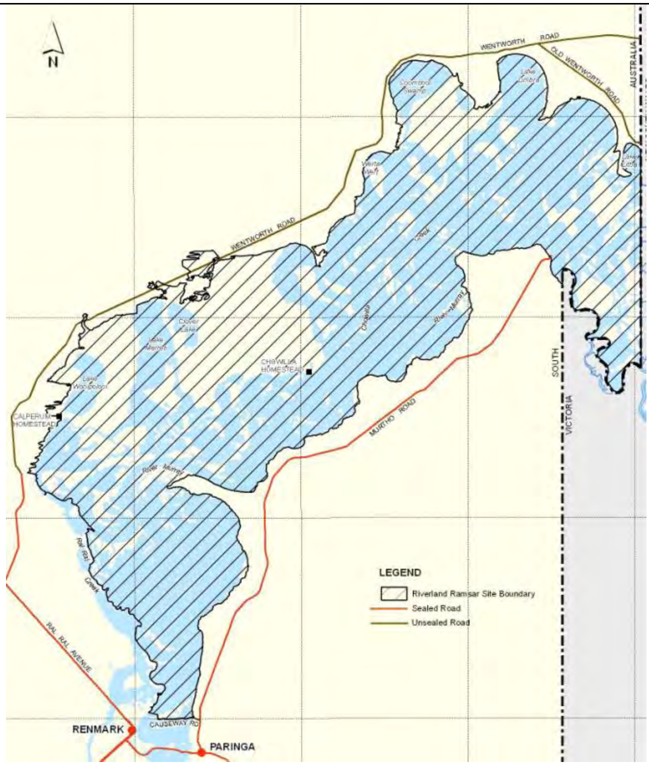
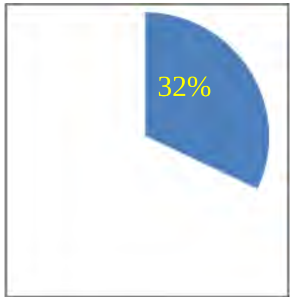


Figure 3.17 (d) Hydrological Conceptual Model 80,000 ML day-1 (=80 GL day-1)



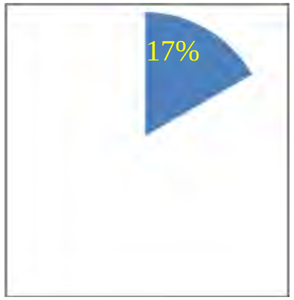
% years occurrence (natural)



% of year exceeded (natural)

% years occurrence (regulated)

% of year exceeded (regulated)



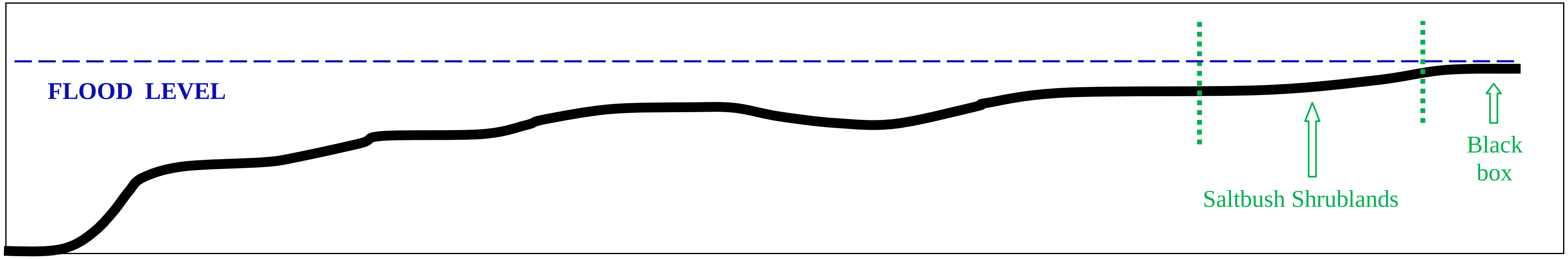


Figure 3.17 (e) Hydrological Conceptual Model 100,000 ML day-1 (=100 GL day-1)

3.5.3 Biological processes

Flooding is, perhaps, the most important natural process at the Site as it links the floodplain and the river (Lloyd et al. 1994). The floods replenish floodplain and lentic habitats with water and allow exchange of nutrients and biota. Flooding provides a period of relative stability (Odum 1969) that results in a period of "predictable" sequence of changes to the environment which can be exploited by many floodplain organisms. For example, flooding boosts invertebrate production, promotes interactions between wetland biota, triggers breeding activity in birds and fish, creates nursery habitat for fish, initiates River Redgum regeneration and growth, and creates extensive areas for aquatic plant colonisation (Lloyd et al. 1991).

The initial inflow of water on to the floodplain triggers these events. Low to higher areas are inundated sequentially until the peak of the flood has passed; nutrients, sediment and biota are contributed to the floodplain during this phase. Water levels recede rapidly at first, until natural sill heights are reached; they then decrease slowly from evaporation or seepage to groundwater (Lloyd et al. 1994).

During flood recession and droughts, river flows decrease and the water level drops, isolating the floodplain further and creating isolated wetlands and pools in anabranches. The isolation and concentration of biota into pools may result in higher mortalities from physiological stress (including oxygen deficits, temperature extremes and physico-chemical changes), increased predation (because predators have increased access to small species) and competition (because large numbers of aquatic animals become concentrated in pools). This is evident in the complete absence of a year class of the River Mussel, *Alathyria jacksoni* in the Mallee Plains zone of the River Murray, corresponding to the 1967-8 drought (Walker 1990).

Flooding drives many of the biological processes of floodplain wetlands. Plants and invertebrates re-colonise the floodplain at downstream areas during floods, either through passive distribution or active production of larvae or propagules. Floodplain wetlands rely upon the interactions between the river and its floodplain. These links are reinforced when the aquatic habitats are replenished with water, allowing exchange of nutrients and biota (Walker 1986; Boulton and Lloyd 1991, 1992).

Many plants require flooding to grow, flower, set seed or germinate. River Redgums at the Site flower and set seed in response to flooding; germinating and the seedlings rapidly grow in the moist floodplain soils. The survival of the seedlings (recruitment) - the most critical phase – is enhanced by mild summers following flooding, and by shallow flooding in subsequent years (Dexter 1967). While perennial hydrophytes sprout from buried rhizomes, annuals are dependent on seed-banks or propagule stores in the soil to re-establish after a dry spell. Some may respond in the first weeks of flooding; others may require several weeks before germinating (Casanova & Brock 1990, Ward 1992; Lloyd et al. 1994).

Flooding is also important to fish as it triggers spawning activity and creates nursery habitat for young fish (Geddes & Puckridge 1989; Gehrke 1990, 1991, 1992;

Puckridge & Walker 1990, Boulton & Lloyd 1992; Lloyd et al. 1994). The rapidity of invertebrate emergence from the sediments produces a valuable food resource suitable for juvenile and post-larval fish (e.g. Golden Perch; Arumugam & Geddes 1987) and waterfowl (Braithwaite 1975, Briggs & Maher 1983, Briggs & Maher 1985, Maher & Carpenter 1984, Crome 1986, Crome & Carpenter 1988).

From studies of wetland sediment samples from the Site, invertebrates emerge from resting stages in the floodplain sediment during the first week of reflooding are small enough to be prey for juvenile fish (Boulton & Lloyd 1992). Callop, Silver Perch and carp gudgeons all first feed at about 5-6 days of age, whereas Murray Cod and catfish undertake first feeding at about 20 days (Lake 1967). This timing matches the peaks of emergence of invertebrates from sediments (Boulton & Lloyd 1992).

During flooding, fish may undertake a range of significant movements. Long migrations of Golden and Silver Perch have been observed during floods (Reynolds 1983, Mallen-Cooper 1989), presumably as part of their spawning behaviour. Shorter movements for breeding, feeding or habitat selection occur during all flows (Lloyd et al. 1991; Mallen-Cooper 1989).

3.5.4 Physico-chemical processes

The pre-regulation River Murray, like other floodplain rivers, was characterised by large variations in flow within and between years (Walker 1986). Under a natural regime, the incoming flood water alters the environment of floodplain habitats as the flow rate increases, supplying water with low salinity, high turbidity, variable temperatures and low oxygen levels. The floodwaters spread over the floodplain, re-connecting the river to isolated backwaters and billabongs and each other. Subsequent flooding of the floodplain wetlands results in further physico-chemical changes.

Nutrients and other chemicals are released from sediments and organic detritus, and through re-colonisation by aquatic organisms. Also, the process of flooding can cause an initial pulse of available nitrogen as nitrates which is then lost as nitrogen gas.

Key nutrient-cycling processes may also be affected indirectly by flooding and drying, through sediment waterlogging and desiccation cycles. It has been demonstrated that nutrient pulses were experienced about four days after floodplain sediments were inundated. Ion concentrations, as well as pH and turbidity, were inversely correlated to water level (Briggs et al. 1985). Concentrations of organic carbon were positively correlated to leaf-fall from River Redgum, phytoplankton productivity and biomass of aquatic plants. Dissolved organic carbon was negatively correlated to water level (Briggs et al. 1993).

Flooding flushes water of low pH, low oxygen concentration and high tannin content from pools on the floodplain into the main river stem (Morison 1989). Although this may be a strong chemical signal of flooding to fish in the river, the dissolved polyphenolic compounds in blackwater are known to be toxic to native fish fry and other animals (Lloyd et al. 1994). These compounds, derived from the decomposition of tannins and lignin from vascular plant material, play other central roles in the wetland ecosystem. They contribute to, and in some cases dominate, the pool of dissolved organic carbon (DOC).

During drought, increases in salinity and temperature (at least in shallow waters), decreases in oxygen concentration and other changes in physico-chemistry, are further stressors for the animals and plants. These changes are a signal to many organisms to avoid drought by setting seed or laying resistant eggs that germinate or hatch in subsequent floods (Casanova & Brock 1990, Brock 1991; Boulton & Lloyd 1992).

3.5.5 Groundwater processes

Relatively fresh groundwater has been shown to be an important source of water for River Redgums on the floodplains of the Site and along the lower River Murray in South Australia (Thorburn & Walker 1993; Thorburn et al., 1992). Upstream of structures such as weirs or locks, groundwater under the floodplain can be raised by as much as two metres. This can have an adverse effect on deep-rooted plant species where the groundwater is saline. These conditions can result in widespread decline in woodland species, especially when combined with reduced flushing from river regulation (Jolly et al. 1992). Locally elevated groundwater can also change the water regime of nearby floodplain wetlands and streams from wet-dry to permanently wet (Lloyd et al. 1994).

Regular floods are important to the groundwater, as they recharge soil water and also flush salts that have accumulated through dry periods (Jolly *et al*., 1993; Overton and Jolly, 2004). The build-up of salts in the soils and around tree roots can stress and even kill trees. Salinisation of floodplain soils is a major factor in the declining health of floodplain trees and, in many areas, it has caused extensive vegetation death (Holland et al. 2006). Dieback is evident on the floodplains of the Site and throughout the lower River Murray in South Australia, which is a function of the combined effects of rising saline groundwater and river regulation. Flushing of salt from floodplain soils now occurs less due to reduced flood frequency (MDBC, 2003). This mechanism is shown in Figure 3.18.

The impacts of river regulation on groundwater process are exacerbated by the effects of the current drought. The lack of medium-large to large floods since prior to listing of the Site has allowed salt accumulation to proceed without significant mitigation and also intensified the water stress being felt by many of the vegetation communities through the reduction of small to medium floods.

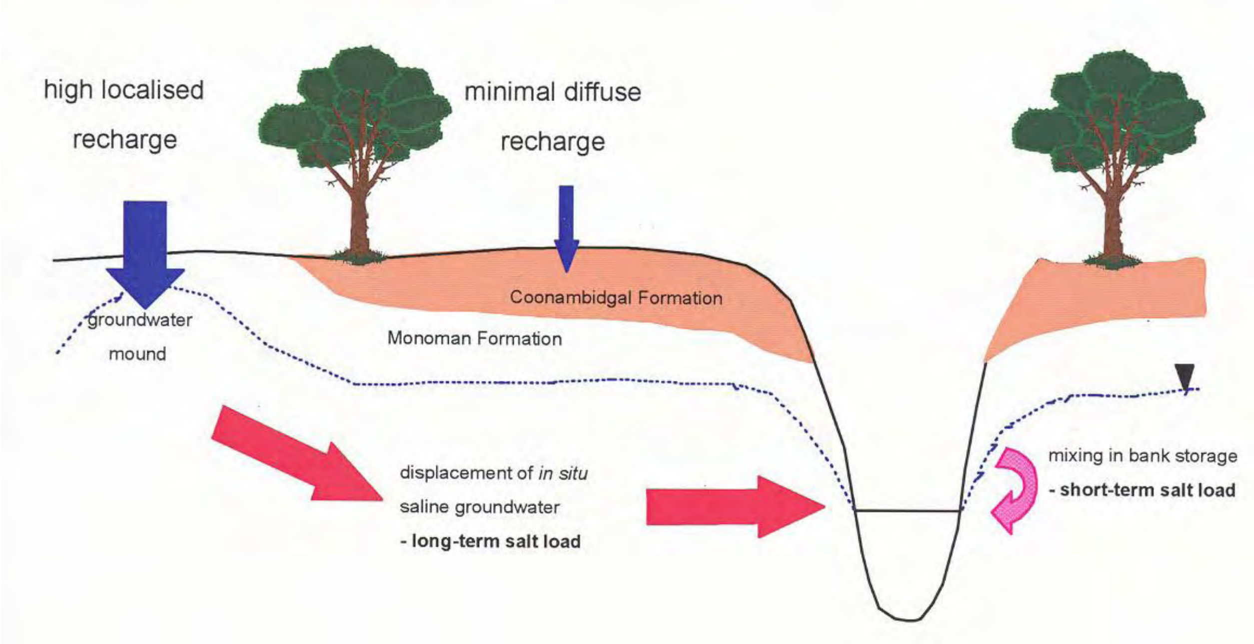


Figure 3.18: Mechanisms that lead to the accession of saline groundwater to floodplain streams, following major floods *Source:* Overton and Jolly, 2004

3.6 Key Actual or Potential Threats to the Site

Hydrology is the driving process for the ecological character of the Site. As detailed in section 3.2.4 of this document, the Site's hydrology can be separated into pre-regulation and post-regulation periods. Hydrological characteristics of these periods comprise:

Pre-regulation:

- seasons with highly variable flows;
- high flows, cool, turbid and fast flowing water in spring and early summer;
- gradual change at end of summer to low flows, warm, clear and slow moving water during autumn and winter;
- marked variation between years;
- cease-to-flow during droughts - contracting to saline pools fed by saline groundwater;
- local anabranches formerly flowed only during floods or high flows; and,
- floodplain inundation (and the refilling of disconnected wetlands) determined by flood magnitude, proximity to the river channel and local topography.

Post-regulation:

- significant changes to the seasonal nature of flow regime, including permanent base flows, leading to permanent inundation of connected wetlands, and also delay in flood initiation and a reduction in flood duration;

- significant change (reduction) in the frequency of small to moderate sized floods, leading to reduction in the moderate sized overbank flow events that covered large portions of the Site;
- reduced recharge of local groundwater ('freshwater lens') in semi-permanent wetlands, leaving insufficient water for trees;and,
- river level raised by 3 m. Impacts include:
  - banking water up into the anabranch system, leading to permanent inundation of some ephemeral wetlands, hence loss of a summer drying phase;
  - a back-pressure on the adjacent groundwater, with saline groundwater consequently flowing into the now inundated anabranches and reaching the River Murray downstream of Lock 6, via the anabranch system; and,
  - back pressure on the groundwater, leading to rising water tables on the floodplain creating salinity stress for the tree cover.

Figure 3.19 displays the influences of regulation on the Site's hydrology, with a marked reduction in the occurrence of higher flows that occurred under a natural (pre-regulation) regime (red lines) compared with the current (post-regulation) regime (blue lines). For example, the probability of a flood exceeding 60 GL/day between 1966 and 1986 with no regulation was 20% (solid red line, Figure 3.19). With regulation, the probability of a similar flow in the same time period dropped to less than 10% (solid blue line, Figure 3.19). The drop in frequency of floods in the range of 5 – 100 GL/day is clearly displayed on the exceedance curve. Although less obvious, the reduction in probability of the larger floods (greater than 100 GL/day) is also significant, as these rare flows are important for large areas of Black Box woodland and chenopod shrubland communities.

Post-listing:

Within the post-regulation period, in the time since listing, the Site has experienced a change of climate, with an extended dry period at the Site and within the Murray-Darling catchment. This has resulted in an exacerbation of many of the impacts caused by regulation, including:

- further reduction (absence) of flooding;
- further reduction of recharge of ground water; and
- greater salinity impacts due to decreased flushing of salts from the soil.

As well as displaying the impacts of regulation, Figure 3.19 also displays changes to the hydrology of the site since the time of listing. The dashed lines in Figure 3.19 show the 1987 to 2007 flow exceedance probabilities, compared with the 1966 to 1986 probabilities. The reduced flows are a function of a drier climate and also increased water extraction upstream. Note that increased water extraction is also a function of a drier climate. Figure 3.19 displays the extent to which the drier climate and increased extractions have exacerbated the impacts of regulation on the post-listing hydrology of the Site, with the dashed blue line showing a large difference from the solid red line. For example the 1 in 5 year flood (i.e. 20 percent probability) has dropped from 60 GL/day in the pre-regulation, prelisting period, to 20 GL/day with regulation impacts and the post-listing climate.

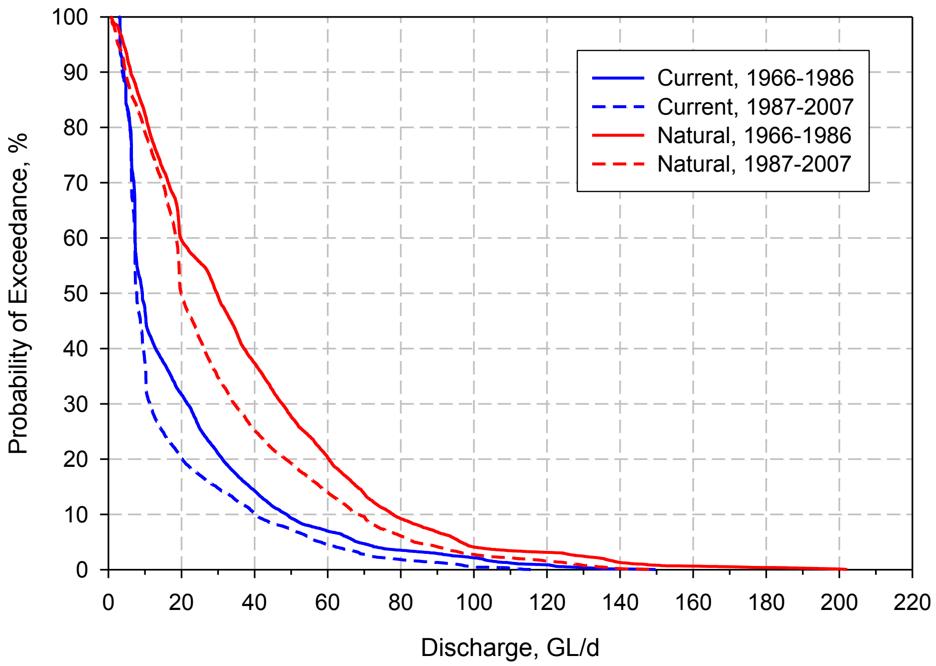


Figure 3.19: Flow exceedance curves for the Site, displaying modelled flows under natural and "current" (= post-regulation) conditions, for the 20 years before listing and 20 years after listing.

The frequency, season, magnitude, duration and rate of rise and fall of high flow events have powerful influences on the many aspects of the biota, including growth, survival, reproduction and recruitment (the replenishment of individuals, to a stage capable of reproducing, across a species).

The hydrological needs vary between species and, within a species, vary between life cycle stages. For example, ibis require floodplain inundation for nest protection from predators. The requirement may be a particular depth (e.g. 0.5 m) for a particular time period (e.g. 3 months). During this time any marked increase or decrease in water may lead to large-scale recruitment failure. However, large-scale recruitment may not be necessary every year, and variations between years may not harm the overall status of the species. Other species (e.g. some aquatic macrophytes) require continual small-scale inundation whereas some tree species, such as Black Box, may require major flooding every twenty years.

Within this context the regulated, altered flow regime is an existing threat due to it creating unnatural, permanent or near-permanent flooding of the anabranches and creeks of the site, and also a reduction in frequency and duration of medium floods that cover much of the site.

The Site's floodplain and wetlands have been degraded by rising saline groundwater and significant reduction in the frequency and inundation period of flood events.

Processes lost from the reduced floods include flushing of soil salts and the replenishment of freshwater lenses overlying the saline groundwaters. This degradation has been exacerbated by grazing pressures (by native and domestic animals) as well as the proliferation of pests and weeds.

Changing climate is a potential threat to the Site through the impact of reduced rainfall and increased evaporation. This poses a very high threat to the ecological character of the Site. If the current 'prolonged drought' in most parts of the Murray-Darling Basin is, in fact, the beginning of a new climatic regime, the impacts will be major for the Site with severely constrained options for water delivery regimes.

Salinity is an actual and potential threat, with its impacts occurring through many potential pathways. The current drought conditions within the Murray-Darling Basin have led to lower groundwater tables and consequently reduced saline discharges from waterways (e.g. Barr Creek) into the main channel of the River Murray. A return to higher rainfalls could increase the risk of increased salt contributions from higher in the catchment. Salinity threats also occur through the groundwater at or near the site, with altered flow regimes causing back-pressure on the saline groundwater and its flow into the anabranches. Similarly, the altered flow regimes and accompanied reduction in flooding in some depressions cause a loss of local freshwater lenses over saline aquifers. These issues will need to be considered and discussed in management plans for the Site. As noted earlier (Section 3.2.4), river regulation has also reduced the frequency and duration of the floods that leach salt from the plant root zone (Overton et al. 2006a). This reduction in flushing exacerbates the impacts of salt deposition from the rising saline groundwaters and has led to a severe decline in the health of riparian vegetation communities on the floodplains of the Site (Overton et al. 2006a). In this way, the reduction in flooding created by regulation of the river not only starves the floodplain trees of water for function and growth, but also creates a level of soil salinity that makes it more difficult for the plant roots to extract water from the soil, due to osmotic pressures, and is potentially toxic to the trees (Overton et al. 2006a). The extent of change since listing, and the predictions for future changes resulting from this threat, are more fully discussed in section 4.

Sedimentation at the site has been noted as increasing markedly. The natural pre-European settlement sedimentation rate for Chowilla wetlands was likely to be in the order of < 1mm/year. At Tareena Billabong, on the NSW part of the lower River Murray floodplain, this increased to 20 mm year early in European settlement and reduced thereafter (Gell et al., 2005). Post-regulation sedimentation rates (as reported by analyses by ANSTO) in Ral Ral Creek are 10 mm/year. This poses a genuine threat of filling in some parts of the wetland, turning it into terrestrial habitat. This issue should be addressed in the management plans for the Site, although controlling the causes may require off-site management.

Obstruction to fish passage is an important threat as this site provides a "natural fishway" around Lock 6, so further structures constructed across floodplain channels may prevent regional and local fish movement. These structures impact on fish populations by preventing fish moving to find mates or food and prevents access new habitats. Some species must swim upstream to breed and barriers may cause these species to re-absorb eggs.

Obstructions to fish passage, grazing pressure, pest flora and fauna, and human recreational impacts to the Site are common problems to many areas of conservation significance and should also be addressed within management plans for the Site.

The major threats can therefore be listed as:

- Altered flow regime;
- Climate change, particularly synergies between decreased rainfall and increased evaporation;
- Salinity;
- Very high sedimentation rates for wetlands;
- Elevated and altered groundwater regime;
- Obstructions to fish passage and desnagging;
- Grazing pressure;
- Pest flora and fauna; and,
- Human access and motorised recreation.

Whilst recognising the importance of all the threats listed above, the three most serious threats and their impacts on components, processes or services of the Site are presented in Table 3.6. The rationale for highlighting these three threats is provided in the paragraphs above, and the implications for monitoring needs is presented in Table 3.7.

Table 3.6 Key threats to the Riverland Ramsar Site

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Likelihood	Timing of threat
Altered flow regime	• significant changes to the seasonal nature of flow regime • permanent, artificial inundation of connected wetlands • delay in flood initiation • reduction in flood duration • reduction in the frequency of small to moderate sized floods • reduction in the moderate sized overbank flow events that cover large portions of the Site • reduced recharge of local groundwater, leaving insufficient water for trees • river level raised by 3 m	Certain - occurring	Immediate
Changed Climate	• further reduction (absence) of flooding • further reduction of recharge of ground water • greater salinity impacts due to decreased flushing of salts from the soil	Currently occurring	Immediate
Salinity	• severe decline in the health of riparian vegetation communities on the floodplains of the Site • combining with altered flow regimes and changed climate to increase stress and death of floodplain vegetation	Currently occurring	Immediate

3.7 Limits of Acceptable Change

Limits of acceptable change are defined as "the range of variation in the components, processes and benefits/services that can occur without causing a change in the ecological character of the site" (DEWHA 2008). Identification of these limits will assist management of the Site, by defining 'ecological boundaries' that cannot be crossed without impacting on its ecological character.

Limits of acceptable change in this document were based on key ecosystem services (Table 3.7) and key components and processes that support these services (vegetation and hydrology, Table 3.8). If the hydrological limits provided for maintenance of the vegetation communities (Table 3.8) are met, then it is likely that the limits for ecosystem services (Table 3.7) will also be met. Limits of acceptable change for water quality are not set, apart from salinity, because they do not strongly affect the ecological character of the Site independent of other factors.

Assessments were constrained by:

- limited knowledge for some components that contribute to the ecological character;
- knowledge gaps in relation to the natural variability of these components; and,
- the need to accommodate the altered flow regime to the Site and its future influence.

Despite these issues, **interim** limits of acceptable change need to be defined based on available data, knowledge and information. These limits can be refined as more data are obtained.

Table 3.7 displays the major ecological services of the site. The table also describes the major threats, the baseline information requirements, and **interim** limits of acceptable change to these services, beyond which the ecological character is changed. The limits provided in Table 3.7, based on ecological services, are high-level 'endpoints' for acceptable change of the Site. These are important for assessing changes to, and status of, the Site's ecological character. However, they must be supported by quantitative limits assigned to the major processes and the key components (Table 3.8) that underlie the ecological services.

The controlling influence of hydrologic regime on the Site's ecological character has been a major theme of this document. Informed management of the hydrologic regime forms the basis of future management of the Site as a whole. The magnitude, frequency, seasonal timing and duration of inundating flows controls the vegetation, salinity, habitat, breeding requirements and, ultimately, the form and function of all benefits and services of the Site. Therefore, the limits of acceptable change for the hydrologic regime, presented in Table 3.8, define the conditions required to support the Site's ecological character. In summary, appropriate management of the Site's hydrologic regime should form the first step in the management of the Site's ecological character.

The limits of acceptable change to ecosystem services, presented in Table 3.7, are primarily for 'endpoints' of the Site's management, whereas the limits of acceptable change for hydrology (Table 3.8) are for the processes that control these endpoints.

Additional LAC explanatory notes

Limits of Acceptable Change are a tool by which ecological change can be measured. However, Ecological Character Descriptions are not management plans and Limits of Acceptable Change do not constitute a management regime for the Ramsar site.

Exceeding or not meeting Limits of Acceptable Change does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting Limits of Acceptable Change may require investigation to determine whether there has been a change in ecological character.

While the best available information has been used to prepare this Ecological Character Description and define Limits of Acceptable Change for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The Limits of Acceptable Change may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this Ecological Character Description and carefully evaluate the suitability of the information for their own purposes.

Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

Table 3.7: Limits of acceptable change for key ecosystem services of the Riverland Ramsar Site

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
<u>Wetland of international significance (& part of Riverland Biosphere Reserve)</u> The Site is listed against the first eight of the Ramsar criteria: 1. representative, rare, or unique example of a wetland type within a bioregion 2. supports vulnerable, endangered, or critically endangered species or threatened ecological communities. 3. supports species important for maintaining the biological diversity of a bioregion. 4. supports species at a critical stage in their life cycles, or provides refuge 5. regularly supports 20,000 or more waterbirds. 6. regularly supports 1% of the individuals in a population of one species or subspecies of waterbird. 7. supports indigenous fish, contributing to global biological diversity. 8. important source of food/habitat/migration path, depended upon by fishes.	Overall, the major direct threat to the status of the Riverland Site and the subjects of its listing criteria is the altered hydrologic regime due to river regulation. Threats that contribute to or augment the effects of altered hydrology include: • climate change; • soil salinity; • groundwater salinity and rising water tables • sedimentation; • fish barriers; and • grazing; • weeds and vermin.	The baseline condition of many components of the site is poorly quantified, including quantitative measures of several of the listing criteria. In particular, the population numbers (and their natural fluctuation) of listed species have not been documented. Similarly, many pre-listing studies of the fish and water birds at the site were mainly focused on species lists rather than quantitative assessment. More recently, quantitative studies of fish and waterbirds at the site have been undertaken, although during a prolonged drought, which was not occuring at the time of listing. Baseline information requirements therefore include: documentation of population numbers of listed species and their natural distributions; and quantitative assessments of bird and fish fauna across the site, including seasonal	At a high level, the baseline condition of the site for this service can be described as 'meeting the first eight listing criteria'. The **short-term and long-term limits** of acceptable change should both be 'no loss of any listing criteria'. These listing criteria comprise most of the other ecological services identified for the Site, and are presented in the rows below.

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
		fluctuations.	
Contains representative and rare, example of a wetland type within the Murray River Drainage Division (includes Ramsar Criterion1: contains a representative, rare, or unique example of a wetland type within a bioregion). The Site is representative of a floodplain system within the region, and also rare in that almost all of the other examples these wetland types in the region have been impacted by irrigation.	Similar to the previous ecosystem service, altered hydrology is the major threat to the wetland types of the site. The key aspects include changes to timing (season), quantities and delivery rates of flows, as well as recurrence intervals and period (length) of inundation. Stresses to the wetland types include the effects on salinity and groundwater, as well as the potential shift in key plant species with changes in the hydrology salinity status.	Baseline information requirements would include data on the health, extent, floristic composition and spatial variability of each identified wetland type within the Site. A broad vegetation survey of the site has been undertaken. The data gathered should be examined for their suitability in contributing to the requirements listed above, and information gaps identified.	The limits of acceptable change are based on a precautionary approach to maintenance of the sites mosaic of wetland types. The **short term limits** of acceptable change should be: no loss of more than 10% of any wetland type over the site as a whole, within any 2-year period. The **long-term limits** of acceptable change should be no loss of more than 20% of any wetland type over the site as a whole, within any 10-year period.
Supports populations of rare, endangered and threatened species (State & National) (includes Ramsar Criterion 2: Supports vulnerable, endangered, or critically endangered species or threatened ecological communities). Four nationally-listed and twenty-two state-listed faunal species have been found at the Site. Approximately half of these species are directly dependent on aquatic habitat, with the remainder dependent on the adjacent	The largest threat to baseline conditions in terms of listed species is again altered hydrologic regime from river regulation, particularly for species dependent on aquatic habitats. For many of the species not directly dependent on aquatic habitats, climate change and increasing soil and water salinity are also major threats. Limits of acceptable change for the hydrologic regime (refer to Table 3.8) have been developed to	The population numbers (and their natural fluctuation) of listed faunal species have not been documented. Similarly, many pre-listing studies of water birds and other animals at the site were mainly focused on species lists rather than quantitative assessment. More recently, quantitative studies of fish and waterbirds at the site have been undertaken, although these represent the Site during a	The condition at the time of listing for many threatened species, particularly faunal species, is unknown (in terms of population numbers, trends, ranges) and requires further assessment. There are more data available for the listed species of flora, through vegetation surveys. There are qualitative data

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
shrublands and woodlands. Twenty eight state-listed floral species have also been recorded at the Site.	provide watering requirements designed to manage these threats.	prolonged drought, which was not being experienced at the time of listing. Baseline information requirements therefore include: documentation of population numbers of listed species and their natural distributions; and quantitative assessments of bird and fish fauna across the site, including seasonal fluctuations. Vegetation survey data needs to be interrogated to ensure that there is sufficient information to enable baseline description and future monitoring of distributions and abundances of listed floral species.	from 2002 (vegetation) and 2003 (fauna) available for the listed species*. The limits of acceptable change will need to be based on quantitatively surveyed numbers of each listed species. Surveys should be undertaken as soon as possible and repeated within 2 to 5 years (see monitoring needs, Section 6 of this document). These surveys can be to define the level of variation. **Short term** and **Long term limits** of acceptable change should be no loss of any listed species of flora and fauna.
<u>Provision of remnant lower River Murray floodplain habitat and species</u> (includes Ramsar Criterion 3: Supports species important for maintaining the biological diversity of a bioregion) Bioregional diversity is maintained through the provision of the mosaic and range of wetland types, which support the species assemblages	Similar to the previous ecosystem service, the largest threat to the biological diversity of the Site lies in the altered hydrologic regime through river regulation. The biota of the Site has developed with, and adapted to, the pre-regulatory hydrologic regime, relying upon the variety of flooding events that occurred under natural conditions. The loss of this natural variability	Baseline information requirements include: documentation of population numbers of listed species and their natural distributions; and quantitative assessments of mammals, reptiles, amphibians, aquatic macroinvertebrates, molluscs, and macrocrustaceans, across the site, including seasonal	<u>Fauna</u>: The pre-listing condition and diversity of the faunal groups is unknown, in terms of complete species lists, distributions and abundances. The **short term limits** of acceptable change should be no loss of recorded species and should be derived from the

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
associated with those habitats. Noted elements of the bioregional diversity within the Site include representative, rare and/or threatened species of flora and fauna (including species of birds, mammals, reptiles, amphibians, aquatic macroinvertebrates, molluscs, macrocrustaceans and fish).	threatens the Site's biodiversity. Also similar to the previously described service, climate change is another major threat to the Site's biodiversity, with the potential to compound the impacts of the altered hydrologic regime, as well as create long-term, near-drought conditions. Salinity increases in groundwater or surface waters can have a significant impact on the riparian and floodplain trees and therefore the whole structure of the ecosystem as well as direct impacts upon wetlands. That said, saline wetlands provide habitat for the vulnerable Murray Hardyhead. Weed invasions, introduced animals, and overgrazing by stock, native and feral animals all threaten native species and communities. Most weed species at the Site are associated with pastoral activities, with grasses and daisies being the most commonly recorded taxa. Several pest plant species can impact or displace native plants, thereby threatening the Site's biodiversity. Similarly, the impacts of overgrazing can reduce the	fluctuations. The appropriate surveys should be undertaken in conjunction with the bird and fish fauna surveys and the listed species surveys (discussed above).	qualitative 2003 baseline information*. A quantitative survey should be undertaken as soon as possible and repeated 5-yearly. The changes can be used to define the level of variation, which could be used in future limits of acceptable change. Flora The baseline condition for flora is better established, with a several vegetation surveys of the Site having been undertaken. The **short term limits** of acceptable change should be: no loss of any rare species of flora over any time period and no loss of any vegetation community type, excluding seasonal variations and natural annual variations. Tree health data recorded in 2003 and work undertaken by CSIRO (CSIRO 2005) show tree health cannot decline further than the 2003 conditions, without causing significant

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
	regenerative capacity of a vegetation community or population, causing changes to the Site's flora and vegetation structure. Feral animals can also pose threats to the faunal biodiversity of the Site, with species of reptiles, mammals and birds at risk of predation from cats and foxes.		changes to the site's ecological character (refer section 4). This was based on an estimated 24% of tree (River Redgum, Black Box and Coobah) cover being healthy. Flora and Fauna The **long-term limits** of acceptable change should be: • no loss of any rare or threatened species of flora or fauna • no net reduction in populations of native bird, fish, mammal, mollusc, macrocrustacean, reptile or amphibian fauna over any 10 year period (currently a knowledge gap); • no loss of more than 20% of any vegetation type over the site as a whole within any 10 year period (see Table 3.3); and, • no deterioration beyond the 2003

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
			condition of tree health (CSIRO 2005).
Diverse and abundant waterbirds Part 1 (includes Ramsar Criterion 4: Supports species at a critical stage in their life cycles, or provides refuge) The site provides critical summer or stopover habitat for migratory birds listed under international agreements. It also provides habitat for nomadic waterbirds during regional drought and for nomadic bush-bird species during the dry summer.	The altered flow regime due to river regulation threatens many of the species that rely on natural flow regimes for breeding. This has been discussed earlier in the Table, whereby specific needs in relation to timing, magnitude and areal extent of flooding are impacted by the artificial flow regime of the site. Another major threat to this ecosystem service is climate change, with water shortages through reduced precipitation across the basin and increased evaporation. Increased salinity of water also poses a significant threat to this ecosystem service, with habitat provision and drinking water likely to be impacted if groundwater salinities increase and/or saline water tables rise. However, the saline Lake Woolpolool harbours species not found in freshwater areas of the site.	The information requirements for this Ecosystem Service would be covered by undertaking the surveys described in the table cells above.	Apart from presence data and some estimates of population sizes at specific locations, much of the pre-listing condition for these species across the Site is not well known. **Short term limits** of acceptable change should be derived from future quantitative surveys. A quantitative survey should be undertaken in the near future and repeated at 5-yearly intervals. Changes would be used to define the level of variation, which could be used in future limits of acceptable change. **Long-term limits** of acceptable change should be: • no net reduction in waterbird breeding numbers over any rolling 10 year period (currently a knowledge gap); and • no net reduction in

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
			waterbird populations (particularly migratory) over any rolling 10 year period (currently a knowledge gap).
Diverse and abundant waterbirds Part 2 (includes Ramsar criteria 5 & 6: Regularly supports 20,000 or more waterbirds AND Regularly supports 1% of the individuals in a population of one species or subspecies of waterbird). The site has regularly been recorded with more than 20,000 individuals of waterbird, including numbers of Freckled Duck, Red-necked Avocet and Red-kneed Dotterel that exceed 1% of their estimated global populations	Altered flow regime due to river regulation and climate change both present the greatest potential impacts to the numbers of waterbirds and the populations of individual species, for reasons discussed above Inappropriate management of individual wetland is also a threat. For instance, ad hoc management of sites which allow inundation for too long or too short a period can affect fish, waterbirds and vegetation.	The information requirements for this Ecosystem Service would be covered by undertaking the surveys described in the table cells above.	**Short term limits** of acceptable change should be derived from future quantitative surveys. A quantitative survey should be undertaken in the near future and repeated at 5-yearly intervals. Changes would be used to define the level of variation, which could be used in future limits of acceptable change. **Long-term limits** of acceptable change should be: • no reduction in number of years with >20,000 waterbirds (currently a knowledge gap); and • The site continues to support >200 Freckled Duck, >260 Red-kneed Dotterel and >1100 Red-necked Avocet

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
			across the whole site at same frequency as present (currently a knowledge gap).
Diverse fish and invertebrate fauna (includes Ramsar criteria 7 & 8: Supports indigenous fish, contributing to global biological diversity AND Provides an important source of food/habitat/migration path, depended upon by fishes). The site supports 14 species of native fish and approximately 100 taxa of invertebrates, with the floodplain wetlands supporting a more diverse macroinvertebrate fauna than the main channel.	Altered flow regime due to river regulation and climate change present the greatest potential impacts to the fish fauna of the Site including: loss/reduction of habitat through decreased flows; loss/reduction of spawning triggers and spawning habitats; and loss of floodplain connectivity with the channels. Other threats include: • Water quality – increased salinity and turbidity and eutrophication have been recorded in the Lower River Murray, with impacts on the fish and invertebrate fauna • Desnagging – removal of coarse woody debris reduces the quantity and diversity of habitat, with impacts on the number and diversity of faunal species • Riverbank stability – altered flow regimes, impacts on riparian vegetation and salinity can all contribute to decreased	The information requirements for this Ecosystem Service would be covered by undertaking the surveys described in the table cells above.	Similar to much of the fauna at the Site, there is currently insufficient information available for quantitative limits of acceptable change. **Short term limits** of acceptable change should be should be derived from comparing data from the 2005/06 baseline information (from Zampatti et al. 2006a & 2006b) and a future survey. The changes would be used to define the level of variation, which should not be exceeded in any 2 year period. **Long-term limits** of acceptable change should be: • no loss of any rare or threatened fish and invertebrate species; and

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
	riverbank stability, reducing habitat for fish and invertebrates • Introduced animals – in particular, European Carp and Eastern Gambusia threaten native fish and invertebrates. European Carp uproot aquatic macrophytes, increasing turbidity, and may compete for food and habitat. Eastern Gambusia also compete for food and habitat, prey on eggs and young of native fish species, and also have adverse effects on aquatic macroinvertebrates and frogs. • Barriers prevent movements of fish		• no net reduction in fish and invertebrate populations over any rolling 10 year period.
<u>High diversity and mosaic of both terrestrial and aquatic habitats</u> The range of classifications of the Site's aquatic and terrestrial habitats has displayed a high diversity for both environments, particularly within the context of the region.	Similar to previous ecosystem services, the largest threat to the biological diversity of the Site lies in the altered hydrologic regime due to river regulation. The habitats of the Site have developed with the pre-regulatory hydrologic regime, relying upon the variety of flooding events that occurred under natural conditions. The loss of this natural variability threatens the Site's habitat diversity.	Although the vegetation of the Site has been surveyed, a detailed examination of the survey data is required to ensure the data is categorised in a form that enables ready assessment of changes in vegetation character and habitat provision. For example, every part of the site could be categorised in terms of Ramsar Wetland Types, with accurate	Baseline condition for habitat diversity can be defined using vegetation surveys undertaken at the Site as a basis (refer Table 3.3, this document). This should be supplemented by future surveys of the Site, as required. The **short term limits** of acceptable change should be no loss of any habitat type, excluding seasonal

Ecosystem service	Threats to ecosystem services	Baseline information requirements	Interim limits of acceptable change
	Also similar to previously described services, climate change is a major threat to the Site's habitat diversity, with the potential to compound the impacts of the altered hydrologic regime, as well as create long-term, near-drought conditions. Soil salinity, groundwater salinity and rising saline water tables threaten the structure of the River Redgum and Black Box forests and woodlands as further trees die, which will have impacts on lack of riparian shading and woody debris provision to the aquatic habitats.	measures of area covered by each wetland type documented.	variations and natural annual variations. No further death of trees and no increase in the area of unhealthy trees should occur in any two year period. The **long term limits** of acceptable change should be no loss of more than 20% of any habitat type, over the site as a whole (i.e. diversity and mosaic must be maintained)

*Baseline information on the presence of flora and fauna species at the site can be found at the DEH website (www.deh.sa.gov.au)

As discussed in Section 3.3 the major process driving the Site's ecological character is hydrology. The influence of hydrology is through the magnitude, frequency, duration of floods and droughts, rates of rise and fall of water levels and seasonal timing of water delivery to the site, and also through depth and salinity of groundwater. Similarly, the vegetation communities are a key component defining the Site's ecological character, providing the habitat and landscape that form the basis of the ecological services (Section 3.2.6). The distribution, growth and health of plant communities are strongly determined by the hydrology of the system.

Therefore, limits of acceptable change must be presented for the vegetation and for the major processes that determine status and viability (water delivery and groundwater salinity). Table 3.8 displays the communities, their hydrological requirements and salinity tolerances. Hydrological requirements for each community vary according to the ecological function being supported. For example, the water delivery requirement for promoting *survival* of individuals within the Black Box community will be different to the water delivery requirement for promoting *recruitment* within the Black Box community.

In this document, "survival" and "recruitment" are defined as:

- survival: maintaining the life of an individual or species' population
- recruitment: the establishment and growth to reproductive maturity of offspring at a spatial scale sufficient to sustain the population

The survival and recruitment requirements for the Riverland Ramsar Site are both presented within Table 3.8.

In normal circumstances, recruitment requirements should form the boundaries for limits of acceptable change, as recruitment is necessary to sustain the community and hence preserve ecological character. However, within the context of current drought conditions and limited water allocations, hydrologic requirements for survival must also be considered. Information in Table 3.8 is derived from a variety of sources, including existing literature (especially Roberts and Marston 2000), personal knowledge of the authors, and expert input from Mike Harper (DEH, Berri). The discharge magnitudes (GL day-1) are specific to the Site. They represent the volumes of water required to inundate the vegetation community at the Site and are based on information presented in Section 3.2.7 of this document.

The entries in the column 'Required hydrologic regime: for survival (= short-term limit for acceptable change)' in Table 3.8 represent the absolute limit of acceptable change in the short-term. Without meeting these minimum requirements, there is an unacceptable likelihood of major loss of the corresponding vegetation community. Longer-term limits of acceptable change (third column of Table 3.8) focus on the hydrologic requirements for the longer-term sustainability of each vegetation community, through provision of a hydrologic regime that enables recruitment.

Two features of the information provided in Table 3.8 need further clarification. These are: the interaction between salinity impacts and water delivery requirements; and the benefits of 'serial' flooding. The water delivery requirements for each community's ecological functioning are often derived independently of salinity regime. However, in some situations the root zone salinity at a site will alter the water delivery requirements for survival of a vegetation community. For example, it is now known that Black Box communities require more frequent flooding or other sources of fresh water once the root zone salinity reaches 40,000 EC (40,000 µS cm^{-1}) (Holland et al. 2006). In Table 3.8, we have allocated root zone salinity tolerances based on available literature and personal observation of the site. Many of the entries were based on Bailey and Boon (2002) 'Upper Salinity Levels'. As the data used in the Bailey and Boon data base were compiled from measured EC conditions at which individual species have been observed, there is a reasonable potential for overestimating tolerances. For example, if a species is observed at an EC of 5000, this does not necessarily mean that the species can reproduce or recruit at that salinity. It only means that an individual of that species can exist for an unknown period of time under those conditions. As a conservative precaution, we have taken the upper level data from Bailey and Boon (2002) and multiplied it by one quarter to derive our salinity estimates in Table 3.8. For the permanent and semi-permanent aquatic communities, and also the fringing reed and sedge communities, we have provided EC tolerances for ambient surface water rather than root zone salinities.

Serial flooding is used here to describe flooding at a location that occurs two or three times in succession. Studies have documented the benefits of serial flooding for a range of biota, including frogs (Mike Harper, pers. comm.) and fish (Lloyd et al. 1991; Lloyd et al. 1994), Black Box and River Redgum (George et al. 2005; Jensen et al. in press). Within stressed vegetation communities, an initial flood promotes the health of the individuals within a population, which leads to greater seed production. River Redgum and Black Box trees (and many other species of *Eucalyptus*) typically hold their seed banks within the canopy for a year or more prior to release. A second flood will promote germination, and a third flood will increase soil moisture and aid survival of seedlings that have not developed a sinker root (which provides some independence of surface soil conditions). Therefore (for example), a recommendation of 'one flood every seven or eight years' may be better applied as 'three floods, approximately one year apart, every 20 years' in a situation where the recruitment of dominant or key taxa will be markedly improved by serial flooding. However, this approach will also need to consider the full suite of biota associated with the site. Species with a short life cycle (e.g. some small fish) clearly need more opportunities to reproduce and recruit than once in 20 years.

Table 3.8: Limits of acceptable change for key components and processes of the Riverland Ramsar Site (refer Table 3.2 for further information on natural associated hydrologic regime for each vegetation community)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †**
Aquatic – permanent Key species: • *Vallisneria americana* • *Potamogeton crispus* • *Myriophyllum* spp.	Required recurrence interval • annual (watercourses) • 1 in 2 years (swamps, billabongs) Duration • permanent Timing (season) • permanent Magnitude (GL/day) • 3 for channels • > 26 for billabongs and swamps Maximum time between events • 0 for channels • 1 year for billabongs and swamps **Percent of Community maintained by this regime: 62% (combined with semi-permanent aquatic community)**	Required recurrence interval • annual (watercourses) • 1 in 2 years (swamps, billabongs) Duration • permanent Timing (season) • permanent Magnitude (GL/day) • 5 for channels • up to 40 for some billabongs and swamps Maximum time between events • 0 for channels • 1 year for billabongs and swamps	1,500 EC (1000 mg/L) (surface water) (James and Hart 1993; Nielsen et al. 2003)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = μS.cm^{-1}) †**
Aquatic – semipermanent Key species: • *Marsilea drummondi*	Required recurrence interval • 1 in 2 years Duration • 3 – 6 months Timing (season) • Spring/Summer Magnitude (GL/day) • 40 Maximum time between events • 1 year **Percent of Community maintained by this regime: 62% (combined with Permanent aquatic)**	Required recurrence interval • 9 years in 10 Duration • Long duration, Frequently not drying out at all Timing (season) • Aug/Sep to Jan/Feb Magnitude (GL/day) • 40 Maximum time between events • 1 year	1,500 EC (1000 mg/L) (surface water) (James and Hart 1993; Nielsen et al. 2003)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	Required hydrologic regime: for survival (=short-term limit for acceptable change)	Required hydrologic regime: for recruitment (= long-term limit for acceptable change)	Root zone salinity tolerances‡ (EC = $\mu S.cm^{-1}$) †
Fringing aquatic reed & sedge Key species: • *Typha domingensis* • *Typha orientalis* • *Phragmites australis* • *Cyperus gymnocaulos* • *Bolboschoenus caldwellii,* • *Bolboschoenus medianus*	Required recurrence interval • 1 in 2 years Duration • 6 months Timing (season) • winter – spring/early summer Magnitude (GL/day) • 25 – 30 (adjacent to channel) • 45 – 60 (on low relict meander plain) Maximum time between events • 1 – 2 years if well established **Percent of Community maintained by this regime: 89%**	Required recurrence interval • 1 in 1 – 2 years (nearly every year) Duration • 3 months (summer) or 6 months (winter), to enable seedlings to establish Timing (season) • shallow inundation for germination, deeper water (10 – 15 cm) for seedling establishment Magnitude (GL/day) • 25 – 30 (adjacent to channel) • 45 – 60 (on low relict meander plain) Maximum time between events • 6 – 9 months	1,500 EC (1000 mg/L) (surface water) (James and Hart 1993; Nielsen et al. 2003)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	Required hydrologic regime: for survival (=short-term limit for acceptable change)	Required hydrologic regime: for recruitment (= long-term limit for acceptable change)	Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †
River Redgum forest (flood dependent understorey) Key understorey species: • *Muehlenbeckia florulenta*	Required recurrence interval • 1 in 3 years; no more than 24 months without flooding Duration • 4 – 7 months on average, no more than 24 months continuous flooding Timing (season) • winter - spring Magnitude (GL/day) • 50 (for approx 1/3 of this veg comm.); 80 (for approx 80% of this veg. comm.) Maximum time between events • 2 years **Percent of Community maintained by this regime: 38% (50 GL/day); 78% (80 GL/day)**	Required recurrence interval • 7-9 years in 10 Duration • 120 days Timing (season) • spring Magnitude (GL/day) • 50 (for approx 1/3 of this veg comm.); 80 (for approx 80% of this veg. comm.) Maximum time between events • serial inundation 2 to 3 years in succession to optimise recruitment probability	1830 EC (1100 mg/L) (based on 25% of Upper Salinity Level from Bailey and Boon 2002)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	Required hydrologic regime: for survival (=short-term limit for acceptable change)	Required hydrologic regime: for recruitment (= long-term limit for acceptable change)	Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †
Lignum shrubland Key species: • *Muehlenbeckia florulenta*	Required recurrence interval • 1 in 3 - 10 years; more frequently in saline soils (>1.5 mS cm^{-1}) Duration • minimum 6 months (possibly as low as 3 months) Timing (season) • unknown. Possible that season may be critical, with summer floods lasting long enough to wet soil profile Magnitude (GL/day) • 50 GL/day will reach 1/3 of community; 70 GL/day will reach 2/3) Maximum time between events • unknown. Complete drying required between floods to enable cracking and aeration of soils. **Percent of Community maintained by this regime: 37% (50 GL/day); 73% (70 GL/day)**	Required recurrence interval • 1 in 2-8 years; more frequently in saline soils (>1.5 mS cm^{-1}) Duration • 120 days Timing (season) • unknown. Possible that season may be critical, with summer floods lasting long enough to wet soil profile Magnitude (GL/day) • 50 GL/day will reach 1/3 of community; 70 GL/day will reach 2/3) Maximum time between events • unknown. Complete drying required between floods to enable cracking and aeration of soils.	1830 EC (1100 mg/L) (based on 25% of Upper Salinity Level from Bailey and Boon 2002)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †**
River Redgum woodland (flood tolerant understorey) Key understorey species: • *Muehlenbeckia florulenta* • *Myoporum platycarpum* • *Sporobolus mitchellii* • *Paspalum vaginatum*	Required recurrence interval • 1 in 3 years; no more than 24 months without flooding Duration • 4 – 7 months on average, no more than 24 months continuous flooding Timing (season) • winter - spring Magnitude (GL/day) • 50 (for approx 1/3 of this veg comm.); 70 (for approx 2/3 of this veg. comm.) Maximum time between events • 2 years **Percent of Community maintained by this regime: 34% (50 GL/day); 70% (70 GL/day)**	Required recurrence interval • 7-9 years in 10 Duration • 120 days Timing (season) • spring Magnitude (GL/day) • 50 (for approx 1/3 of this veg comm.); 70 (for approx 2/3 of this veg. comm.) Maximum time between events • serial inundation 2 to 3 years in succession to optimise recruitment probability	1830 EC (1100 mg/L) (based on 25% of Upper Salinity Level for *Muehlenbeckia florulenta* from Bailey and Boon 2002)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †**
River saltbush chenopod shrubland Key species: • *Atriplex rhagodioides* • *Atriplex nummularia*	Required recurrence interval • 1 year in 30 Duration • 2 – 4 months Timing (season) • possibly not critical Magnitude (GL/day) • 60 (for approx 1/4 of this veg comm.); 300 (for majority of this veg. comm.) Maximum time between events • unknown **Percent of Community maintained by this regime: 27% (60 GL/day); ~100% (300 GL/day)**	Required recurrence interval* • 1 year in 10 (2-3 years in succession every 30 years) Duration • long enough to saturate surface soil, with slow recession Timing (season) • unknown Magnitude (GL/day) • 60 (for approx 1/4 of this veg comm.); 300 (for majority of this veg. comm.) Maximum time between events • unknown	Up to 23,000 (Norman 2007)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = $\mu S.cm^{-1}$) †**
Low chenopod shrubland Key species: • *Disphyma clavellatum* • *Disphyma crassifolium* • *Enchylaena tomentosa* • *Maireana schistocarpa*	Required recurrence interval • 1 year in 30 Duration • 2 – 4 months Timing (season) • possibly not critical Magnitude (GL/day) • 70 (for approx 1/2 of this veg comm.); 300 (for most of this veg. comm.) Maximum time between events • unknown **Percent of Community maintained by this regime: 49% (70 GL/day); ~100% (300 GL/day)**	Required recurrence interval* • 1 year in 10 (2-3 years in succession every 30 years) Duration • long enough to saturate surface soil, with slow recession Timing (season) • unknown Magnitude (GL/day) • 70 (for approx 1/2 of this veg comm.); 300 (for most of this veg. comm.) Maximum time between events • unknown	Soil ECe = 20 dS/m (recruitment) and 30 dS/m (survival)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	**Required hydrologic regime: for survival (=short-term limit for acceptable change)**	**Required hydrologic regime: for recruitment (= long-term limit for acceptable change)**	**Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †**
Samphire low shrubland Key species: • *Halosarcia pergranulata* • *Sarcocornia quinqueflora*	Required recurrence interval • 1 in 3 - 10 years; more frequently in saline soils (>1.5 mS cm^{-1}) Duration • minimum 6 months (possibly as low as 3 months) Timing (season) • unknown. Possible that season may be critical, with summer floods lasting long enough to wet soil profile Magnitude (GL/day) • 50 – 60 (for approx 60% of this veg comm.); 80 (for 80% of this veg. comm.) Maximum time between events • unknown **Percent of Community maintained by this regime: 60% (60 GL/day); ~82% (80 GL/day)**	Required recurrence interval • 1 in 2-8 years; more frequently in saline soils (>1.5 mS cm^{-1}) Duration • 120 days Timing (season) • unknown. Possible that season may be critical, with summer floods lasting long enough to wet soil profile Magnitude (GL/day) • 50 - 60 (for approx 60% of this veg comm.); 80 (for 80% of this veg. comm.) Maximum time between events • unknown	Soil ECe = 20 dS/m (recruitment) and 30 dS/m (survival)

Vegetation Community (as defined with hydrologic regime in Table 3.2)	Required hydrologic regime: for survival (=short-term limit for acceptable change)	Required hydrologic regime: for recruitment (= long-term limit for acceptable change)	Root zone salinity tolerances‡ (EC = µS.cm^{-1}) †
Black Box woodland Key understorey species: • *Atriplex rhagodioides* • *Atriplex nummularia*	Required recurrence interval • 1 year in 30 Duration • 2 – 4 months Timing (season) • possibly not critical Magnitude (GL/day) • 70 (for approx 20% of this veg comm.); 100 (for 40% of this veg. comm.); 300 (for almost all of this veg. comm.) Maximum time between events • 30 years **Percent of Community maintained by this regime: 22% (70 GL/day); 41% (100 GL/day); ~100% (300 GL/day)**	Required recurrence interval* • 1 year in 10 (2-3 years in succession every 30 years) Duration • long enough to saturate surface soil, with slow recession Timing (season) • unknown Magnitude (GL/day) • 70 (for approx 20% of this veg comm.); 100 (for 40% of this veg. comm.); 300 (for almost all of this veg. comm.) Maximum time between events • unknown	40,000 maximum (<40 dSm^{-1}, Holland et al. 2006)

*required recurrence interval should be subject to adaptive management to achieve rapid succession flooding

‡, The salinity estimates in this Table have been derived from upper level data in Bailey and Boon (2002) and multiplied by one quarter as a conservative approach

† For aquatic communities (i.e. the permanent and semi-permanent aquatic communities, and also the fringing reed and sedge communities), EC tolerances are provided for ambient surface water rather than root zone salinities