ecological
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SDL Floodplain Watering Projects: Rationale and Outcomes

Mallee Catchment Management Authority

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The Commonwealth Environment and Biodiversity Protection Act gives effect to four international agreements to protect migratory birds:

- the Bonn Convention
- the Japan Australia Migratory Bird Agreement (JAMBA)
- the China Australia Migratory Bird Agreement (CAMBA)
- the Republic of Korea Australia Migratory Bird Agreement (ROKAMBA)

This report presents the status of birds under these agreements.

Under JAMBA, CAMBA and ROKAMBA bird species are 'listed'.

The Bonn Convention appendices identify migratory taxa at and below the species level as well as some whole families. The following codes are used to represent the status of Australian species under the appendices of the convention:

- A1 - species listed explicitly in Appendix 1
- A2S - species listed explicitly in Appendix 2
- A2H - species is a member of a family listed in Appendix 2
- A2S* - species listed as a result of a recent taxonomic revision of a species listed explicityl in Appendix 2

Bioregional Conservation Status of Ecological Vegetation Classes

Status	**Status Code**	**Criteria**
Presumed Extinct	X	Probably no longer present in the bioregion (the accuracy of this resumption is limited by the use of remotely - sensed 1:100 000 scale woody vegetation cover mapping to determine depletion - grassland, open woodland and wetland types are particularly affected).
Endangered	E	Contracted to less than 10% of former range; OR -European than 10 extent remains; OR Co rarity is comparable overall to the above: • 10 to 30% pre-European extent remains and severely degraded over a majority of this area; or • naturally restricted EVC reduced to 30% or less of former range and moderately degraded over a majority of this area; or • rare EVC cleared and/or moderately degraded over a majority of former area.
Vulnerable	V	10 to 30% pre-European extent remains; OR Combination of depletion, degradation, current threats and rarity is comparable overall to the above: • greater than 30% and up to 50% pre-European extent remains and moderately degraded over a majority of this area; or • greater than 50% pre-European extent remains and severely degraded over a majority of this area; or • naturally restricted EVC where greater than 30% pre-European extent remains and moderately degraded over a majority of this area; or • rare EVC cleared and/or moderately degraded over a minority of former area.
Depleted	D	Greater than 30% and up to 50% pre-European extent remains; OR of depletion, degradation and current threats is comparable overall to the above and: • greater than 50% pre-European extent remains and moderately degraded over a majority of this area.
Rare	R	Rare EVC (as defined by geographic occurrence) but neither depleted, degraded nor currently threatened to an extent that would qualify as Endangered, Vulnerable or Depleted.
Least Concern	LC	Greater than 50% pre-European extent remains and subject to little to no degradation over a majority of this area.

Species Conservation Status under the EPBC Act

Status	Status Code	Criteria
Extinct	EX	A native species is eligible to be included in the **extinct** category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
Critically Endangered	CR	A native species is eligible to be included in the **critically endangered** category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered	EN	A native species is eligible to be included in the **endangered category** at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable	VU	A native species is eligible to be included in the **vulnerable category** at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.

Species Conservation Status under the Victorian Advisory List of Threatened Plants in Victoria 2005

Status	Status Code	Criteria
Presumed Extinct in Victoria	X	Not recorded from Victoria during the past 50 years despite field searches specifically for the plant, or, alternatively, intensive field searches (since 1950) at all previously known sites have failed to record the plant.
Endangered in Victoria	E	At risk of disappearing from the wild state if present land use and other causal factors continue to operate.
Vulnerable in Victoria	V	Not presently endangered but likely to become so soon due to continued depletion; occurring mainly on sites likely to experience changes in land-use which would threaten the survival of the plant in the wild; or, taxa whose total population is so small that the likelihood of recovery from disturbance, including localised natural events such as drought, fire or landslip, is doubtful.
Rare in Victoria	R	Are but not considered otherwise threatened - there are relatively few known populations or the taxon is restricted to a relatively small area.
Poorly Known in Victoria	K	Poorly known and suspected, but not definitely known, to belong to one of the above categories (x, e, v or r) within Victoria. At present, accurate distribution information is inadequate.
Listed	L	Listed under the Flora and Fauna Guarantee Act 1998 (Vic)

Species Conservation Status under the Victorian Advisory List of Threatened Vertebrate Fauna in Victoria 2013

Status	Status Code	Criteria
Extinct	X	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual) and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Regionally Extinct	RX	As for Extinct but within a defined region (in this case the state of Victoria) that does not encompass the entire geographic range of the taxon. A taxon is presumed Regionally Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout the region have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild	EW	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered	CR	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (IUCN Standards and Petitions Subcommittee 2010), and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Endangered	EN	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (IUCN Standards and Petitions Subcommittee 2010), and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable	VU	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (IUCN Standards and Petitions Subcommittee 2010), and it is therefore considered to be facing a high risk of extinction in the wild.
Near Threatened	NT	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for, or is likely to qualify for, a threatened category in the near future.
Data Deficient	DD	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

1 INTRODUCTION

1.1 SCOPE OF WORK

Ecological Associates was engaged by the Mallee Catchment Management Authority to develop the ecological background, rationale and objectives for seven proposed SDL Offset project sites.

The legal and policy framework for the use of environmental water in the Murray-Darling Basin is set out in the Basin Plan. The Basin Plan places a Sustainable Diversion Limit (SDL) on the water that can be extracted from the system for irrigation and other uses. The SDL is based on an assessment of the water that must be left in the system to maintain ecosystem health. To comply with the initial Basin Plan SDL, water must be purchased from existing entitlement holders and applied to environmental needs.

The Basin Plan includes a mechanism to adjust the SDL. The SDL may be increased if there are supply measures available that achieve an equivalent environmental benefit with less water. A program to develop supply measures and other SDL offset measures has been developed to meet the requirements of the Basin Plan. Business cases will be prepared for each project and funding arrangements will be proposed. The performance of twelve ecological elements under the broad categories of waterbirds, fish and vegetation will be evaluated across the southern connected Murray-Darling Basin to assess the environmental benefit of the supply measures (Overton, et al. 2014).

The Mallee CMA is preparing business cases for seven supply measure projects: Lindsay Island, Wallpolla, Hattah, Belsar-Yungera, Nyah, Burra and Vinifera. The projects will deliver water to floodplain ecosystems to directly address environmental water needs.

Central to the SDL adjustment process and the business cases, is the environmental benefit that supply measures achieve. The environmental benefit must exceed that of the base case (benchmark) scenario to justify an offset. Environmental benefit can be assessed in terms of how well they address the Basin Plan's priorities for environmental water use. These include, among other things, ecosystems that:

- are rare, near-natural or unique;
- provide vital habitat
- support threatened species or communities
- support significant biodiversity

To build business cases and to assess their strength, the Mallee CMA requires Ecological Rationale and Outcomes reports for the seven SDL project sites. The reports will describe the ecological character of the systems and set objectives for the use of water to promote ecosystem function and health. The contribution of the SDL works to the objectives and their ecological benefit will be described.

2 THE LINDSAY ISLAND FLOODPLAIN MANAGEMENT PROJECT

2.1 PROJECT DETAILS

The Lindsay Floodplain Management Project is a Supply Measure project located in Murray-Sunset National Park on the River Murray floodplain, 100 km west of Mildura in northwest Victoria. The project is located entirely within Crown Land. In future the project area may be extended to private land by negotiation.

The Lindsay Island floodplain system comprises Lindsay Island and adjacent floodplain areas. The system is located on the left (southern) bank of the River Murray between 720 and 659 river km and has an area of 15,000 ha.

The purpose of the project is to restore the productivity and integrity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use a weir, stop banks, regulators and pumps to intermittently pond water across the floodplain to meet environmental watering targets.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

Figure 1. Location of the Lindsay Island Floodplain Management Project

2.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

Lindsay Island is part of the Murray-Sunset National Park and Toupnein Island Reference Area. The system is managed by Parks Victoria. The island is a component of the Chowilla Floodplain and Lindsay-Wallpolla Islands Living Murray Icon Site.

Lindsay Island is a floodplain system enclosed between the River Murray and the Lindsay River anabranch. Lindsay River diverges from the River Murray below Lock 8 and rejoins the river above Lock 6, bypassing Lock 7. The island and its adjacent floodplain cover 18,000 ha and extend 28 km from east to west. The floodplain incorporates a complex range of landforms including creeks, temporary anabranches, wetlands, woodlands and grasslands.

The Lindsay Island floodplain is contiguous with the broader Murray-Sunset National Park which extends 100 km to the south and encompasses 633,000 ha. The national park is an important biodiversity corridor that enables the movement and migration of biota and provides resilience to climate change. Fauna that regularly use the corridor include regent parrot and major mitchell's cockatoo. These birds feed in mallee vegetation and nest in hollow-bearing trees on the floodplain. Many mammals and birds, including fat-tailed dunnart, carpet python, bats and bush birds, live in both the floodplain and terrestrial landscapes.

Wetland habitat covers more than 2,000 ha of Lindsay Island and is important to the value of the site as a wetland of national significance (Environment Australia 2001). Flooded trees near wetlands and watercourses provide nesting habitat for colonial nesting waterbirds including egrets, glossy ibis, spoonbills, cormorants and night herons (Ecological Associates 2007), (Kingsford and Porter 2011). Frequently flooded low-lying wetlands support populations of wetland-dependent fish species including murray-darling rainbow fish, gudgeon species and flat-headed galaxias.

An important habitat component of Lindsay Island is lignum shrubland, which vegetates extensive areas of the floodplain. Flooded lignum shrublands provide nesting platforms for waterbirds including ibis, cormorants, pelicans and freckled duck. Flooded lignum is a highly productive aquatic habitat, providing abundant food and physical habitat for small native fish species and frogs. In the dry phase between flood events lignum is important habitat for the giles' planigale, which preys on invertebrates and shelters in cracking clays (Mallee CMA 2011).

The largest wetland at Lindsay Island, covering 828 ha, is Lake Wallawalla. The lake is itself a wetland of national significance (Environment Australia 2001). When flooded it retains water for several years and provides reliable aquatic habitat in an otherwise dry landscape. The lake supports breeding by thousands of waterbirds including colonial nesting species that form rookeries in the fringing *Eucalyptus camaldulensis and E. largiflorens* trees and platform-building species such as black swan and grebes. Receding water levels over summer and autumn provide habitat for wading birds including caspian tern and greenshank, which are protected under the JAMBA and CAMBA international migratory bird agreements (Environment Australia 2001). The nationally vulnerable sedge *Eleocharis obicis* is present at Lake Wallawalla (Australian Ecosystems 2013).

Lindsay Island is critical to the biodiversity of the lower River Murray because of the fast-flowing aquatic habitat that it provides. Fast-flowing habitat has been largely eradicated from the lower 900 km of the river by the pooling of water upstream of locks and weirs, leading to the decline or local extinction of murray cod, australian smelt, murray crayfish, river snail and river mussel (Walker 2006). Due to the position of Lock 7 and the natural alignment of floodplain watercourses, Lindsay Island provides a 4 km reach of fast-flowing habitat along Mullaroo Creek. Mullaroo Creek and Chowilla Creek, which is located in the nearby Chowilla floodplain, are the only two significant murray cod breeding habitats in the lower River Murray (Mallen-Cooper, et al. 2008)(Saddlier, O'Mahony and Ramsey 2008). Lindsay Island watercourses also support a number of aquatic fauna of conservation significance including freshwater catfish, silver perch, golden perch, growling grass frog and broad-shelled turtle.

Flooding maintains the productivity of floodplain habitats. Dense understorey vegetation provides the prey species and structural habitat on which carpet python and lace monitor depend. High levels of insect productivity, derived from both wetland and woodland inundation, contribute to Lindsay Island's diverse bat fauna which comprises nine species (GHD 2014). Organic matter generated on the floodplain is conveyed to the river channel by receding flood water and contributes to the energy requirements of the river ecosystem.

WATER DEPENDENT FLORA AND FAUNA

FLORA

Lindsay Island has a diverse flora and supports numerous plant species of conservation significance. A recent vegetation survey (Australian Ecosystems 2013) reported 228 indigenous plant species of which 44 are floodplain species that are rare or threatened under the Victorian Advisory List of Threatened Plants. One species, *Eleocharis abicis*, is vulnerable in Victoria and listed vulnerable under the Commonwealth EPBC Act.

The survey confirmed the presence of most species that had been reported from databases and previous surveys (Table 1).

Table 1. Plant species of conservation significance reported from Lindsay Island (Australian Ecosystems 2013)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-base s
		EPBC	FFG	VROTS		
Asperula gemella	Twin-leaf Bedstraw			R	x	x
Atriplex holocarpa	Pop Saltbush		L	V	x	x
Atriplex limbata	Spreading Saltbush		L	V	x	x
Atriplex lindleyi subsp. *conduplicata*	Baldoo			R	x	x
Atriplex nummularia subsp. omissa	Dwarf Old-man Saltbush			R	x	x
Atriplex pseudocampanulata	Mealy Saltbush			R	x	x
Atriplex rhagodioides	Silver Saltbush		L	V	x	x
Bergia trimera	Small Water-fire			V	x	x
Calotis cuneifolia	Blue Burr-daisy			R	x	x
Centipeda crateriformis subsp. compacta	Compact Sneezeweed			R	x	x
Centipeda thespidioides s.l.	Desert Sneezeweed			R	x	x
Craspedia haplorrhiza	Plains Billy-buttons			K	x	x
Crinum flaccidum	Darling Lily		L	V	x	x

Cynodon dactylon var. *pulchellus*	Native Couch			K	x	x
Eleocharis obicis	Striate Spike-sedge	V		V	x	x
Eragrostis lacunaria	Purple Love-grass			V	x	x
Eremophila bignoniiflora	Bignonia Emu-bush		L	V	x	x
Eremophila divaricata subsp. *divaricata*	Spreading Emu-bush			R	x	x
Frankenia serpyllifolia	Bristly Sea-heath			R	x	x
Glossostigma drummondii	Desert Mud-mat			K	x	x
Haloragis glauca f. *glauca*	Bluish Raspwort			K	x	x
Lawrencia spicata	Salt Lawrencia			R	x	x
Lepidium fasciculatum	Bundled Peppercress			K	x	x
Lepidium papillosum	Warty Peppercress			K	x	x
Lepidium pseudohyssopifolium	Native Peppercress			K	x	x
Malacocera tricornis	Goat Head			R	x	x
Mimulus prostratus	Small Monkey-flower			R	x	x
Picris squarrosa	Squat Picris			R	x	x
Rumex crystallinus s.s.	Glistening Dock			V	x	x
Sclerolaena decurrens	Green Copperburr			V	x	x
Sclerolaena divaricata	Tangled Copperburr			K	x	x
Sclerolaena muricata var. *muricata*	Black Roly-poly			K	x	x
Senecio cunninghamii var. *cunninghamii*	Branching Groundsel			R	x	x
Solanum lacunarium	Lagoon Nightshade			V	x	x
Stellaria sp. 2	Rangeland Starwort			K	x	x
Swainsona greyana	Hairy Darling-pea		L	E	x	x
Swainsona microphylla	Small-leaf Swainson-pea			R	x	
Swainsona phacoides	Dwarf Swainson-pea		L	E	x	x
Tecticornia triandra	Desert Glasswort			R	x	x
Tetragonia moorei	Annual Spinach			K	x	
Wahlenbergia tumidifructa	Mallee Annual-bluebell			R	x	
Tecticornia tenuis	Slender Glasswort			R		x
Tetragonia eremaea s.l.	Desert Spinach			K		x
Zygophyllum ammophilum	Sand Twin-leaf			R		x

In Victoria vegetation mapping units are known as Ecological Vegetation Classes and are assigned conservation ratings within each bioregion (Table 2). One EVC, Disused Floodway Shrubby Herbland, is endangered and four EVCs are vulnerable: Lake Bed Herbland, Lignum Swamp, Shallow Freshwater Marsh, Alluvial Plains Semi-arid Shrubland and Sub-saline Depression Shrubland.

Table 2. Bioregional conservation status of Lindsay Island Ecological Vegetation Classes

Ecological Vegetation Class	Bioregional Conservation Status
102 Low Chenopod Shrubland	Depleted
103 Riverine Chenopod Woodland	Depleted
104 Lignum Swamp	Vulnerable
106 Grassy Riverine Forest	Depleted
107 Lake Bed Herbland	Vulnerable
200 Shallow Freshwater Marsh	Vulnerable
806 Alluvial Plains Semi-arid Shrubland	Vulnerable
807 Disused Floodway Shrubby Herbland	Endangered
808 Lignum Shrubland	Least Concern
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
813 Intermittent Swampy Woodland	Depleted
818 Shrubby Riverine Woodland	Least Concern
820 Sub-saline Depression Shrubland	Vulnerable
823 Lignum Swampy Woodland	Depleted

FAUNA

Twelve native fish species are encountered regularly at Lindsay Island (Table 3).

Small fish species that inhabit localised riparian and wetland habitats include flat-headed galaxias, southern pygmy perch and hardyhead species. Large-bodied fish that specialise in deeper channel habitat include murray cod, golden perch and silver perch. Freshwater catfish spend time in deep channel habitat but use wetlands to breed.

Fast-flowing habitat in Mullaroo Creek supports one of only two self-sustaining populations of murray cod in the lower River Murray, the other being in Chowilla Creek (Mallen-Cooper, et al. 2008)(Saddlier, O'Mahony and Ramsey 2008). The high quality of fish habitat in Mullaroo Creek also contributes to healthy populations of golden perch, australian smelt and freshwater catfish.

Table 3. Native fish fauna of Lindsay Island (Lloyd 2012)

Scientific Name	Common Name	Conservation Status		
		EPBC	FFG	VROTS
Retropinna semoni	Australian smelt			
Galaxias rostratus	Flat-headed galaxias			DD
Nannoperca australis	Southern pygmy perch			
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead			DD
Melanotaenia fluviatilis	Murray-darling rainbowfish		L	
Philypnodon grandiceps	Flat-headed gudgeon			
Hypseleotris spp.	Carp gudgeon			
Nematalosa erebi	Bony herring			
Tandanus tandanus	Freshwater catfish			V
Macquaria ambigua	Golden perch			V
Biyanus bidyanus	Silver perch			CE
Maccullochella peelii	Murray cod	V		V

Lindsay Island has a highly diverse bird fauna with 196 bird species reported from the site, of which 35 have conservation significance at the state and national level and four are protected under international migratory bird agreements (Table 4). A recent bird survey in 2013 observed 93 species (GHD 2014).

Wetlands provide habitat for dabbling, diving and filter feeding ducks while small fish will provide prey for piscivorous waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Flooded woodland and lignum shrubland provide nesting sites for waterbirds including waterfowl and colonial nesting species. Broad areas of shallow flooding in alluvial plains and wetlands provide feeding areas for waterbirds, including migratory species which visit Lindsay Island in summer and early autumn.

Flooding promotes plant productivity and will increase the food resources for bush birds that depend on fruit, seeds, nectar and insects. Understorey complexity will increase the availability of vertebrate prey species such as lizards and will provide sheltering and nesting sites for bush birds.

Table 4. Birds of conservation significance expected to occur at Lindsay Island (GHD 2014)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements	
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA
Anas rhynchotis	Australasian Shoveler			V		
Ardea intermedia	Intermediate Egret		L	E		
Ardea modesta	Eastern Great Egret		L	V		C J
Aythya australis	Hardhead			V		
Biziura lobata	Musk Duck			V		
Burhinus grallarius	Bush Stone-curlew		L	E		
Charadrius australis	Inland Dotterel			V		
Chlidonias hybridus javanicus	Whiskered Tern			NT		
Chrysococcyx osculans	Black-eared Cuckoo			NT		
Circus assimilis	Spotted Harrier			NT		
Dromaius novaehollandiae	Emu			NT		
Egretta garzetta nigripes	Little Egret		L	E		
Falco subniger	Black Falcon			V		
Gelochelidon nilotica macrotarsa	Gull-billed Tern		L	E		
Geopelia cuneata	Diamond Dove		L	NT		
Haliaeetus leucogaster	White-bellied Sea-Eagle		L	V		C
Hydroprogne caspia	Caspian Tern		L	NT		C J
Lophocroa leadbeateri	Major Mitchell's Cockatoo		L	V		
Lophoictinia isura	Square-tailed Kite		L	V		
Melanodryas cucullata cucullata	Hooded Robin		L	NT		
Ninox connivens connivens	Barking Owl		L	E		
Nycticorax caledonicus hillii	Nankeen Night Heron			NT		
Oreoica gutturalis gutturalis	Crested Bellbird		L	NT		
Oxyura australis	Blue-billed Duck		L	E		
Phalacrocorax varius	Pied Cormorant			NT		
Platalea regia	Royal Spoonbill			NT		
Polytelis anthopeplus monarchoides	Regent Parrot	V	L	V		
Pomatostomus temporalis temporalis	Grey-crowned Babbler		L	E		
Ptilonorhynchus maculatus	Spotted Bowerbird		L	CE		
Pyrrholaemus brunneus	Redthroat		L	E		

Stictonetta naevosa	Freckled Duck		L	E		
Struthidea cinerea	Apostlebird		L			
Todiramphus pyrropygia pyrropygia	Red-backed Kingfisher			NT		
Tringa nebularia	Common Greenshank			V	A2H	C J R
Turnix pyrrhothorax	Red-chested Button-quail		L	V		

The bat fauna of Lindsay Island is diverse with nine species observed at the site (Table 5). The bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey while trees provide roosting habitat in bark, crevices and hollows.

Table 5. Native mammal species reported from Lindsay Island (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	gould's wattled bat				x	x
Chalinolobus morio	chocolate wattled bat				x	
Hydromys chrysogaster	water rat				x	x
Macropus fuliginosus	western grey kangaroo				x	x
Macropus giganteus	eastern grey kangaroo				x	x
Macropus rufus	red kangaroo				x	x
Mormopterus sp. 3	inland freetail bat					x
Mormopterus sp. 4	southern freetail bat					x
Nyctophilus geoffroyi	lesser long-eared bat					x
Ornithorhynchus anatinus	platypus					x
Planigale gilesi	giles' planigale		L	NT	x	x
Scotorepens balstoni	inland broad-nosed bat				x	
Sminthopsis crassicaudata	fat-tailed dunnart			NT	x	x
Tachyglossus aculeatus	short-beaked echidna				x	x
Tadarida australis	white-striped freetail bat					x
Trichosurus vulpecula	common brushtail possum					x
Vespadelus regulus	southern forest bat					x
Vespadelus vulturnus	little forest bat					x

The open plains and grassland provide habitat for kangaroo species while watercourses and wetlands provide habitat for water rat and platypus. Understorey vegetation, including lignum shrublands, is an important habitat component for gile's planigale.

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs. Twenty eight reptiles have been reported from Lindsay Island including five species of conservation significance(Table 6). Six frog species occur at Lindsay Island, of which one, the growling grass frog is vulnerable nationally and endangered in Victoria (GHD 2014).

Table 6. Reptiles and amphibians of conservation significance reported from Lindsay Island (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Reptiles						
Furina diadema	red-naped snake		L	V		x
Chelodina expansa	broad-shelled turtle		L	E		x
Morelia spilota metcalfei	carpet python		L	E		x
Pseudonaja aspidorhyncha	patch-nosed brown snake			NT		x
Varanus varius	lace monitor			E	x	x
Amphibians						
Litoria raniformis	growling grass frog	V	L	E		x

FORMAL CONSERVATION AGREEMENTS

Lindsay Island is part of the Murray-Sunset National Park and Toupnein Island Reference Area designated under the National Parks Act 1975 (Victoria).

Lindsay Island and Lake Wallawalla are wetlands of national significance and are listed in the Directory of Important Wetlands in Australia (Environment Australia 2001).

Lindsay Island provides habitat for a number of migratory bird species listed under the Japan-Australia, China-Australia and Republic of Korea-Australia migratory bird agreements.

VITAL HABITAT AT THE SITE

Mullaroo Creek, which flows through Lindsay Island, supports one of only two self-sustaining populations of murray cod in the lower River Murray. The creek also provides good habitat for a number of other native fish including australian smelt, silver perch and golden perch.

Lindsay Island is important as habitat for both nomadic and migratory waterbirds during times of drought in central and eastern Australia.

Lindsay Island supports plant and animal species of conservation significance under Commonwealth and Victorian frameworks.

A significant population of the nationally listed growling grass frog is present at Lindsay Island which provides the combined habitat of permanent water and intermittently flooded forest wetland vegetation (P. Robertson 2011).

Lindsay Island's linkage to the broader 633,000 ha Murray-Sunset National Park represents an important biodiversity corridor. The corridor allows the movement and dispersal of biota between floodplain and terrestrial bioregions.

Lindsay Island features wetland habitats which, under a natural water regime, were persistently flooded and provided reliable aquatic habitat and refuge during regional droughts.

2.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVES

The overall objective of water management at Lindsay Island is:

"to protect and restore the key species, habitat components and functions of the Lindsay Island ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- enhancing murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing habitat
- maintaining resident populations of frogs and small fish in wetlands
- providing reliable breeding habitat for waterbirds, including colonial nesting species
- frequently providing habitat for thousands of waterbirds
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements in key areas of the Lindsay Island floodplain. Seven water regime classes have been identified at Lindsay Island (Table 7). The following describes their ecology and water requirements.

Table 7. Lindsay Island Water Regime Classes

Water Regime Class	Area (ha)	Data sources for Water Regime Classification
Semi-permanent Wetlands	350	Areas where hydraulic modelling indicates depth in

		standing waterbodies of more than 1m water at flows over 50,000 ML/d comprising polygons of: Floodway Pond Herbland Bare Rock / Ground Shallow Freshwater Marsh Lignum Shrubland
Temporary Wetlands	456	Floodway Pond Herbland Shallow Freshwater Marsh Disused Floodway Shrubby Herbland
Watercourses	402	Bare Rock / Ground Waterbody - Fresh
Red Gum Forest and Woodland	2,935	Grassy Riverine Forest / Floodway Pond Herbland Complex Grassy Riverine Forest Intermittent Swampy Woodland
Lignum Shrubland and Woodland	6,851	Lignum Shrubland Lignum Swamp Lignum Swampy Woodland
Black Box Woodland	6,267	Riverine Chenopod Woodland Shrubby Riverine Woodland
Alluvial Plain	2,923	Alluvial Plains Semi-arid Grassland Low Chenopod Shrubland Sub-saline Depression Shrubland
Plains Woodland and Forest	181	Semi-arid Woodland Semi-arid Chenopod Woodland

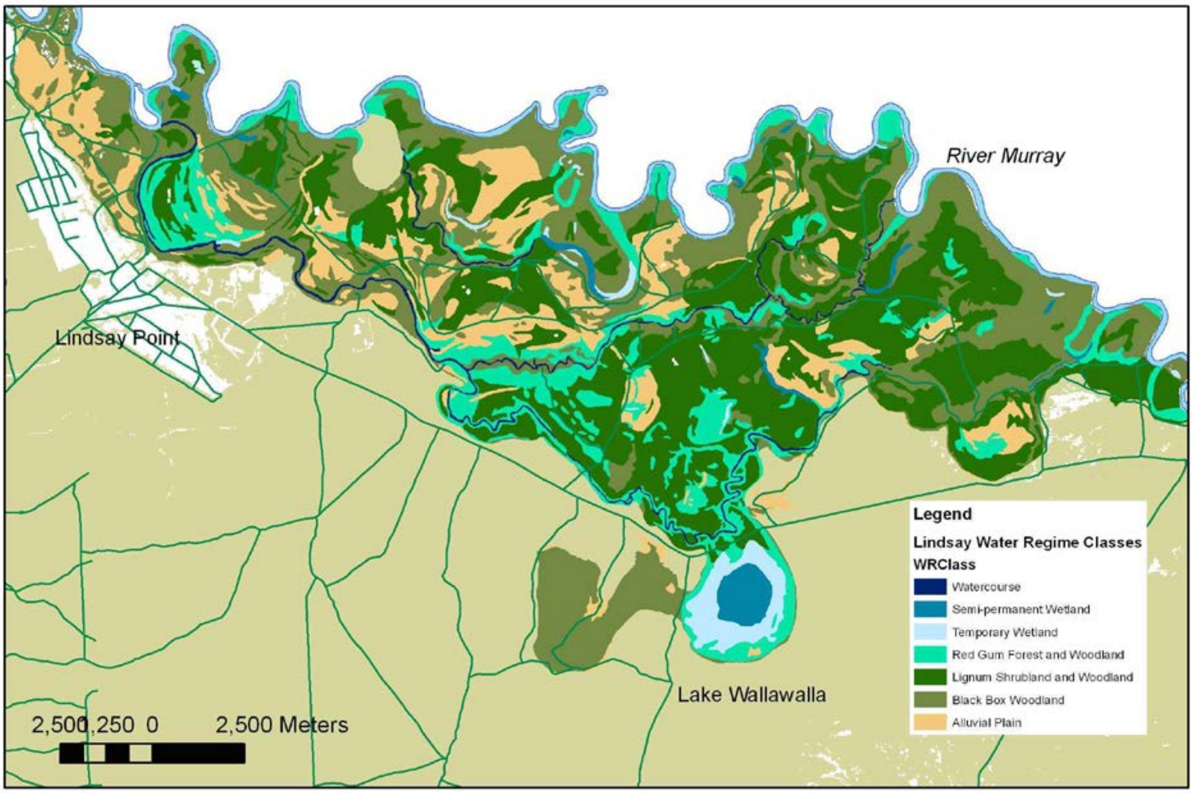


Figure 2. Lindsay Island Water Regime Classes

SEMI-PERMANENT WETLANDS

Ecology

Semi-permanent wetlands occur close to the river channels and at the fringes of the principal anabranches.

Under natural conditions water was almost always present in these wetlands due to low flow thresholds, frequent peaks in river flow, and the capacity of wetlands to retain water for long periods. Many wetlands would only dry out during rare, prolonged periods of low flow. Water levels would vary seasonally such that wetlands would tend to be flooded most deeply and frequently in spring and would tend to have lowest water levels in summer and autumn.

Persistent, deep flooding will exclude emergent macrophytes from the central wetland bed, which will instead have either open water or semi-emergent vegetation of *Myriophyllum* spp., *Vallisneria americana* and *Potamogeton* spp. When dry the bed will be bare or provide habitat for lake bed herbs such as *Alternanthera denticulata, Agrostis avenacea, Eleocharis acuta, Glychyrrhiza acanthocarpa* and *Centipeda cunninghamii.*

Seasonal inundation of the wetland fringe provides habitat for emergent macrophytes such as *Phragmites australis, Bolboschoenus medianus* and *Cyperus gymnocaulos*. Vegetation at the perimeter grades into the grass and sedge-rich understorey of the surrounding red gum forest and woodland.

Regular drying and re-flooding of the fringe is important to wetland productivity. Flooding of the reed zone mineralises organic matter, promoting microbial, algal and macro-invertebrate production.

Persistent flooding of the wetland bed allows the development of a community of large zooplankton, shrimp (*Paratya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. These animals provide prey for fish such as smelt, bony bream and hardyhead, while flying adult insects contribute to the food requirements of bats and birds. Persistent flooding would also support resident populations of tortoise.

Dabbling ducks such as freckled duck, australasian shoveler and pink-eared duck feed on soft-leaved aquatic plants and aquatic macro-invertebrates. Semi-permanent wetlands provide reliable breeding habitat for bird species which build nests using reeds on scrapes in and around fringing vegetation and require water to be present for at least three months in winter and spring. Reeds provide frogs with a source of food, a substrate for eggs and shelter from predators. Grazing waterfowl including black swan, australian shelduck and wood duck will also be favoured by semi-emergent vegetation and will regularly breed.

Inundation of the forest or woodland adjacent to semi-permanent wetlands for periods of three to six months will provide nesting habitat for colonial nesting waterbirds. These birds will nest in the flooded trees and seek food in nearby wetlands and flooded vegetation.

Water Requirements

In order to maintain resident populations of aquatic fauna, semi-permanent wetlands may only dry out on rare occasions, in 5 to 10% of years. The wetland depth should exceed 0.5 m 80% of the time and 1 m 30% of the time. Inflows are required in more than 80% of years to provide seasonal inundation of the littoral zone, which will mineralise organic matter and maintain emergent macrophytes beds.

Table 8. Water management objectives for semi-permanent wetlands

Objectives Addressed	Enhance murray cod habitat by improving the productivity of connected riparian and wetland habitat while maintaining fast-flowing habitat Maintain resident populations of frogs and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds
Strategy	Restore seasonal flooding and semi-permanent inundation to deep, low-lying wetlands and restore hydraulic connections to riverine habitats
Hydrological Targets	Water depth to exceed 0.5 m 80% of the time Water depth to exceed 1 m 30% of the time Inflows to reach the wetland perimeter in more than 90% of years

TEMPORARY WETLANDS

Ecology

Temporary wetlands mainly occur close to anabranches and the River Murray. They represent a variety of flooding frequencies, durations and depths but are characterised by an intermittent, broadly seasonal flooding regime.

Temporary wetlands alternate between flooded and dry states. They tend to be filled by freshes in river flow in winter and spring after which they gradually dry out. Flooding may persist over several years if the wetlands receive summer inflows, but will dry out to some degree between inflow events. The wetlands may remain dry over several years if river levels fail to reach the wetland sill.

When flooded, soft-leaved semi-emergent vegetation will colonise the deeper parts of the lake bed including *Myriophyllum sp.* and *Potamogeton* sp. Open water may be present in the central part of the wetlands where water is too deep to support these species. Emergent macrophytes such as *Cyperus gymnocaulos* and *Eleocharis acuta* will occupy the narrow seasonally inundated zone at the fringe of the wetland. *Duma florulenta* and *Eragrostis infecunda* may also extend into the bed of less-frequently flooded wetlands.

Flooded wetlands will be colonised by the larvae of flying insects and by invertebrates released from resting stages on the lake bed. Over several weeks the wetlands will provide productive food sources for small fish, waterbirds, frogs and turtles.

The drying wetland bed will support a range of wetland herbs such as *Centipeda cunninghamii, Persicaria lapathifolia, Alternanthera* sp. *Glossostigma elatinoides* and *Heliotropum* sp. Between flood events the wetland bed will develop a community of lake bed herbs and grasses such as *Glycyrrhiza acanthocarpa* and *Persicaria lapathifolia.* These plants, together with colonising *Eucalyptus camaldulensis*, will die during subsequent sustained flood events.

In sustained dry periods the wetland water levels will fall below the reed zone to expose a muddy herbland on the lake bed. Small wading birds such as ruddy turnstone and red-necked stint will feed on macro-invertebrates in shallow water and mud. Fish-eating birds and carrion feeders, including white-bellied sea-eagle, will feed on stranded fish.

Water Requirements

To achieve the ecological objectives, temporary wetlands should be intermittently inundated and exposed on a broadly seasonal cycle. This water regime will create productive aquatic habitats with diverse aquatic plant and animal communities.

Temporary wetlands should be completely filled between 25% and 90% of years. The peak in wetland level is required some time between September and December to match the growth requirements of emergent macrophytes and the breeding requirements of waterbirds, small native fish and frogs. Drying of 80% of the wetland bed is required in more than 50% of years to promote the growth of wetland macrophytes and herbs on the wetland bed and to mineralise organic matter.

Table 9. Water management objectives for temporary wetlands

Objectives Addressed	Frequently provide habitat for thousands of waterbirds Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore intermittent inundation of floodplain wetlands
Hydrological Targets	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years

WATERCOURSES

Ecology

Flowing watercourses provide a contrasting cool, turbulent and well-oxygenated aquatic habitat to wetlands and the slow-flowing environment of the River Murray channel. Watercourses provide a hydraulic connection between floodplain wetlands and the river channel.

Watercourses generally have open water in the channel but in backwaters and near the banks support scattered patches of semi-emergent macrophytes including *Vallisneria* sp. and *Ottelia ovalifolia* (Water Technology 2009). Frequently flowing reaches support dense riparian vegetation of *Phragmites australis* with *Typha* sp. present along slow-flowing channels. Rarely-flowing reaches will support sparse drought-tolerant sedges such as *Cyperus gymnocaulos.*

Flowing water habitat is an important habitat component for a number of fish. Water flowing from watercourses provides attractant flows for fish, encouraging their upstream migration (Leigh and Zampatti 2005). Stream complexes that include fast- and slow-flowing water are associated with large, viable populations of murray cod (Saddlier, O'Mahony and Ramsey 2008). Mullaroo Creek provides murray cod recruitment habitat and supports significant populations of golden perch and silver perch (Conallin and Meredith 2006). Flowing water provides breeding habitat for australian smelt (Sheldon and Lloyd 1990).

Variation in flow (and therefore water level) is an important component of fast flowing habitat. Increasing discharge in spring is associated with spawning in golden perch, smelt and silver perch (King, Tonkin and Mahoney 2007) as it is believed to act as a reliable indicator of the imminent availability of productive floodplain habitat to support juvenile fish recruitment. Variation in flow is also important in maintaining the bacteria-rich biofilms on which River Snail and other invertebrates depend. Biofilms tend to be rich in bacteria soon after the inundation of suitable substrate, but become dominated by algae over time (Burns and Walker, Effects of water level regulation on algal biofilms in the River Murray, South Australia 2000),(Burns and Ryder 2001).

Permanent watercourses provide an aquatic habitat for a range of generalist aquatic fauna. Watercourses will support a species-poor climax community of aquatic invertebrates comprising large zooplankton, shrimp (*Paratava* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. Together with small-bodied fish living in the fringing macrophytes, these provide prey for large bodied fish. Large bodied fish will also visit the fringing vegetation and snags, which provide benthic invertebrate prey and shelter from predators. Watercourses may support resident populations of turtle. The watercourses represent an alternative habitat to the River Murray for these large aquatic species, which move between the floodplain and the river during peaks in river flow.

Water Requirements

Under natural conditions the river channel provided the principal flowing-water habitat while anabranches provided additional habitat during peaks in flow. Since the channel was regulated, floodplain anabranches now represent the only opportunity to promote flow-dependent fauna. It is an important objective to maintain the existing flowing habitat in Mullaroo Creek while promoting flowing habitat in other watercourses where possible. High-level floodplain channels provide temporary flowing reaches.

Murray cod and golden perch are favoured by habitat where water velocity ranges between 0.2 and 0.4 m/s, ideally in the upper part of this range (Mallen-Cooper, et al. 2008).

Table 10. Water management objectives for watercourses

Objectives Addressed	Enhance murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing habitat
Strategy	Maintain fast flowing habitat in upper Mullaroo Creek Maintain the extent of permanent watercourses Increase the intermittent inundation of temporary watercourses
Hydrological Targets	Maintain fast flowing habitat in upper Mullaroo Creek in the higher part of the range of velocities 0.2 and 0.4 m/s Inundate banks and backwaters to a level equivalent to 50,000 ML/d 10 years in 10. - five of these events are to be 6 weeks long - five of these events are to be 10 weeks long

RIVER RED GUM FOREST AND WOODLAND

Ecology

River red gum forest is a minor component of Lindsay Island and mainly occurs on meander scroll bars with low flooding thresholds adjacent to the River Murray. It is not affected to a significant extent by the proposed works.

River red gum woodland is a substantial component of the vegetation and occurs mainly on low river terraces along watercourses and around wetlands. Inundation occurs mostly in spring so that the ground is generally dry over summer and autumn. The plant community comprises species that benefit from seasonal flooding but tolerate dry conditions over summer and occasional years without any flooding. During floods aquatic plants develop from propagules including *Marsilea drummondii, Eleocharis acuta* and *Triglochin multifructum.* The drier areas are dominated by grasses and sedges including *Cyperus gymnocaulos* and *Sporobolus mitchellii* and may include *Duma florulenta*. Species, which colonise the drying forest floor, include *Lachnagrostis filiformis, Glycyrrhiza acanthocarpa* and *Centipeda cunninghamii.*

Inundation of red gum woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

During longer flooding events red gum woodland will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as nankeen night heron, cormorant and australasian darter. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for carpet python, bats and brush-tailed possum. Red gum growing close to water provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering which supports nectar-eating insects and birds and insectivorous birds.

Water Requirements

Flows of 70,000 to 90,000 ML/d inundate red gum woodland at Lindsay Island. Under natural conditions these events occurred almost annually and lasted for two to three months.

Red gum woodland has been severely degraded at Lindsay Island. Mean flood duration has declined to less than 6 weeks while flood frequency has declined to approximately one event every two years. *Duma florulenta* has invaded the understorey and the density of river red gum has increased. The diversity of understorey vegetation has declined. Waterbird breeding events are smaller and less frequent.

Flooding in spring and early summer for two to three months will meet the seasonal requirements of understorey plants and maintain vegetation structure and diversity. Flooding at this time of year will also address the seasonal breeding requirements of native fish, frogs and waterbirds.

Long flooding events, lasting over six months, are required to support breeding by colonial nesting waterbirds. These events will influence the structure of the vegetation, limiting reducing the cover of *Duma florulenta* and *Eucalyptus camaldulensis* and promoting wetland understorey species.

Flooding frequencies of 6 years in 10 are recommended for lower-lying areas and 5 years in 10 for high floodplain areas.

Table 11. Water management objectives for red gum forest and woodland

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting species Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore the inundation of red gum forest and woodland
Hydrological Targets	Inundation events should commence between September and December For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long

LIGNUM SHRUBLAND AND WOODLAND

Ecology

Lignum shrubland and woodland occurs on intermediate floodplain terraces and shallow floodplain depressions. Lignum (*Duma florulenta*) is the dominant species and, when flooded frequently, can form extensive, dense thickets. Other large shrubby species *Chenopodium nitrariaceum* and *Eragrostis australasica* can co-occur with lignum. The trees *Eucalyptus camaldulensis, E. largiflorens* and *Acacia stenophylla* can form a sparse overstorey.

Lignum shrublands experience intermittent flooding separated by potentially long dry periods. When flooded frequently the shrubs grow quickly and form dense, continuous thickets. The ground layer supports a range of wetland herbs including *Marsilea drummondii, Eleocharis acuta, Cyperus gymnocaulos* and *Rumex* spp. When flooding is less frequent the shrubs are smaller and more widely spaced allowing the groundlayer vegetation to become more dense and diverse, supporting shrubs, grasses and herbs including *Dysphyma crassifolium, Atriplex leptocarpa, A. lindleyi, Sclerolaena tricuspis* and *Austrodanthonia* sp.

Inundation of lignum shrubland represents an extension of the habitat for aquatic floodplain fauna such as fish, reptiles and frogs. Their bushy structure and debris provides a productive substrate for epiphytes that supports high macroinvertebrate productivity and also provides shelter from predators. Flooded lignum is also used as a platform by nesting waterbirds including ibis and spoonbill. Floodwater draining from lignum will carry dissolved and particulate carbon as well as algae and invertebrates which will contribute to the food web of the river channel.

Between flood events, lignum is an important habitat for terrestrial vertebrate fauna including lizards and giles' planigale.

Water Requirements

Lignum shrubland and woodlands at Lindsay Island is generally in poor condition. In the higher, less frequently flooded parts of the floodplain lignum shrublands have been replaced by low chenopod shrubs. The size and density of shrubs in remaining stands has declined and formerly frequently flooded areas have developed a more terrestrial vegetation.

A range of flooding frequencies is required to achieve the ecological objectives. Lower-lying shrublands (equivalent to 70,000 ML/d flow threshold) should be flooded 8 years in 10. Brief events, of two months duration will maintain ecosystem structure and productivity and will provide seasonal habitat for aquatic fauna. Longer floods, of four to six months duration, should be provided in four of these years to support waterbird breeding.

Higher areas (equivalent to 85,000 ML/d flow threshold) should be flooded 4 years in 10. Half of these events should be one month long to maintain ecosystem structure. Half of the events should be of two to three months duration to promote breeding by fish, frogs and waterbirds.

Table 12. Water management objectives for lignum shrubland and woodland

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to lignum shrubland and woodland
Hydrological Targets	For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long

BLACK BOX WOODLAND

Ecology

Black box woodland occurs mostly on high, infrequently flooded floodplain terraces. The canopy is open and the community has a diverse, shrubby understorey that includes *Duma florulenta, Chenopodium nitrariaceum, Rhagodia spinescens, Enchylaena tomentosa* and *Acacia stenophylla*. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses.

Tree recruitment and the productivity of the vegetation is strongly linked to flooding. Flooding maintains a diverse age structure and a complex understorey plant community that is required by carpet python and other vertebrate fauna. The diversity of birds is particularly high because black box woodland contributes to the habitat requirements of both riverine and dryland species (Carpenter 1990). Black box woodland supports a high proportion of ground foragers and hollow-nesting species. Black box woodlands are important for canopy feeding bush birds such as superb fairy-wren, little friarbird and blue-faced Honeyeater. Black box woodland also supports seasonal migrants normally associated with higher rainfall areas such as grey fantail and white-bellied cuckoo-shrike. Black box is an important habitat component for insectivorous bats.

Flood events that inundate black box woodland contribute to the carbon requirements of permanent watercourses. Receding flood water conveys organic debris to the river channel where it promotes macro-invertebrate productivity and maintains the riverine food web.

Water Requirements

Flows of 80,000 to 115,000 ML/d inundate black box woodland at Lindsay Island. Under natural conditions these flows occurred in approximately 3 years in 10 and lasted approximately 1 month. While the duration of flood events is similar under the current flow regime, the frequency of events has declined to 1 year in 10 of years.

The overall structure of black box woodland has been maintained, but tree recruitment and productivity has declined, threatening the long-term viability of vertebrate fauna populations. Resilience to prolonged drought events, where understorey vegetation becomes sparse and food resources diminish, is poor.

Black box woodland productivity can be restored by increasing the frequency of floods equivalent to 100,000 ML/d to 3 years in 10 and reducing the maximum dry spell between events to seven years.

Table 13. Water management objectives for black box woodland

Objectives Addressed	Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to black box woodland
Hydrological Targets	Provide flooding 3 years in 10 for 2 to 6 weeks duration The maximum period between events is to be 7 years

ALLUVIAL PLAIN

Ecology

Alluvial plains occupy the high floodplain terraces on Lindsay Island and the extensive plains at the southern perimeter of the floodplain.

The alluvial plain vegetation comprises terrestrial vegetation of salt and waterlogging tolerant species. The dominant species include chenopods such as *Atriplex vesicaria, A. stipitata* and *Maireana pentagona* as well as the larger shrubs *Lawrencia squamata* and *Nitraria billardieri*. *Dysphyma crassifolium* ssp. *clavellatum* forms an extensive groundcover in saline areas. Trees are largely absent, but *Acacia oswaldii* or *Alectyron oleifolius* may be present on local rises.

Alluvial plains are rarely flooded and do not normally support wetland plant species. However flooding creates a productive feeding resource for waterbirds, including those that may be nesting in wetland, lignum and woodland habitats. Widespread, shallow flood water is an important feeding habitat for migratory wading birds which visit Lindsay Island in late summer and early autumn.

Water Requirements

Alluvial plains represent a terrestrial vegetation community and flooding is not required to maintain its structure or productivity.

Flooding does provide opportunistic habitat for floodplain fauna, including feeding habitat for wading birds. Flooding of the alluvial plain will contribute to the success of waterbird breeding events by increasing the availability of food. Extensive flooding may also attract birds to the site and trigger breeding behaviour.

Alluvial plains should be flooded to complement waterbird breeding objectives in wetland, lignum and woodland habitats. When flooding events of four to six months are provided to promote breeding in these areas, floods of one to two months duration should also be provided to alluvial plains.

To maintain the terrestrial character of the alluvial plains, flooding should not be provided more than 3 times in 10 years.

Table 14. Water management objectives for alluvial plains

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds
Strategy	Restore flooding to alluvial plains
Hydrological Targets	Provide flooding 1 years in 10 for 3 weeks in summer. Highest prioirty years are during major waterbird breeding events. Inundate the alluvial plains no more than 3 times in 10 years.

2.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Lindsay Island Floodplain Management Project will

- increase population size, health and age structure of native fish populations in floodplain watercourses, including murray cod in Mullaroo Creek
- protect and restore semi-permanent wetland habitat, increasing the range and resilience of aquatic fauna such as growling grass frog
- provide seasonal waterbird breeding opportunities
- protect and restore frequent breeding opportunities for colonial nesting waterbirds
- protect and restore the productivity and structure of floodplain woodland and shrubland communities, increasing the viability of vertebrate fauna populations including carpet python, giles' planigale, fat-tailed dunnart and bat species
- supply organic matter to the River Murray channel ecosystem

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Lindsay Island (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

Table 15. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Lindsay Island project.

Ecological Class	Ecological Element	Lindsay Island
Waterbirds	Bitterns, crakes and rails	◆
	General abundance and health - all waterbirds	◆◆◆
	Breeding - Colonial-nesting waterbirds	◆◆
	Breeding - other waterbirds	◆◆
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	◆◆
	Forests: river red gum (*Eucalyptus camaldulensis*)	◆
	Forests and woodland: black box (*Eucalyptus largiflorens*)	◆◆◆
	Shrublands	◆◆◆
	Tall grasslands, sedgelands and rushlands	◆
	Benthic herblands	◆
Fish	Short-lived / small-bodied fish	◆◆◆
	Long-lived / large-bodied fish	◆◆◆

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
◆	The contribution is infrequent or small in relation to other sites
◆◆	The contribution is frequent but small or substantial but rare in relation to other sites
◆◆◆	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

The proposed Lindsay Island supply measure restores flooding and productivity to extensive areas of red gum woodland, black box woodland and lignum shrubland. It will contribute significantly to the feeding and breeding requirements of platform-building waterbirds that nest in lignum, including colonial nesting species. Frequent flooding of wetlands will maintain wetland habitat for sedgelands and rushlands and support populations of for small-bodied fish and cryptic waterbirds such as bitterns, crakes and rails. Large wetlands areas, particularly Lake Wallawalla, provide extensive habitat for benthic herblands which in turn contribute to the habitat requirements of small-bodied fish and a wide variety of waterbirds.

Lindsay Island is an important site for large-bodied fish, particularly murray cod. The habitat for these species is promoted by increasing access to physically complex and productive riparian and wetland habitat.

2.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

The Lindsay Island floodplain system comprises Lindsay Island and the adjacent floodplain areas. The system is located between 720 and 659 river km in a reach where the river flows predominantly from east to west.

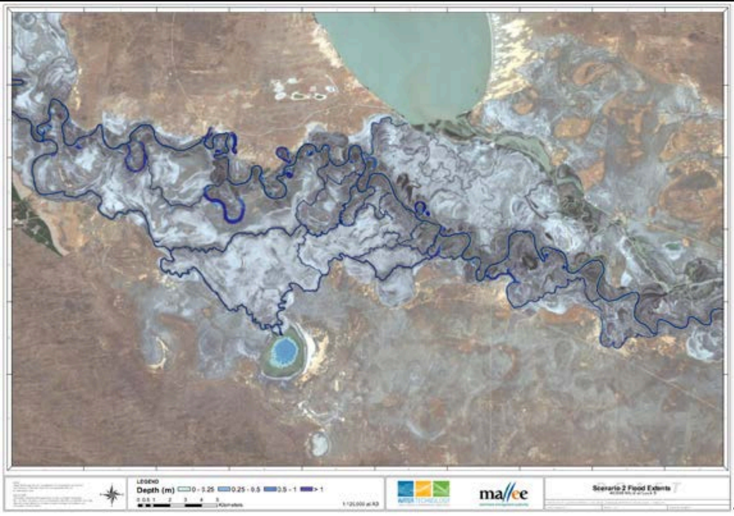
Lock 6 is located downstream of Lindsay Island in South Australia at 620 river km. The weir has raised the river to a normal operating level of 19.25 m AHD and ponds water in the channels in the west of the island, including Lindsay River, Toupnein Creek and lower Mullaroo Creek. Lock 7 is located alongside Lindsay Island at 703 river km and maintains a pool level of 22.2 m AHD. Water from the weir pool flows into one floodplain anabranch, Mullaroo Creek, creating a continuous fast-flowing environment in the first 4 km of the channel.

The weirs maintain a stable water level in the river under regulated flow conditions. The river becomes unregulated when the weirs are removed to allow high flows to pass.

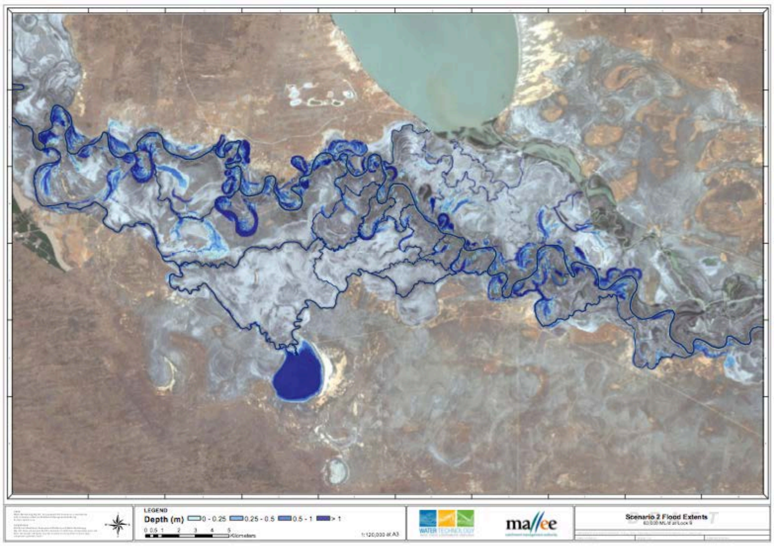
Lake Victoria lies to the north of the Lindsay Island floodplain system, on the right bank of the river. The lake stores water diverted from the River Murray above Lock 9 and releases water to the river just downstream of 703 river km. The capacity of the outlet is 9,000 ML/d so releases can result in a significantly higher flow below Lock 7 than above.

Websters Lagoon is a wetland adjacent to Toupnein Creek below Lock 7 and has an environmental regulator to retain or exclude water. The wetland is readily inundated by small changes in river flow as it lies close to the tailwater of the weir.

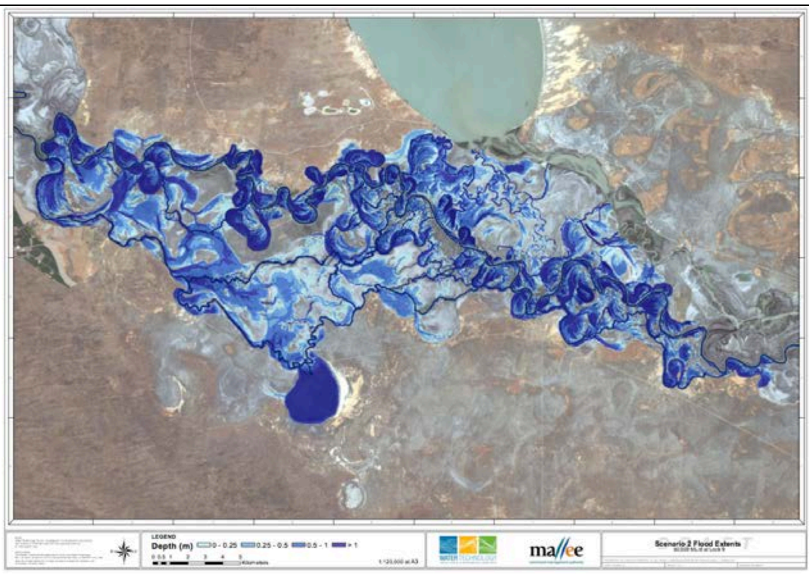
As river levels rise, flow into Mullaroo Creek increases and two upstream effluents of Lindsay River become active. Regulators have been constructed at the entrance to these channels to control inflows at a range of weir and river levels. Lindsay River and Mullaroo Creek are deeply incised and flow generally remains in well-defined channels until river discharge exceeds 40,000 ML/d. Above this threshold water spills to the benches alongside the channels and to the floodplain surrounding Toupnein Creek. Water also enters low-lying meander loops along the bank of the River Murray.



40,000 ML/d



60,000 ML/d



90,000 ML/d

Figure 3. Lindsay Island floodplain inundation at flows of 40,000, 60,000 and 90,000 ML/d (Water Technology 2014).

A number of floodplain wetlands are inundated at flows between 40,000 and 60,000 ML/d including Lake Wallawalla, Pollards Lagoon, The Crankhandle, the Mullaroo Wetland Complex and the Upper Lindsay Complex (Figure 3). The largest of these is Lake Wallawalla which is an 828 ha deflation basin to the south of Lindsay River. The lake receives inflows at river flows of 40,000 ML/d, flows and is filled by flows exceeding 80,000 M/d. An environmental regulator on Lake Wallawalla is operated to prolong flooding by controlling the return of water from the lake to Lindsay River.

Widespread floodplain inundation occurs at flows exceeding 70,000 ML/d. Initially Red Gum Woodland is inundated then Black Box Woodland. Lignum tends to occur in shallow floodplain depressions that are inundated by floods and seasonally waterlogged by local rainfall.

High flows, exceeding 120,000 ML/d, mainly introduce water to floodplain grasslands and chenopod shrublands and inundate the majority of the floodplain system.

HYDROLOGY

Lindsay Island is located downstream of the confluence of the Darling and Murray rivers. Their contrasting hydrologies influence the hydrology of the river at Lindsay Island.

River Murray flows originate in the largely temperate southern Murray-Darling basin which includes the Murray, Murrumbidgee and Goulburn tributaries. These produce largely seasonal flows that are highest from late winter to early summer. The Darling River, which drains the northern basin, is often influenced by sub-tropical weather systems that generate large flows in summer. The largest flow events at Lindsay Island occur when both Darling and Murray systems are in flood.

River hydrology has been altered significantly by regulation and diversion upstream. Storages in Victoria and New South Wales are managed to capture water in winter and spring and to deliver this water at manageable flow rates to consumers (primarily irrigators) during the summer. The impact on river hydrology has been a reduction in large winter and spring flow peaks and enhancement of low summer flows (Maheshwari et al., 1995). Locks and weirs have further altered floodplain water regimes by stabilising river levels.

The ecologically significant effects of these hydrological and hydraulic changes are:

- largely eliminating flowing water habitat under normal regulated flows;
- permanent inundation of wetlands, the river channel and low-lying floodplain areas in the vicinity of the weir pools; and
- the reduction in the frequency of inundation in higher-level wetlands and floodplain areas.

The hydrology of the river below Lock 7 has been characterised by analysing the MSM_Bigmod daily flow series for Natural and Current (Cap conditions) scenarios, using data from 1891 to 2009. Spell independence was defined by a period of 7 days between spells (Figure 4).

The river now spends more time at very low flows, less than 10,000 ML/d, than under natural conditions as indicated by higher than natural spell frequency but much shorter spell duration.

Both spell duration and frequency have been impacted under current conditions. Events that inundate low-lying wetlands, between 40,000 and 60,000 ML/d, now occur at approximately half the frequency of natural conditions. The duration of these events, when they do occur, has also been reduced by approximately 50%.

The impact of development on floodplain inundation is also significant. While the duration of spells exceeding 80,000 ML/d under current conditions is similar to natural, the frequency of these events has declined to as much as 25% of natural. This has resulted in a major increase in the interval between spells for very high flows.

The spell timing (represented by start day) was shifted forward by around one month for spells with threshold lower than 80,000 ML/d.

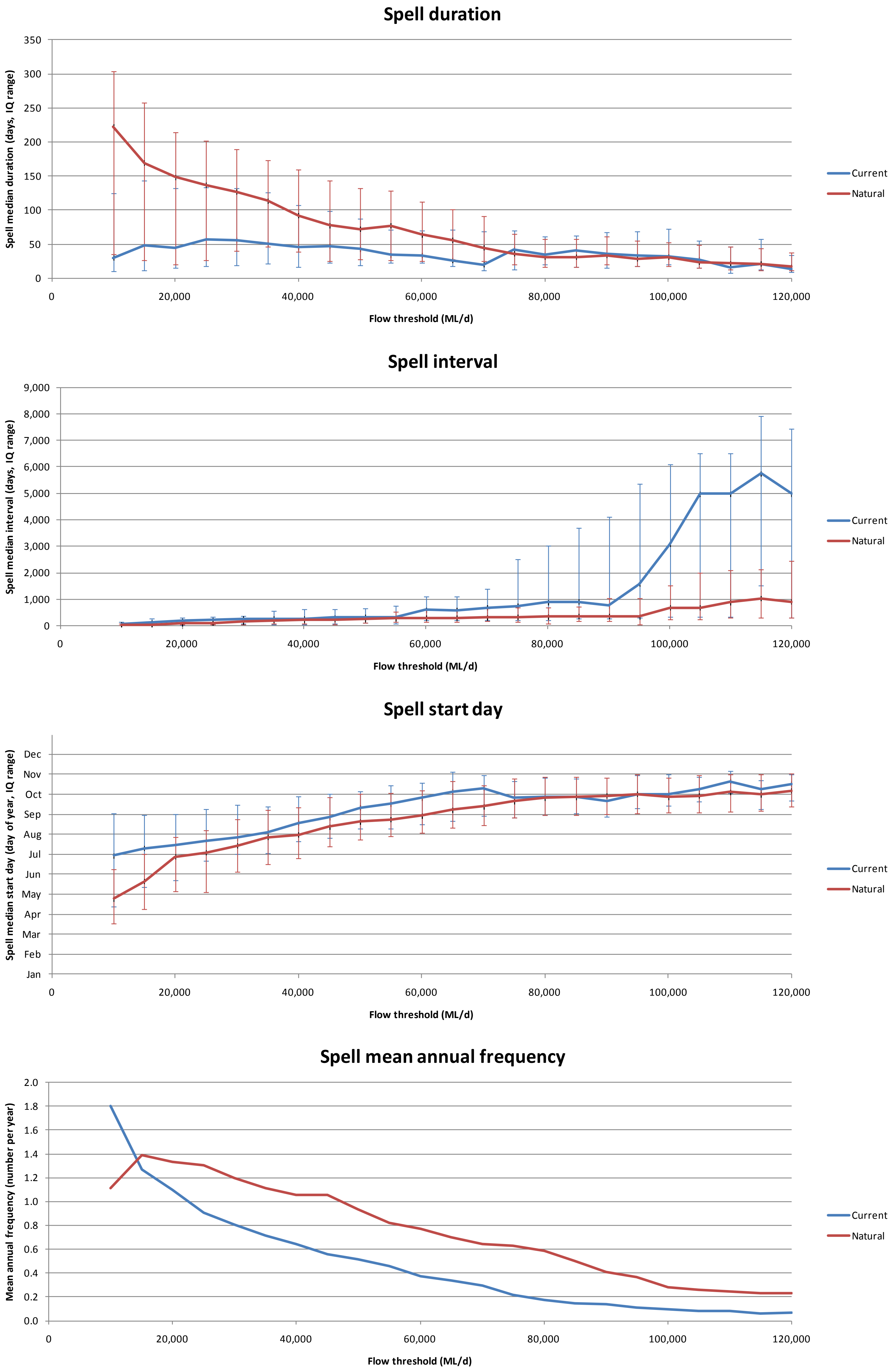


Figure 4. Comparison of characteristics of spells at 5,000 ML/d intervals for Natural and Current series' 1891 to 2009. Solid lines are median, and whiskers are inter-quartile range (25th to 75th percentile) (Ecological Associates 2010).

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

It is proposed to meet hydrological targets for flood duration and frequency by promoting floodplain inundation with a system of flow detention and regulating structures. The system creates three tiers of inundation that can utilise peaks in river flow, pumped water or a combination of the two. Supplementary works will promote inundation in three adjacent floodplain areas.

The primary component of the works is a new regulator and levee system in the western part of Lindsay River near Berribee Homestead. The regulator will allow the level in Lindsay River to be raised as high as 23.2 m AHD. This would inundate up to 3,782 ha including floodplain areas adjacent to the river, Lake Wallawalla and the river benches and wetlands associated with the Mullaroo Creek and upper Lindsay River. Lock 7 would be raised at the same time by up to 1.1 m to provide the driving head required to achieve floodplain inundation.

The second tier of flooding will be created in the floodplain north of the Berribee Regulator. Water may be released from the Berribee weir pool to flood Billgoes Billabong and the Crankhandle Wetland Complex. A number of stop banks and regulators will contain water over an area of 335 ha.

Outflows from the Crankhandle Complex will create a third tier of flooding in Crankhandle West over an area of 147 ha. When flooding targets are met, water will be returned to the River Murray.

Supplementary works will promote floodplain inundation in three high-level floodplain areas; Lake Wallawalla East and West and Lindsay River South. Regulators will be constructed on these shallow floodplain basins to detain flood water or to store water pumped from the Berribee Weir pool.

Analysis of flood flow equivalence (GHD 2013) shows that:

- the proposed works achieve an inundation extent in the Berribee Weir Pool, Crankhandle Complex and Crankhandle West equivalent to flows between 50,000 and 90,000 ML/d
- the inundation of Lake Wallawalla West, Lake Wallawalla East and Lindsay South is equivalent to flows exceeding 120,000 ML/d

The works inundate a range of water regime classes from watercourses through to alluvial plain (Table 16, Figure 19).

Table 16. Area of inundation by water regime class at Lindsay island

Water Regime Class	Area (ha)
Watercourse	223
Semi-permanent Wetland	254
Temporary Wetland	365
River Red Gum Forest and Woodland	854
Lignum Shrubland and Woodland	1777
Black Box Woodland	1030
Alluvial Plain	607
Plains Woodlands and Forest	24

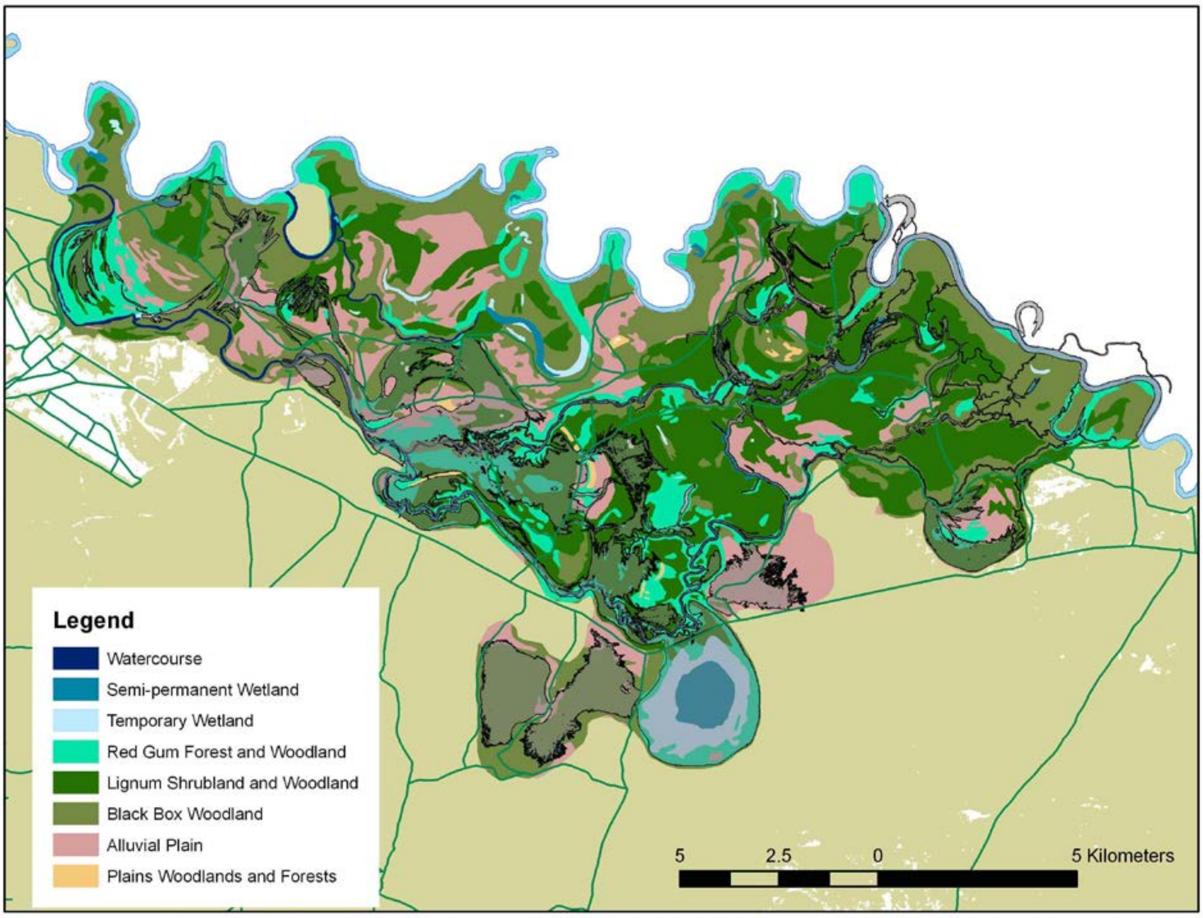


Figure 5. Inundation area of proposed works at Lindsay Island

The structures will be operated to meet environmental watering targets and in response to the ambient flow in the River Murray and ecological cues.

The requirement to inundate in-channel benches and low-lying wetlands will be met by operating Berribee Weir will be operated in conjunction with Lock 7. Water levels will be raised in Lindsay River and Mullaroo Creek 5 years in 10 in later winter and early summer for two to three months. The duration of floods caused by small peaks in flow may be extended in the Crankhandle and Crankhandle West areas by closing regulators to capture water. In the absence of flow peaks, water may be pumped into the floodplain to meet frequency targets.

The water requirements of mid-level floodplain areas will be met by raising the Berribee Regulator in conjunction with Lock 7. The water level will be raised to inundate red gum forest and woodland areas, lignum shrubland and black box vegetation. The regulator may be operated to augment existing peaks in flow to independently simulate flow peaks and can be operated at a range of levels, depending the objectives of individual events.

The water requirements of high-level floodplain areas will be met by pumping water from the Berribee Weir pool to the Wallawalla West, Wallawalla East and Lindsay South areas, or by closing regulators to capture flood water.

Under normal flow conditions, when no environmental watering is occur, all watercourse and floodplain regulators would be open.

Table 17. Hydrological Targets and Ecological Objectives

Targeted Water Regime Classes	Hydrological Targets	Ecological Objectives
Semi-permanent Wetland	Water depth to exceed 0.5 m 80% of the time Water depth to exceed 1 m 30% of the time Inflows to reach the wetland perimeter in more than 90% of years	Enhance murray cod habitat by improving the productivity of connected riparian and wetland habitat while maintaining fast-flowing habitat Maintain resident populations of frogs and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds
Temporary Wetlands	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years	Frequently provide habitat for thousands of waterbirds Contribute to the carbon requirements of the River Murray channel ecosystem
Watercourses	Maintain fast flowing habitat in upper Mullaroo Creek in the higher part of the range of velocities 0.2 and 0.4 m/s Inundate banks and backwaters to a level equivalent to 50,000 ML/d 10 years in 10. - five of these events are to be 6 weeks long - five of these events are to be 10 weeks long	Enhance murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing habitat
Red Gum Forest and Woodland	Inundation events should commence between September and December For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long	Provide reliable breeding habitat for waterbirds, including colonial nesting species Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Lignum Shrubland and Woodland	For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long	Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of

	- three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long	waterbirds Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Black Box Woodland	Provide flooding 3 years in 10 for 2 to 6 weeks duration The maximum period between events is to be 7 years	Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale Contribute to the carbon requirements of the River Murray channel ecosystem

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray(Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

Table 18. Lindsay Island specific ecological targets

Objective	Target
Enhance murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing habitat	The population of adult murray cod in Mullaroo Creek and Lindsay River increases by 25% from 2015 levels by 2030. The average lateral extent of aquatic macrophyte vegetation stands on the banks of Mullaroo Creek and Lindsay River increases by 100% from 2015 levels by 2030. The average December projected cover of aquatic macrophytes exceeds 50% in at least 100 ha in wetland habitat in the period between 2025 and 2030.
Maintain resident populations of frogs and small fish in wetlands	At least four native fish species are present in at least five wetland sites throughout the period from 2025 to 2035. At least three frog species are present in at least five wetland sites throughout the period from 2025 to 2035.
Provide reliable breeding habitat for waterbirds, including colonial nesting species	Any species of waterfowl, crake, rail, waterhen or coot breed every year between 2025 and 2035 in at least five wetland sites. Platform-building waterbirds breed in lignum shrublands on at least three occasions between 2025 and 2035. Cormorants and / or nankeen night heron breed at Lindsay Island on at least three occasions between 2025 and 2035.
Frequently provide habitat for thousands of waterbirds	The total summer waterbird abundance at Lindsay Island exceeds 3,000 in at least three seasons between 2025 and 2035.
Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale	All red gum and black box stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035. The total abundance of bats on Lindsay Island increases by 25% from 2015 levels by 2030.
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Lindsay Island for the period 2025 to 2035 is double 2015 to 2020 levels.

3 THE WALLPOLLA ISLAND FLOODPLAIN MANAGEMENT PROJECT

3.1 PROJECT DETAILS

The Wallpolla Floodplain Management Project is a Supply Measure project located in the Murray-Sunset National Park on the River Murray floodplain, 40 km west of Mildura in northwest Victoria. The project is located entirely within the Crown Land.

The Wallpolla Island floodplain system comprises Wallpolla Island and adjacent floodplain areas. The system is located on the left (southern) bank of the River Murray between Lock 10 and Lock 9 and has an area of approximately 9,000 ha.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to construct a series of stop banks to intermittently pond water across the floodplain to meet environmental watering targets.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

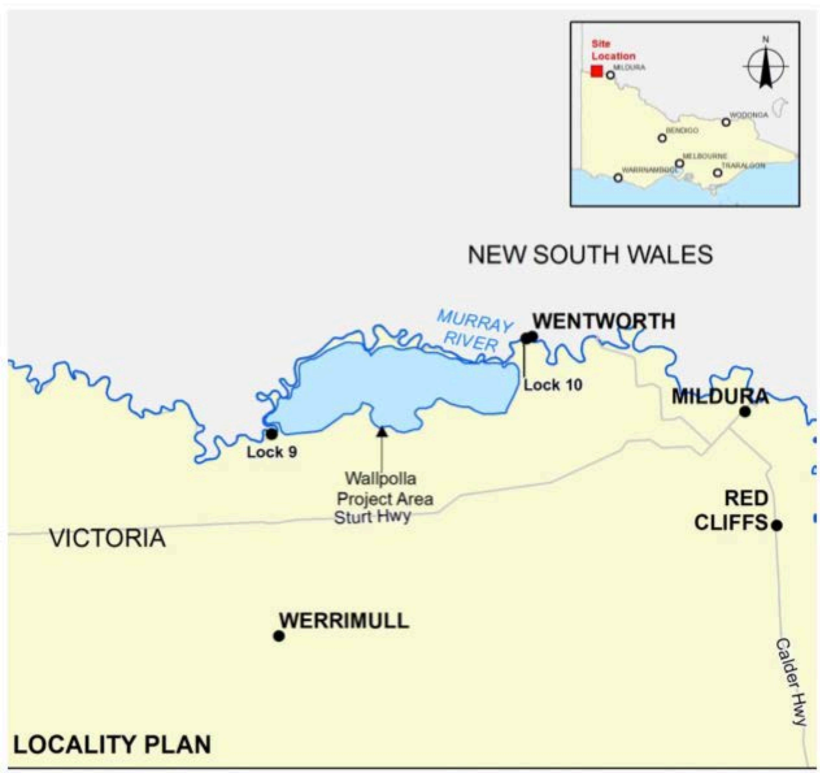


Figure 6. Location of the Wallpolla Island Floodplain Management Project

3.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

Wallpolla Island lies mainly within the Murray-Sunset National Park. It also includes areas of the River Murray Reserve and proposed Murray River Park, all of which are managed by Parks Victoria. The island is a component of the Chowilla Floodplain and Lindsay-Wallpolla Islands Living Murray Icon Site and is a wetland of national significance (Environment Australia 2001).

Wallpolla Island is a floodplain system enclosed between the River Murray and the Wallpolla Creek anabranch. Wallpolla Creek diverges from the River Murray below Lock 10 and rejoins the river above Lock 9. The island and its adjacent floodplain cover 9,000 ha and extend 28 km from east to west. The floodplain incorporates a complex range of landforms including creeks, temporary anbranches, wetland, woodlands and grasslands and is 19 km broad at its widest point.

The Wallpolla Island floodplain is part of a continuous tract of floodplain and terrestrial vegetation that includes Ned's Corner Station and the broader Murray-Sunset National Park. The tract extends 100 km to the west and south and encompasses 633,000 ha. The area represents an important biodiversity corridor that enables the movement and migration of biota and provides resilience to climate change. Fauna that regularly use the corridor include regent parrot and major mitchell's cockatoo which feed in mallee vegetation and nest in hollow-bearing trees on the floodplain. Many mammals and birds, including fat-tailed dunnart, carpet python, bats and bush birds, live in both the floodplain and terrestrial landscapes.

Wallpolla Island has a complex system of waterways and wetlands. The Lock 9 weir creates permanent flooding in lower Wallpolla Creek and other channels in the west of the island. These watercourses are lined by dense riparian vegetation that provides habitat for small fish and turtles. Permanent waterbodies provide an aquatic refuge from which frogs, such as growling grass frog, can disperse to temporary floodplain habitat during floods. Cryptic waterbirds, including the baillon's crake live in dense reedy vegetation. Fish-eating waterbirds, such as the white-bellied sea-eagle perch in trees near watercourses and hunt in the channels.

Peaks in river flow introduce water to channels in the east of the island, creating flow through the anabranches and providing habitat for channel specialist fish such as murray cod and golden perch. Temporary wetlands become connected as the river rises and are colonised by aquatic fauna including freshwater catfish and small vegetation-dependent fish such as gudgeon species and river murray rainbowfish.

Low-lying meander loops near the river channel are frequently flooded by relatively small peaks in river flow and support river red gum woodland and forest. Wetlands within these areas, including the Lilyponds and Horseshoe Lagoon provide semi-permanent wetland habitat and can support breeding by significant numbers of waterbirds including egrets, glossy ibis, spoonbills, cormorants and night herons (Ecological Associates 2007). Woodlands higher on the floodplain are dominated by black box woodland and provide a productive habitat for woodland birds, mammals and reptiles including carpet python, western grey kangaroo and the threatened De Vis banded snake.

Lignum shrubland vegetates extensive areas of Wallpolla Island. Flooded lignum shrublands provide nesting platforms for waterbirds including ibis, cormorants, pelicans and waterfowl such as freckled duck. Flooded lignum is a highly productive aquatic habitat, providing abundant food and physical habitat for small native fish species and frogs. In the dry phase between flood events lignum is important habitat for the giles' planigale, which preys on invertebrates and shelters in cracking clays (Mallee CMA 2011).

Large floods extend to areas of grassland and chenopod shrubland at the outer limits of the floodplain. When flooded, these broad areas provide feeding habitat for large numbers birds that feed on small fish, frog larvae and aquatic invertebrates. The flooded grasslands provide breeding waterbirds with a food source. In late summer and autumn shallow flooding provides stop-over habitat for number of migratory bird species listed under the Japan-Australia, China-Australia and Republic of Korea-Australia migratory bird agreements (Newall, et al. 2009).

Flooding maintains the productivity of floodplain habitats. Dense understorey vegetation provides the prey species and structural habitat on which carpet python depends. High levels of insect productivity, derived from both wetland and woodland inundation, contribute to Wallpolla Island's highly diverse bat fauna which comprises sixteen taxa (Biosis 2013). Organic matter generated on the floodplain is conveyed to the river channel by receding flood water and contributes to the energy requirements of the river ecosystem.

WATER DEPENDENT FLORA AND FAUNA

FLORA

Wallpolla Island has a diverse flora and supports plant species of conservation significance (Table 1). A recent vegetation survey (Ogyris 2013) reported 194 indigenous plant species from the site of which 30 are floodplain species that are rare or threatened under the Victorian Advisory List of Threatened Plants. One species, *Neobassia proceriflora,* is endangered and in Victoria is known only from Wallpolla Island and Lindsay Island.

In Victoria vegetation mapping units are known as Ecological Vegetation Classes and are assigned conservation ratings within each bioregion (Table 2). Of the 19 EVCs present at Wallpolla Island seven are considered depleted in the Murray Scroll Belt bioregion and four are considered Vulnerable. Disused Floodway Shrubby Herbland is Endangered.

Table 19. Plant species of conservation significance reported from Wallpolla Island (Ogyris 2013)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Ammannia multiflora	jerry-jerry			V		
Asperula gemella	twin-leaf Bedstraw			R	x	x
Atriplex pseudocampanulata	mealy saltbush			R	x	x
Atriplex rhagodioides	silver saltbush		L	V	x	x
Austrobyronia micrantha	mallee cucumber			R		
Calotis cuneifolia	blue burr-daisy			R	x	x
Crinum flaccidum	darling lily		L	V	x	x
Cynodon dactylon var. pulchellus	native couch			K		
Cyperus pygmaeus	dwarf flat-sedge			V		
Duma horrida subsp. horrida	spiny lignum			R		
Eragrostis australasica	cane grass			V		
Eremophila divaricata subsp. divaricata	spreading emu-bush			R	x	x
Eremophila maculata subsp. maculata	spotted emu-bush			R	x	
Lepidium fasciculatum	bundled peppercress			K	x	x
Lepidium papillosum	warty peppercress			K	x	x
Leptochloa fusca subsp. fusca	brown-beetle grass			R		
Malacocera tricornis	goat head			R	x	x
Minuria integerrima	smooth minuria			R		
Neobassia proceriflora	soda bush			E	x	
Picris squarrosa	squat picris			R	x	x
Rorippa eustylis	dwarf bitter-cress			R		
Sarcozona praecox	sarcozona			R		
Sclerolaena lanicuspis	woolly copperburr					
Sclerolaena muricata var. muricata	black roly-poly			K	x	x
Senecio cunninghamii var. cunninghamii	branching groundsel			R	x	x
Sida ammophila	sand sida			V	x	
Tecticornia triandra	desert glasswort			R		
Tetragonia moorei	annual spinach			K		
Verbena officinalis var. gaudichaudii	native verbena			K		
Zygophyllum simile	white twin-leaf			R		

Table 20. Bioregional conservation status of Wallpolla Island Ecological Vegetation Classes

Ecological Vegetation Class	Bioregional Conservation Status
97 Semi-arid Woodland	Vulnerable
98 Semi-arid Chenopod Woodland	Depleted
102 Low Chenopod Shrubland	Depleted
103 Riverine Chenopod Woodland	Depleted
104 Lignum Swamp	Vulnerable
106 Grassy Riverine Forest	Depleted
107 Lake Bed Herbland	Vulnerable
200 Shallow Freshwater Marsh	Vulnerable
806 Alluvial Plains Semi-arid Shrubland	Vulnerable
807 Disused Floodway Shrubby Herbland	Endangered
808 Lignum Shrubland	Least Concern
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
813 Intermittent Swampy Woodland	Depleted
818 Shrubby Riverine Woodland	Least Concern
819 Spike-sedge Wetland	Vulnerable
820 Sub-saline Depression Shrubland	Vulnerable
823 Lignum Swampy Woodland	Depleted
992 Waterbody - Fresh	Not Applicable

FAUNA

Eleven native fish species are encountered regularly in the vicinity of Wallpolla Island (Table 3).

Small fish species that inhabit localised riparian and wetland habitats include flat-headed galaxias, southern pygmy perch and hardyhead species. Large-bodied fish that specialise in deeper channel habitat include murray cod, golden perch and silver perch. Freshwater catfish spends time in deep channel habitat but use wetlands to spawn.

Carbon generated on the floodplain is conveyed to the river channel by floodwater. This material contributes to the productivity of the riverine ecosystem on which channel-specialist fish depend, including murray cod, silver perch and golden perch.

Table 21. Native fish fauna of Wallpolla Island (Henderson, et al. 2013)

Scientific Name	Common Name	Conservation Status		
		EPBC	FFG	VROTS
Biyanus bidyanus	*silver perch*			CE
Craterocephalus stercusmuscarum fulvus	*un-specked hardyhead*			DD
Leiopotherapon unicolor	*spangled perch*			
Maccullochella peelii	*murray cod*	V		V
Macquaria ambigua	*golden perch*			V
Melanotaenia fluviatilis	*murray-darling rainbowfish*		L	
Nematalosa erebi	*bony herring*			
Philypnodon grandiceps	*flathead gudgeon*			
Philypnodon macrostomus	*dwarf flathead gudgeon*			
Retropinna semoni	*australian smelt*			
Tandanus tandanus	*freshwater catfish*		L	V

Wallpolla Island has a diverse bird fauna with 129 bird species reported from the site, of which 17 have conservation significance at the state or national level and three are protected under migratory bird agreements (Table 4). A recent survey in 2013 observed 83 species (Biosis 2013).

Wetlands provide habitat for dabbling, diving and filter feeding ducks while small fish will provide prey for piscivorous waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Flooded woodland and lignum shrubland provide nesting sites for waterbirds including waterfowl and colonial nesting species. Broad areas of shallow flooding in alluvial plains and wetlands provide feeding areas for waterbirds, including migratory species that visit Wallpolla Island in summer and early autumn.

Flooding promotes plant productivity and will increase the food resources for bush birds that depend on fruit, seeds, nectar and insects. Understorey complexity will increase the availability of vertebrate prey species such as lizards and will provide sheltering and nesting sites for bush birds.

Table 22. Birds of conservation significance expected to occur at Wallpolla Island (Biosis 2013)

Scientific Name	Common Name	Conservations Status			Migratory Bird Agreements		2013 Survey	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Anas rhynchotis	australasian shoveler			V				x
Ardea modesta	eastern great egret		L	V		C J	x	x
Aythya australis	hardhead			V				x
Chlidonias hybridus javanicus	whiskered tern			NT				x
Climacteris picummnus victoriae	brown treecreeper (south-eastern ssp.)			NT				x
Dromaius novaehollandiae	emu			NT			x	x
Haliaeetus leucogaster	white-bellied sea-eagle		L	V		C	x	x
Hydroprogne caspia	caspian tern		L	NT		C J		x
Melanodryas cucullata cucullata	hooded robin		L	NT			x	x
Ninox connivens connivens	barking owl		L	E				x
Nycticorax caledonicus hillii	nankeen night heron			NT				x
Oxyura australis	blue-billed duck		L	E				x
Phalacrocorax varius	pied cormorant			NT			x	x
Platalea regia	royal spoonbill			NT			x	
Porzna pusilla	baillon's crake		L	V				x
Struthidea cinerea	apostlebird		L					x
Todiramphus pyrrhopygius	red-backed kingfisher			NT				x

The bat fauna of Wallpolla Island is highly diverse with sixteen taxa observed at the site. The bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey while trees provide roosting habitat in bark, crevices and hollows.

Wallpolla Island supports a range of woodland mammal species including western grey kangaroo and red kangaroo that feed in grasslands and woodlands and benefit from the forage provided by wetland vegetation. Lignum shrublands provide cover and a source of prey for small mammals and are the preferred habitat of gile's planigale.

Table 23. Native mammal species reported from Wallpolla Island (Biosis 2013)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	gould's wattled bat				x	x
Chalinolobus morio	chocolate wattled bat				x	
Chalinolobus picatus	little pied bat				?	
Hydromys chrysogaster	water rat					x
Macropus fuliginosus	western grey kangaroo				x	x
Macropus rufus	red kangaroo				x	x
Marmopterus sp. 2	eastern freetail bat				x	
Mormopterus sp. 3	inland freetail bat				x	x
Mormopterus sp. 4	southern freetail bat				x	x
Myotis macropus	large-footed myotis			NT	x	
Nyctophilus geoffroyi	lesser long-eared bat					x
Nyctophilus spp.	long-eared bat species				x	
Planigale gilesi	giles' planigale		L	NT	x	x
Saccolaimus flaviventris	yellow-bellied sheathtail bat				?	
Scotorepens balstoni	inland broad-nosed bat				x	
Scotorepens greyii	little broad-nosed bat			NT	x	
Tachyglossus aculeatus	short-beaked echidna				x	x
Tadarida australis	white-striped freetail bat				x	x
Trichosurus vulpecula	common brushtail possum					x
Vespadelus baverstocki	inland forest bat				x	
Vespadelus regulus	southern forest bat				x	x
Vespadelus vulturnus	little forest bat				x	x

? Identification unconfirmed

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs (Table 6). Twenty one reptile species have been reported from Wallpolla Island including five species of conservation significance. Seven frog species occur at Wallpolla Island, of which one, the growling grass frog is vulnerable nationally and endangered in Victoria (Robertson and Ahern 2007).

Table 24. Reptiles and amphibians of conservation significance reported from Wallpolla Island (Robertson and Ahern 2007),(Biosis 2013)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Reptiles						
Denisonia devisi	de vis' banded snake			V		x
Furina diadema	red-naped snake		L	V		x
Morelia spilota metcalfei	carpet python		L	E		x
Rhynchoedura ornata	beaked gecko		L	CR		x
Varanus varius	lace monitor			E	x	x
Amphibians						
Litoria raniformis	growling grass frog	V	L	E		x

FORMAL CONSERVATION AGREEMENTS

Walpolla Island is part of the Murray-Sunset National Park and River Murray Reserve designated under the National Parks Act 1975 (Victoria).

Wallpolla Island is a wetland of national significance and are listed in the Directory of Important Wetlands in Australia (Environment Australia 2001).

Wallpolla Island provides habitat for a number of migratory bird species listed under the Japan-Australia, China-Australia and Republic of Korea-Australia migratory bird agreements.

VITAL HABITAT AT THE SITE

Wallpolla Island supports plant and animal species of conservation significance under Commonwealth and Victorian frameworks.

The nationally listed growling grass frog is present at Wallpolla Island which provides the combined habitat of permanent water and still to slow-flowing areas and nearby forests.

Wallpolla Island has a highly diverse bat fauna which depends on woodland vegetation to provide roosting sites and a productive floodplain ecosystem to maintain an insect food supply.

Wallpolla Island's linkage to the broader 633,000 ha Murray-Sunset National Park represents an important biodiversity corridor. The corridor allows the movement and dispersal of biota between floodplain and terrestrial bioregions and contributes to ecosystem resilience to climate change.

Wallpolla Island features persistently flooded wetland habitats including Wallpolla Creek and Horseshoe Lagoon that provide reliable aquatic habitat and refuge from regional drought.

In late summer and autumn shallow flooding provides stop-over habitat for number of migratory bird species listed under the Japan-Australia, China-Australia and Republic of Korea-Australia migratory bird agreements (Newall, et al. 2009).

3.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVES

The overall objective of water management at Wallpolla Island is:

"to restore the key species, habitat components and functions of the Wallpolla Island ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- increasing resident populations of frogs, waterbirds and small fish in wetlands
- providing reliable breeding habitat for waterbirds, including colonial nesting species
- enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
- frequently providing habitat for thousands of waterbirds
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements in key areas of the Wallpolla Island floodplain. Seven water regime classes have been defined at Wallpolla Island (Table 25). The following describes their ecology and water requirements.

Table 25. Wallpolla Island Water Regime Classes

Water Regime Class	Area (ha)	Data Used to Define Water Regime Class
Semi-permanent Wetlands	123	Deep point-bar billabongs and wetlands identified as filling to more than 1 m at flows of 60,000 ML/d by hydraulic modelling and Lake Bed Herbland
Temporary Wetlands	82	Floodway Pond Herbland Shallow Freshwater Marsh Floodway Pond Herbland Disused Floodway Shrubby Herbland
Watercourses	407	Waterbody - Fresh Spike Sedge Wetland
Red Gum Forest and Woodland	1030	Grassy Riverine Forest / Floodway Pond Herbland Complex Grassy Riverine Forest Intermittent Swampy Woodland
Lignum Shrubland and Woodland	7541	Lignum Shrubland Lignum Swamp Lignum Swampy Woodland
Black Box Woodland	5706	Riverine Chenopod Woodland Shrubby Riverine Woodland
Alluvial Plain	2783	Alluvial Plains Semi-arid Shrubland Sub-saline Depression Shrubland Low Chenopod Shrubland
(Plains Woodlands and Forest)* *Not inundated	76	Semi-arid Chenopod Woodland Semi-arid Woodland

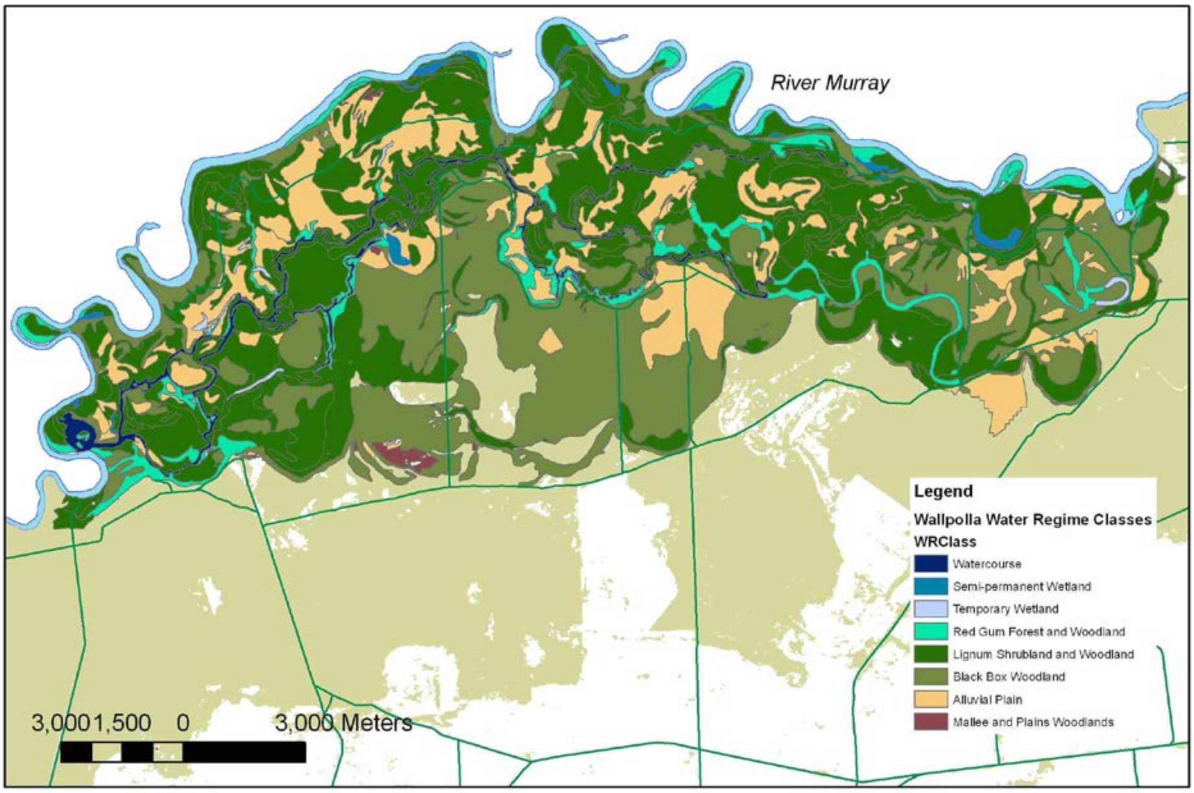


Figure 7. Walpolla Island Water Regime Classes

SEMI-PERMANENT WETLANDS

Ecology

Semi-permanent wetlands occur close to the river in low-lying meander scrolls, in anabranches flooded by the Lock 9 weir pool and adjacent floodplain depressions. They include Horseshoe Lagoon and The Liliponds.

Under natural conditions water was almost always present in these wetlands due to low flow thresholds, frequent peaks in river flow, and the capacity of wetlands to retain water for long periods. The wetlands would only dry out during rare, prolonged periods of low flow. Water levels would vary seasonally such that wetlands would tend to be flooded most deeply and frequently in spring and would tend to have lowest water levels in summer and autumn.

Persistent, deep flooding will exclude trees and emergent macrophytes from the central wetland bed, which will instead have either open water or semi-emergent vegetation of *Myriophyllum* spp., *Vallisneria americana* and *Potamogeton* spp. When dry the bed will be bare or provide habitat for lake bed herbs such as *Alternanthera denticulata, Persicaria lapathifolia, Eleocharis acuta, Glychyrrhiza acanthocarpa* and *Centipeda cunninghamii.*

Seasonal inundation of the wetland fringe provides habitat for emergent macrophytes such as *Phragmites australis, Bolboschoenus medianus* and *Cyperus gymnocaulos*. Vegetation at the perimeter grades into the grass and sedge-rich understorey of the surrounding red gum forest and woodland.

Regular drying and re-flooding of the fringe is important to wetland productivity. Flooding of the reed zone mineralises organic matter, promoting microbial, algal and macro-invertebrate production.

Persistent flooding of the wetland bed allows the development of a community of large zooplankton, shrimp (*Paratya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. These animal provide prey for fish such as smelt, bony bream and hardyhead, while flying adult insects contribute to the food requirements of bats and birds. Persistent flooding would also support resident populations of tortoise.

Dabbling ducks such as freckled duck, australasian shoveler and pink-eared duck feed on soft-leaved aquatic plants and aquatic macro-invertebrates. Semi-permanent wetlands provide reliable breeding habitat for bird species which build nests using reeds on scrapes in and around fringing vegetation and require water to be present for at least three months in winter and spring. Reeds provide frogs with a source of food, a substrate for eggs and shelter from predators. Grazing waterfowl including black swan, australian shelduck and wood duck will also be favoured by semi-emergent vegetation and will regularly breed.

Inundation of the forest or woodland adjacent to semi-permanent wetlands for periods of three to six months will provide nesting habitat for colonial nesting waterbirds. These birds will nest in the flooded trees and seek food in nearby wetlands and flooded vegetation.

Water Requirements

In order to maintain resident populations of aquatic fauna, semi-permanent wetlands may only dry out on rare occasions, in 5 to 10% of years. The wetland depth is required to exceed 0.5 m 80% of the time and 1 m 30% of the time. Inflows are required in more than 80% of years to provide seasonal inundation of the littoral zone, to mineralise organic matter and to maintain emergent macrophytes beds.

Table 26. Water management objectives for semi-permanent wetlands

Objectives Addressed	Increase resident populations of frogs, waterbirds and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting speices Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Strategy	Restore semi-permanent inundation to deep, low-lying wetlands and restore hydraulic connections to riverine habitats
Hydrological Targets	Water depth to exceed 0.5 m 80% of the time Water depth to exceed 1 m 30% of the time Inflows to reach the wetland perimeter in more than 80% of years

TEMPORARY WETLANDS

Ecology

Temporary wetlands mainly occur close to anabranches and the River Murray. They may be formed by floodplain depressions or by the deep holes in watercourses that retain water when channels cease to flow. Temporary wetlands represent a variety of flooding frequencies, durations and depths but are characterised by an intermittent, broadly seasonal flooding regime.

Temporary wetlands alternate between flooded and dry states. They tend to be filled by freshes in river flow in winter and spring after which they gradually dry out. Flooding may persist over several years if the wetlands receive summer inflows, but will dry out to some degree between inflow events. The wetlands may remain dry over several years if river levels fail to reach the wetland sill.

When flooded, soft-leaved semi-emergent vegetation will colonise the deeper parts of the lake bed including *Myriophyllum sp.* and *Potamogeton* sp. Open water may be present in the central part of the wetlands where water is too deep to support these species. Emergent macrophytes such as *Cyperus gymnocaulos* and *Eleocharis acuta* will occupy the narrow seasonally inundated zone at the fringe of the wetland. *Duma florulenta* and *Eragrostis infecunda* may also extend into the bed of less-frequently flooded wetlands.

Flooded wetlands will be colonised by the larvae of flying insects and by invertebrates released from resting stages on the lake bed. Over several weeks the wetlands will provide productive food sources for small fish, waterbirds, frogs and turtles.

The drying wetland bed will support a range of wetland herbs such as *Centipeda cunninghamii, Persicaria lapathifolia, Alternanthera* sp. *Glossostigma elatinoides* and *Heliotropum* sp. Between flood events the wetland bed will develop a community of lake bed herbs and grasses such as *Glycyrrhiza acanthocarpa* and *Persicaria lapathifolia.* These plants, together with colonising *Eucalyptus camaldulensis*, will die during subsequent sustained flood events.

In sustained dry periods the wetland water levels will fall below the reed zone to expose a muddy herbland on the lake bed. Small wading birds such as ruddy turnstone and red-necked stint will feed on macro-invertebrates in shallow water and mud. Fish-eating birds and carrion feeders, including white-bellied sea-eagle, will feed on stranded fish.

Water Requirements

To achieve the ecological objectives, temporary wetlands should be intermittently inundated and exposed on a broadly seasonal cycle. This water regime will create productive aquatic habitats with diverse aquatic plant and animal communities.

Temporary wetlands should be completely filled between 25% and 90% of years. The peak in wetland level is required some time between September and December to match the growth requirements of emergent macrophytes and the breeding requirements of waterbirds, small native fish and frogs. Drying of 80% of the wetland bed is required in more than 50% of years to promote the growth of wetland macrophytes and herbs on the wetland bed and to mineralise organic matter.

Table 27. Water management objectives for temporary wetlands

Objectives Addressed	Increase resident populations of frogs, waterbirds and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting speices Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Strategy	Restore intermittent inundation of floodplain wetlands
Hydrological Targets	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years

WATERCOURSES

Ecology

Water is pooled in the watercourses of western Wallpolla Island by the Lock 9 weir to create a permanent and mostly lentic environment. Watercourses in the east of the island are activated by peaks in river flow that create intermittent fast-flowing habitat.

Watercourses generally have open water in the channel. The banks support scattered patches of semi-emergent macrophytes including *Vallisneria* sp. and *Ottelia ovalifolia* (Water Technology 2009). Persistently flooded reaches support dense riparian vegetation of *Phragmites australis* with *Typha* sp. present along slow-flowing channels. Rarely-flowing reaches will support sparse drought-tolerant sedges such as *Cyperus gymnocaulos.*

Permanent watercourses provide an aquatic habitat for a range of generalist aquatic fauna. Watercourses will support a species-poor climax community of aquatic invertebrates comprising large zooplankton, shrimp (*Paratya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. Together with small-bodied fish living in the fringing macrophytes, these provide prey for large bodied fish. Large bodied fish will also visit the fringing vegetation and snags, which provide benthic invertebrate prey and shelter from predators. Watercourses may support resident populations of turtle. The watercourses represent an alternative habitat to the River Murray for these large aquatic species, which move between the floodplain and the river during peaks in river flow.

Water Requirements

The habitat value of watercourses can be increased with a water regime that promotes productivity and migration and dispersal opportunities for aquatic fauna. A seasonally fluctuating water regime will promote a broad zone of macrophytes on the channel banks and will increase habitat complexity, shelter and feeding opportunities for fish, frogs and waterbirds. High water levels that connect channels to floodplain wetlands will promote the dispersal of fauna and increase access to refuge habitat.

Under natural conditions median monthly water levels in the Lock 9 weir pool ranged over 3 m over the course of a year (Ecological Associates 2013). Water levels should be varied on a seasonal basis with a water level range of 1 to 3 m. The maximum level should provide hydraulic connection to floodplain wetlands for at least two months between June and November.

Table 28. Water management objectives for watercourses

Objectives Addressed	Increase resident populations of frogs, waterbirds and small fish in wetlands Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Strategy	Introduce seasonal variation in anabranch water levels
Hydrological Targets	Water levels in anabranches to follow a seasonal cycle with minimum levels in autumn and maximum levels in spring Maximum levels in spring to provide hydraulic connection to floodplain wetlands for 2 to 6 months between June and November

RED GUM FOREST AND WOODLAND

Ecology

River red gum forest and woodland occurs mainly on meander scrolls along the River Murray. Inundation occurs mostly in spring so that the ground is generally dry over summer and autumn. The plant community comprises species that benefit from seasonal flooding but tolerate dry conditions over summer and occasional years without any flooding. During floods aquatic plants develop from propagules including *Marsilea drummondii, Eleocharis acuta* and *Triglochin multifructum.* The drier areas are dominated by grasses and sedges including *Cyperus gymnocaulos* and *Sporobolus mitchellii* and may include *Duma florulenta*. Species which colonise the drying forest floor include *Lachnagrostis filiformis, Glycyrrhiza acanthocarpa* and *Centipeda cunninghamii.*

Inundation of red gum forest and woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

During longer flooding events red gum forest and woodland will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as nankeen night heron, cormorant and australasian darter. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for nesting wood duck, carpet python, bats and brush-tailed possum. Red gum growing close to water provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering which supports nectar-eating insects and birds and insectivorous birds.

Water Requirements

Flows of 70,000 to 90,000 ML/d inundate red gum forests and woodlands (Ecological Associates 2007). Under natural conditions these events occurred almost annually and lasted for two to three months.

Red gum forest and woodland has been severely degraded at Wallpolla Island. Mean flood duration has declined to less than 6 weeks while flood frequency has declined to approximately one event every two years.

Duma florulenta has invaded the understorey and the density of river red gum has increased. The diversity of understorey vegetation has declined. Waterbird breeding events are smaller and less frequent.

Flooding in spring and early summer for two to three months will meet the seasonal requirements of understorey plants and maintain vegetation structure and diversity. Flooding at this time of year will also address the seasonal breeding requirements of native fish, frogs and waterbirds.

Long flooding events, lasting over six months, are required to support breeding by colonial nesting waterbirds. These events will influence the structure of the vegetation, limiting reducing the cover of *Duma florulenta* and *Eucalyptus camaldulensis* and promoting wetland understorey species.

Flooding frequencies of 6 years in 10 are recommended for lower-lying areas and 5 years in 10 for high floodplain areas.

Table 29. Water management objectives for red gum forest and woodland

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting speices Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore seasonal inundation to red gum forest and wetlands
Hydrological Targets	Inundation events should commence between September and December For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long

LIGNUM SHRUBLAND AND WOODLAND

Ecology

Lignum shrubland and woodland occurs on intermediate floodplain terraces and shallow floodplain depressions. Lignum (*Duma florulenta*) is the dominant species and, when flooded frequently, can form extensive, dense thickets. Other large shrubby species *Chenopodium nitrariaceum* and *Eragrostis australasica* can co-occur with lignum. The trees *Eucalyptus camaldulensis, E. largiflorens* and *Acacia stenophylla* can form a sparse overstorey.

Lignum shrubland and woodland experiences intermittent flooding separated by potentially long dry periods. When flooded frequently the shrubs grow quickly and form dense, continuous thickets. The ground layer supports a range of wetland herbs including *Marsilea drummondii, Eleocharis acuta, Cyperus gymnocaulos* and *Rumex* spp. When flooding is less frequent the shrubs are smaller and more widely spaced allowing the groundlayer vegetation to become more dense and diverse, supporting shrubs, grasses and herbs including *Dysphyma crassifolium, Atriplex leptocarpa, A. lindleyi, Sclerolaena tricuspis* and *Austrodanthonia* sp.

Inundation of lignum shrubland represents an extension of the habitat for aquatic floodplain fauna such as fish, reptiles and frogs. Their bushy structure and accumulated debris provides a productive substrate for epiphytes that supports high macroinvertebrate productivity. Flooded lignum is also used as a platform by nesting waterbirds including ibis and spoonbill. Floodwater draining from lignum will carry dissolved and particulate carbon as well as algae and invertebrates which will contribute to the food web of the river channel.

Between flood events, lignum is an important habitat for terrestrial vertebrate fauna including lizards and giles' planigale.

Water Requirements

Lignum shrubland and woodland at Wallpolla Island is generally in poor condition. In the higher, less frequently flooded parts of the floodplain lignum shrublands have been replaced by low chenopod shrubs. The size and density of shrubs in remaining stands has declined and formerly frequently flooded areas have developed a more terrestrial vegetation.

A range of flooding frequencies is required to achieve the ecological objectives. Lower-lying shrublands (equivalent to 65,000 ML/d flow threshold) should be flooded 8 years in 10. Brief events, of two months duration will maintain ecosystem structure and productivity and will provide seasonal habitat for aquatic fauna. Longer floods, of four to six months duration, should be provided in four of these years to support waterbird breeding.

Higher areas (equivalent to 85,000 ML/d flow threshold) should be flooded 4 years in 10. Half of these events should be one month long to maintain ecosystem structure. Half of the events should be of two to three months duration to promote breeding by fish, frogs and waterbirds.

Table 30. Water management objectives for lignum shrubland and woodland

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting speices Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's planigale Frequently provide habitat for thousands of waterbirds Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to lignum shrubland and woodland
Hydrological Targets	For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long

BLACK BOX WOODLAND

Ecology

Black box woodland occurs mostly on high, infrequently flooded floodplain terraces. The canopy is open and the community has a diverse, shrubby understorey that includes *Duma florulenta, Chenopodium nitrareacum, Rhagodia spinescens, Enchylaena tomentosa* and *Acacia stenophylla*. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses.

Tree recruitment and the productivity of the vegetation is strongly linked to flooding. Flooding maintains the diverse tree age structure and complex understorey that is required by carpet python and other vertebrate fauna. The diversity of birds is particularly high because black box woodland contributes to the habitat requirements of both riverine and dryland species (Carpenter 1990). Black box woodland supports a high proportion of ground foragers and hollow-nesting species. Black box woodlands are important for canopy feeding bush birds such as superb fairy-wren, little friarbird and blue-faced Honeyeater. Black box woodland also supports seasonal migrants normally associated with higher rainfall areas such as grey fantail and white-bellied cuckoo-shrike. Black box is an important habitat component for insectivorous bats.

Flood events that inundate black box woodland contribute to the carbon requirements of permanent watercourses. Receding flood water conveys organic debris to the river channel where it promotes macro-invertebrate productivity and maintains the riverine food web.

Water Requirements

Flows of 80,000 to 115,000 ML/d inundate black box woodland at Wallpolla Island. Under natural conditions these flows occurred in approximately 3 years in 10 and lasted approximately 1 month. While the duration of flood events is similar under the current flow regime, the frequency of events has declined to 1 year in 10 of years.

The overall structure of black box woodland has been maintained, but tree recruitment and productivity has declined, threatening the long-term viability of vertebrate fauna populations. Resilience to prolonged drought events, where understorey vegetation becomes sparse and food resources diminish, is poor.

Black box woodland productivity can be restored by increasing the frequency of floods equivalent to 100,000 ML/d to 3 years in 10 and reducing the maximum dry spell between events to seven years.

Table 31. Water management objectives for black box woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's planigale Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to black box woodland
Hydrological Targets	Provide flooding 3 years in 10 for 2 to 6 weeks duration The maximum period between events is to be 7 years

ALLUVIAL PLAIN

Ecology

Alluvial plains occupy the high floodplain terraces on Wallpolla Island and the extensive plains at the southern perimeter of the floodplain. The soils are saline, clay-rich and poorly drained.

The alluvial plain vegetation comprises terrestrial species tolerant of salt and seasonal waterlogging. The dominant species include chenopods such as *Atriplex vesicaria, A. stipitata* and *Maireana pentagona* as well as the larger shrubs *Lawrencia squamata* and *Nitraria billardieri*. *Dysphyma crassifolium* ssp. *clavellatum* forms an extensive groundcover in saline areas. Trees are largely absent, but *Acacia oswaldii* or *Alectyron oleifolius* may be present on local rises.

Alluvial plains are rarely flooded and do not normally support wetland plant species. However flooding creates a productive feeding resource for waterbirds, including those that may be nesting in more frequently flooded areas. Widespread, shallow flood water is an important feeding habitat for migratory wading birds which visit Wallpolla Island in late summer and early autumn.

Water Requirements

Alluvial plains represent a terrestrial vegetation community. Flooding is not required to maintain its structure or productivity.

Flooding does provide opportunistic habitat for floodplain fauna, including feeding habitat for wading birds. Flooding of the alluvial plain will contribute to the success of waterbird breeding events by increasing the availability of food. Extensive flooding may also attract birds to the site and trigger breeding behaviour.

Alluvial plains should be flooded to complement waterbird breeding objectives in wetland, lignum and woodland habitats. When flooding events of four to six months are provided to promote breeding in these areas, floods of one to two months duration should also be provided to alluvial plains.

To maintain the terrestrial character of the alluvial plains, flooding should not be provided more than 3 times in 10 years.

Table 32. Water management objectives for alluvial plains

Objectives Addressed	Provide reliable breeding habitat for waterbirds, including colonial nesting species Frequently provide habitat for thousands of waterbirds
Strategy	Restore flooding to alluvial plains
Hydrological Targets	Provide flooding 1 years in 10 for 3 weeks in summer. Highest prioirty years are during major waterbird breeding events. Inundate the alluvial plains no more than 3 times in 10 years.

3.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Wallpolla Island Floodplain Management Project will

- increase the population size, health and age structure of native fish populations in floodplain watercourses
- restore and protect semi-permanent wetland habitat, increasing the range and resilience of aquatic fauna such as growling grass frog
- provide seasonal waterbird breeding opportunities
- restore frequent breeding opportunities for colonial nesting waterbirds
- restore and protect the productivity and structure of floodplain woodland and shrubland communities, increasing the viability of vertebrate fauna populations including carpet python, giles' planigale, fat-tailed dunnart and bat species
- supply organic matter to the River Murray channel ecosystem

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Wallpolla Island (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

The proposed Wallpolla Island supply measure restores flooding and productivity to extensive areas of red gum woodland, black box woodland and lignum shrubland. It will contribute significantly to the feeding and breeding requirements of platform-building waterbirds that nest in lignum, including colonial nesting species, and provides and extensive and productive aquatic habitat for small-bodied fish species.

The quality of wetland and watercourse habitat at Wallpolla Island will be significantly improved by the proposed works. The extent of aquatic habitat and feeding opportunities for large-bodied fish will be improved through management of watercourses. Wetland habitat along floodplain watercourses and adjacent to the River Murray will provide improved feeding and breeding opportunities for waterbirds.

Table 33. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Wallpolla Island project.

Ecological Class	Ecological Element	Wallpolla Island
Waterbirds	Bitterns, crakes and rails	◆
	General abundance and health - all waterbirds	◆◆
	Breeding - Colonial-nesting waterbirds	◆◆
	Breeding - other waterbirds	◆
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	◆◆
	Forests: river red gum (*Eucalyptus camaldulensis*)	
	Forests and woodland: black box (*Eucalyptus largiflorens*)	◆◆
	Shrublands	◆◆◆
	Tall grasslands, sedgelands and rushlands	◆
	Benthic herblands	◆
Fish	Short-lived / small-bodied fish	◆◆◆
	Long-lived / large-bodied fish	◆

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

3.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

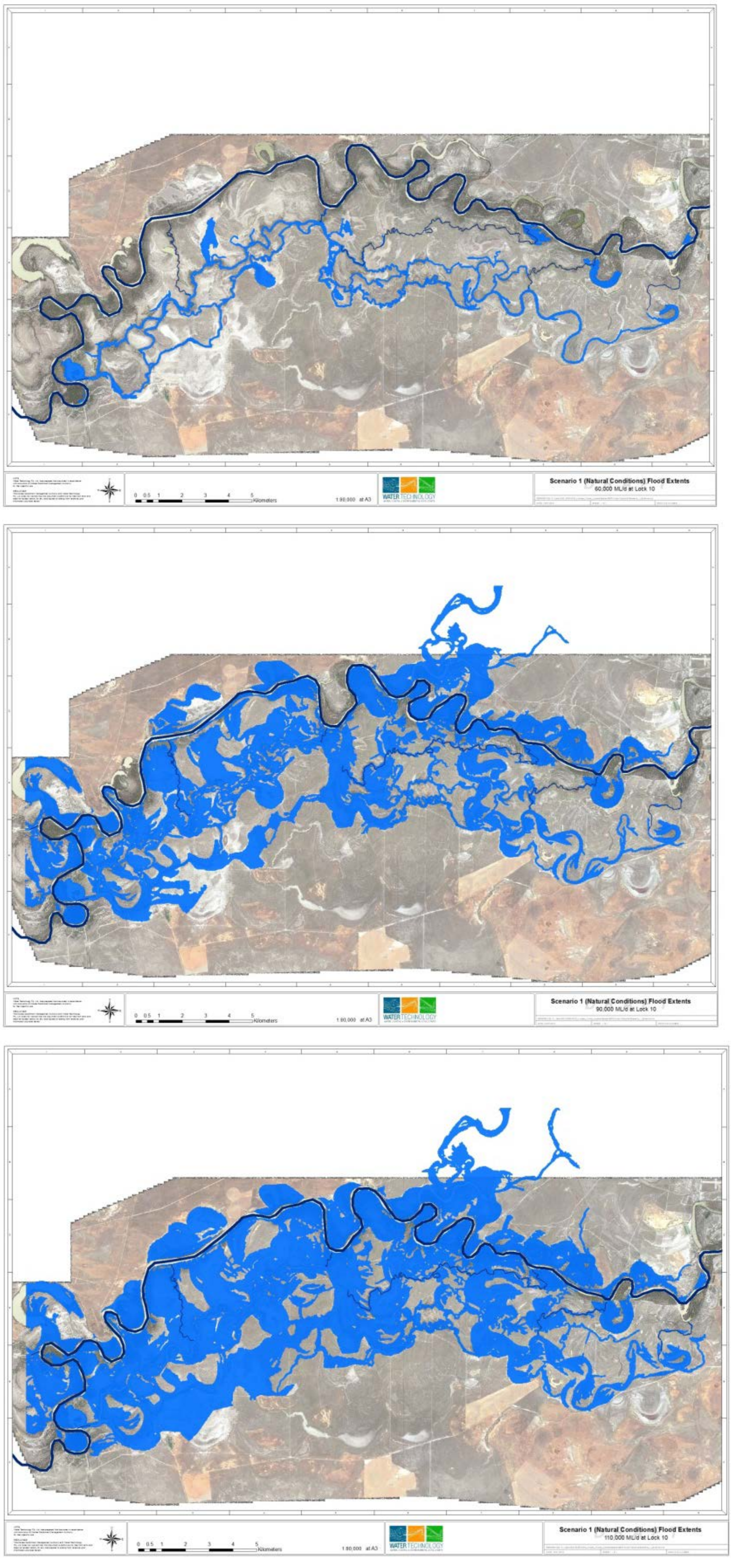
CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

The Wallpolla Island floodplain is made up of watercourses, wetland basins and freely-draining floodplain areas.

The watercourses are deeply incised in the floodplain and are permanently inundated by the Lock 9 weir pool in the west of the island. The weir pool of Lock 9 extends 25 km upstream through Walpolla Creek and a number of other channels (Ecological Associates 2007). The weir maintains a stable water level in the river under low, regulated flows and the anabranches act as permanent wetlands under these conditions.

The upstream connections of watercourses in the east of the island start to become active at River Murray flows exceeding 3,000 ML/d, but significant anabranch flow requires higher levels. Finnigans Creek becomes active at flows exceeding 8,000 ML/d and Sandy Creek flows when river discharge exceeds 33,000 ML/d. The upstream connection of Wallpolla Creek becomes active when river discharge exceeds 70,000 ML/d.



60,000 ML/d

90,000 ML/d

110,000 ML/d

Figure 8. Wallplla Island floodplain inundation at flows of 60,000, 90,000 and 110,000 ML/d (data supplied by Water Technology).

There are few low-lying wetland areas at Wallpolla Island. Water backs into scroll bar wetlands along the river bank at flows exceeding 30,000 ML/d, including the Lilyponds. The Horseshoe Lagoon meander cut-off also starts to fill at 30,000 ML/d. As river levels continue to rise water spills into the surrounding river red gum forest and woodland.

Several low-lying wetlands adjacent lie to the anabranches and are filled as river levels increase. The Bong, close to the Lock 9 weir pool is permanently inundated, but other basins are filled at flows between 30,000 and 60,000 ML/d. The higher level wetlands grade into lignum habitat.

Flood water is largely confined within the wetlands and deeply incised channels until river flows exceed 70,000 ML/d at which point water spills to black box woodlands and lignum shrublands. Widespread floodplain inundation, including to alluvial plain vegetation, occurs at flows exceeding 90,000 ML/d.

HYDROLOGY

Wallpolla Island is located downstream of the confluence of the Darling and Murray rivers. Their contrasting hydrologies influence the hydrology of the river at Wallpolla Island.

River Murray flows are derived from the temperate southern Murray-Darling basin which includes the Murray, Murrumbidgee and Goulburn tributaries. These catchments produce largely seasonal flows that are highest in late winter to early summer. In contrast, the Darling River drains the northern basin, and is often influenced by sub-tropical weather systems that generate large flows in summer. The river at Wallpolla Island therefore provides highly variable, but seasonally consistent peaks in winter and spring, occasionally augmented by Darling flows that extend and increase high flows through summer. The largest flow events at Wallpolla Island occur when both Darling and Murray systems are in flood.

River hydrology has been altered significantly by regulation and diversion upstream. Storages in Victoria and New South Wales capture water in winter and spring and for delivery to consumers (primarily irrigators) during the summer. The impact on river hydrology has been a reduction in winter and spring flow peaks and enhancement of summer flows (Maheshwari et al., 1995). Locks and weirs have further altered floodplain water regimes by stabilising river levels.

The ecologically significant effects of these hydrological and hydraulic changes are:

- the loss of flowing water habitat under normal regulated flows;
- permanent inundation of anabranches in the vicinity of the weir pools; and
- the reduction in the frequency of inundation in higher level wetlands and floodplain areas.

As a result of river regulation there has been a significant change in the characteristics of spells in terms of duration and frequency (Table 34). The time the river exceeds the flows required to initiate anabranch flow and inundate low-lying wetlands (approximately 40,000 ML/d) has declined from 40% of the time to 15% of the time. The frequency and duration of these events has almost halved so that wetlands like the Lilyponds and Horseshoe Lagoon are rarely and usually briefly flooded.

The flows required to initiate floodplain inundation, particularly in lignum and woodland vegetation (65,000 ML/d), have also decreased. The freqency of these events has declined from approximately 3 years in 4 to 1 year in 4, while the duration of those events has also declined significantly.

The flows that provide widespread inundation. While flows exceeding 115,000 ML/d occured in 23% of years under natural conditions, they now occur in only 6% of years. Consequently the productivity of the floodplain has declined, the health and extent of flood-dependent vegetation (including black box and lignum) has declined and the foraging habitat required by waterbirds is available less frequently.

Table 34. River Murray Hydrology at Lock 9 (Ecological Associates 2007)

Threshold Murray Discahrge (ML/d)	Percent time flow exceeded		Events per 100 years		Median Event Duration	
	Natural	Current	Natural	Current	Natural	Current
20,000	57	24	118	94	160	72
35,000	40	15	118	62	110	59
65,000	10	7	77	27	57	48
115,000	3	1	23	6	34	40

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

It is proposed to meet targets for flood duration and frequency by promoting floodplain inundation with a system of flow detention and regulating structures.

The system controls inundation in three management areas, Mid, Upper and South Wallpolla. Water is detained in each area by stop banks constructed across the floodplain. Flow through the stop banks is controlled by regulators.

The management areas represent three tiers of flooding with water held at the highest level in Upper Wallpolla at 32.0 m AHD. Water can be released from this area to Mid Wallpolla where structures will detain water up to 30 m AHD. South Wallpolla will hold water at levels up to 30.6 m AHD and can be partially filled with water released from Mid Wallpolla. It can also be filled by pumping or by detaining peaks in river flow.

The Upper Wallpolla management area will be created by a major regulating structure on Wallpolla Creek where it nears the Old Mail Road. The flooded area will be contained by raising existing tracks over a length of 2.6 km. Two small additional regulators will be required. At a level of 32.0 m AHD, 861 ha is inundated of which approximately half is black box woodland. The area will be filled by capturing peaks in river flow or by pumping in water from the River Murray.

The Mid Wallpolla management area will be created by a major regulating structure on Wallpolla Creek just upstream of Dedmans Creek. When the system is not in operation, the regulator will be open to allow the free passage of water. To contain the water, 235 m of existing tracks will be raised and minor regulators at will be constructed at two locations. The estimated extent of flooding is 1,091 ha and comprises black box woodland, red gum woodland and lignum shrubland. The area will be filled by capturing peaks in river flow or by pumping in water from the River Murray.

The South Wallpolla management area comprises a shallow, high-level basin between Wallpolla Creek and the Old Mail Road. Water can be contained in the basin by a temporary water retaining structure (such as sand bags) on an existing track. At a level of 30.6 m AHD, 668 ha is inundated including 446 ha of black box woodland. The area will be filled predominantly by pumping in water from Wallpolla Creek.

These works can be complemented by a program to raise and lower Lock 9 to restore a seasonal cycle to water levels in the weir pool and watercourses of western Wallpolla Island.

Table 35. Hydrological Change

Targeted Water Regime Classes	Hydrological Targets	Ecological Objectives
Semi-permanent Wetland	Water depth to exceed 0.5 m 80% of the time Water depth to exceed 1 m 30% of the time Inflows to reach the wetland perimeter in more than 80% of years	Increase resident populations of frogs, waterbirds and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting speices Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Temporary Wetlands	Completely fill wetlands between 25% and 90% of years Peak water level between September and December Dry 80% of the wetland bed in more than 50% of years	Increase resident populations of frogs, waterbirds and small fish in wetlands Provide reliable breeding habitat for waterbirds, including colonial nesting speices Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Watercourses	Water levels in anabranches to follow a seasonal cycle with minimum levels in autumn and maximum levels in spring Maximum levels in spring to provide hydraulic connection to floodplain wetlands for 2 to 6 months between June and November	Increase resident populations of frogs, waterbirds and small fish in wetlands Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands
Red Gum Forest and Woodland	Inundation events should commence between September and December For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long	Provide reliable breeding habitat for waterbirds, including colonial nesting speices Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's plangiale Contribute to the carbon requirements of the River Murray channel ecosystem
Lignum Shrubland and	For areas above an inundation threshold equivalent to 70,000 ML/d	Provide reliable breeding habitat for waterbirds, including colonial nesting speices

Woodland	- provide flooding 6 years in 10 - three of these events to be 4 weeks long - three of these events to be 10 weeks long For areas above an inundation threshold equivalent to 85,000 ML/d - provide flooding 5 years in 10 - two of these events to be 3 weeks long - two of these events to be 6 weeks long	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's planigale Frequently provide habitat for thousands of waterbirds Contribute to the carbon requirements of the River Murray channel ecosystem
Black Box Woodland	Provide flooding 3 years in 10 for 2 to 6 weeks duration The maximum period between events is to be 7 years	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and gile's planigale Contribute to the carbon requirements of the River Murray channel ecosystem

The works inundate a range of water regime classes from watercourses forest through to alluvial plain (Table 37, Figure 9).

Table 36. Area of inundation by water regime class at Wallpolla Island

Water Regime Class	Area (ha)
Watercourse	96
Semi-permanent Wetland	32
Temporary Wetland	41
River Red Gum Forest and Woodland	213
Lignum Shrubland and Woodland	704
Black Box Woodland	466
Alluvial Plain	399

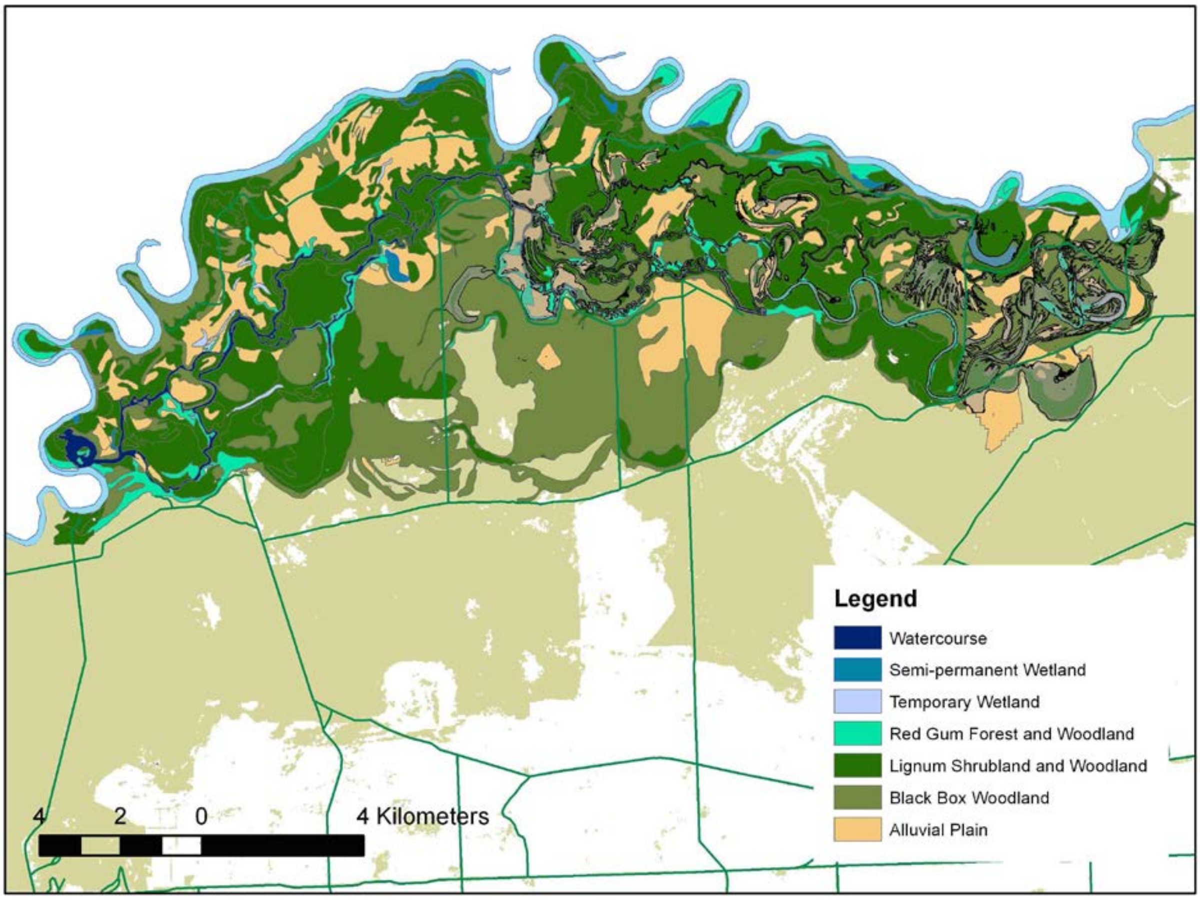


Figure 9. Inundation area of proposed works at Wallpolla Island

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

Table 37. Wallpolla Island specific ecological targets

Objective	Target
Increase resident populations of frogs, waterbirds and small fish in wetlands.	At least four native fish species are present in at least three wetland sites throughout the period from 2025 to 2035. At least three frog species are present in at least three wetland sites throughout the period from 2025 to 2035.
Provide reliable breeding habitat for waterbirds, including colonial nesting species	Any species of waterfowl, crake, rail, waterhen or coot to breed every year in at least four wetland sites in the period between 2025 and 2035. Platform-building waterbirds breed in lignum shrublands on at least three occasions between 2025 and 2035. Cormorants and / or nankeen night heron breed at Wallpolla Island on at least three occasions between 2025 and 2035
Enhance local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands	The population of adult murray cod in Wallpolla Island watercourses increases by 25% from 2015 levels by 2030. The population of adult golden perch in Wallpolla Island watercourses increases by 25% from 2015 levels by 2030. The average lateral extent of aquatic macrophyte vegetation on the banks of permanent floodplain watercourse reaches increases by 100% from 2015 levels by 2030. The average December projected cover of aquatic macrophytes exceeds 50% in at least 100 ha in wetland habitat in the period between 2025 and 2030.
Frequently provide habitat for thousands of waterbirds	Total summer waterbird abundance at Wallpolla Island exceeds 2,000 in at least three seasons between 2025 and 2035.
protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and giles' planigale	Total bat abundance increases by 25% from 2014 levels by 2030.
contributing to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Wallpolla Island for the period 2025 to 2035 is double 2015 to 2020 levels.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray (Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

4 THE HATTAH NORTH FLOODPLAIN MANAGEMENT PROJECT

4.1 PROJECT DETAILS

The Hattah Lakes North Floodplain Management Project is a Supply Measure project located in the Hattah-Kulkyne National Park on the River Murray floodplain, 60 km south-east of Mildura in northwest Victoria. The project is located entirely within Crown Land.

The Hattah floodplain system is located on the left (western) bank of the River Murray between Robinvale and Colignan. The system comprises approximately 20 lakes and surrounding woodlands that are flooded by peaks in River Murray flow.

Under The Living Murray (TLM) program an extensive package of works was completed, including a new pump station, creek lowering and environmental regulators. The works address environmental water requirements of the central floodplain by increasing the frequency and duration of flooding in the lakes, wetlands and surrounding woodlands.

The Hattah Lakes North Floodplain Management Project proposes to build on the benefits of the TLM works by extending the flood management area at two locations, the Chalka North Area and the Lake Boolca Area. The project provides inundation of up to 720 ha of floodplain in areas that support a suite of threatened flora and fauna species.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

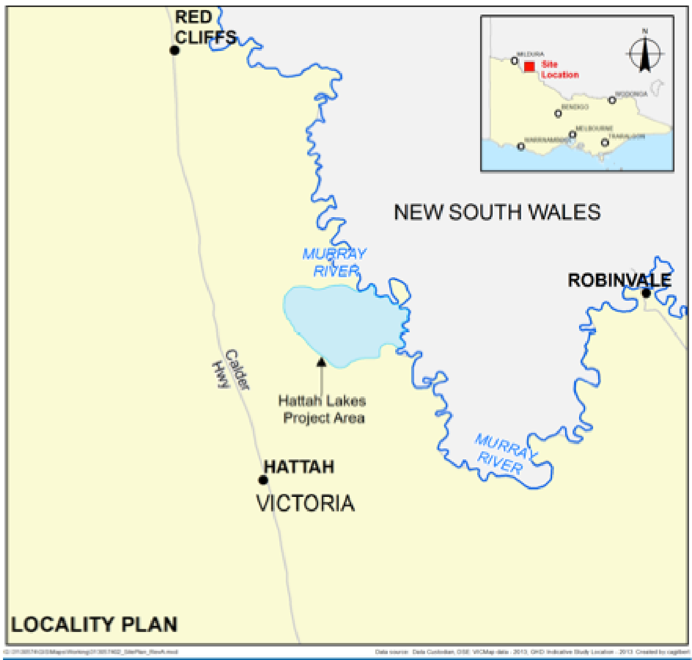


Figure 10. Location of the Hattah North Floodplain Management Project

4.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

The Hattah Floodplain comprises a mosaic of approximately 20 lakes set within a mallee dune field, distributed over an area of approximately 57,000 ha. Water enters the system from the River Murray; initially by Chalka Creek South and at higher river levels by Chalka Creek North and Cantala Creek. Water is distributed through the lakes by connecting floodways and eventually spills to the surrounding floodplain. Several of the wetlands are deep, filled frequently and provide semi-permanent aquatic habitat. Higher lakes and floodplain areas are inundated only rarely.

The Chalka North Area comprises the floodplain adjacent to Chalka Creek north of Oateys Crossing. Chalka Creek is incised in the floodplain and is a principal drainage route for water leaving the lakes on the flood recession. At high river levels water spills to the banks of the creek where it inundates red gum forest, lignum shrubland and black box woodland.

The Lake Boolca Area is a relatively high and remote part of the floodplain and among the last areas to be inundated. The area comprises wetlands and floodways confined between sand dunes. Two floodways connect the area to the broader Hattah floodplain. The Bitterang floodway extends north from Lake Bitterang while Raakjlim Creek provides a westerly connection from Chalka Creek North. Flood water reached the Lake Boolca Area with an approximate frequency of 3-5 times in 100 years under natural conditions, with water likely to persist for one to two years after inflow events (Ecological Associates 2007).

Intermittent flooding maintains the distinctive habitat features of the Lake Boolca Area. The flood-dependent woodland and grassland communities contrast with the surrounding mallee landscape and provide important complementary habitat components.

Black box trees line the watercourses, floodways and lakes of Hattah North. The trees are sustained by intermittent flooding events. Flooding promotes growth and recruitment and suppresses the encroachment of dryland tree species. The large hollows provided by black box trees are rarely found in mallee vegetation but are critical to many fauna species. Hollows provide nesting sites for a number of bird species including regent parrot, sulphur crested cockatoo, mallee ringneck, major mitchells cockatoo and barking owl. Common brushtail possum shelter in tree hollows and bats shelter in hollows and the complex crevices formed by the bark of black box trees. Hollows in trees and fallen logs provide shelter for large reptiles including lace monitor and carpet python.

Intermittent flooding maintains the open grassy vegetation of the lakes which contrasts with the closed woodland vegetation of the mallee. The grassland provides a source of seed for granivorous birds and provides forage for grazing animals such as grey and red kangaroo. Cracking clays on the lake bed provide crevices for small reptiles such as tessellated gecko.

When flooded, the lakes become productive aquatic habitats. Nutrients released from decomposing organic matter support high levels of invertebrate production. Waterbirds feed on invertebrates, fish and aquatic plants that establish in the lakes and roost and nest in the surrounding trees.

Waterbirds will generally leave the system when the wetlands dry. The majority of aquatic fauna, including fish, will be stranded and become prey for scavenging birds, mammals and reptiles.

The Hattah floodplain is part of a continuous tract of intact floodplain and terrestrial vegetation that extends 125 km to the west through the Hattah State Forest and Murray-Sunset National Park and encompasses over 633,000 ha. The area represents an important biodiversity corridor that enables the movement and migration of biota and provides resilience to climate change. Fauna which regularly use the corridor include regent parrot and major mitchells cockatoo which feed in mallee vegetation and nest in hollow-bearing trees on the floodplain. Many mammals and birds, including fat-tailed dunnart, carpet python, bats and bush birds, live in both the floodplain and terrestrial landscapes and move between the two.

WATER DEPENDENT FLORA AND FAUNA

FLORA

Hattah Lakes has a highly diverse flora with over 756 species known to occur at the site. The high diversity of plants is related to the close proximity of contrasting mallee and floodplain vegetation. The vegetation includes a high proportion of xeric plant species as well as flood-dependent wetland species.

A recent survey in November 2013 recorded 169 native plant species at the site of which 94 are floodplain species with conservation significance (Table 1). Two species of national conservation significance are present, *Lepidium monoplocoides* (Endangered EPBC) and *Swainsona pyrophila* (Vulnerable EPBC).

Table 38. Plant species of conservation significance reported from Hattah North (Australian Ecosystems 2014)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Alternanthera nodiflora	Common Joyweed			k	x	
Alternanthera sp. 1 (Plains)	Plains Joyweed			k		x
Amaranthus macrocarpus var. *macrocarpus*	Dwarf Amaranth			v	x	
Ammannia multiflora	Jerry-jerry			v	x	
Asperula gemella	Twin-leaf Bedstraw			r	x	
Asperula wimmerana	Wimmera Woodruff			r	x	x
Atriplex acutibractea subsp. acutibractea	Pointed Saltbush		f	v	x	
Atriplex holocarpa	Pop Saltbush		f	v	x	
Atriplex lindleyi subsp. *conduplicata*	Baldoo			r	x	
Atriplex lindleyi subsp. *lindleyi*	Flat-top Saltbush			k	x	
Atriplex papillata	Coral Saltbush			r	x	
Atriplex pseudocampanulata	Mealy Saltbush			r	x	
Atriplex spinibractea	Spiny-fruit Saltbush			e	x	
Atriplex vesicaria subsp. *minor*	Bladder Saltbush			k	x	
Austrobryonia micrantha	Mallee Cucumber			r	x	
Austrostipa hemipogon	Half-bearded Spear-grass			r	x	
Austrostipa tuckeri	Tucker's Spear-grass			e	x	

Bergia ammannioides	Jerry Water-fire			v	x	
Bergia trimera	Small Water-fire			v	x	
Callistemon brachyandrus	Prickly Bottlebrush			r	x	
Calotis cuneifolia	Blue Burr-daisy			r	x	
Calotis cymbacantha	Burr-daisy			r	x	
Cardamine moirensis	Riverina Bitter-cress			r	x	x
Centipeda crateriformis subsp. compacta	Compact Sneezeweed			r	x	
Centipeda nidiformis	Cotton Sneezeweed			r	x	
Centipeda thespidioides s.l.	Desert Sneezeweed			r	x	
Ceratophyllum demersum	Hornwort			k	x	
Convolvulus recurvatus subsp. *recurvatus*	Recurved Bindweed			r	x	
Cullen cinereum	Hoary Scurf-pea		f	e	x	
Cynodon dactylon var. *pulchellus*	Native Couch			k	x	x
Cyperus flaccidus	Lax Flat-sedge			v	x	
Cyperus pygmaeus	Dwarf Flat-sedge			v	x	
Cyperus rigidellus	Curly Flat-sedge		f	e	x	
Dianella porracea	Riverine Flax-lily			v	x	
Elachanthus glaber	Smooth Elachanth			r	x	
Elachanthus pusillus	Small Elachanth			r	x	
Eleocharis pallens	Pale Spike-sedge			k	x	
Eragrostis australasica	Cane Grass			v	x	
Eragrostis lacunaria	Purple Love-grass			v	x	
Eragrostis setifolia	Bristly Love-grass			v	x	x
Eremophila bignoniiflora	Bignonia Emu-bush		f	v	x	
Eremophila divaricata subsp. *divaricata*	Spreading Emu-bush			r	x	
Eremophila maculata subsp. *maculata*	Spotted Emu-bush			r	x	
Eriochlamys behrii s.s.	Woolly Mantle			r	x	
Fimbristylis aestivalis	Summer Fringe-sedge			k	x	
Frankenia crispa	Hoary Sea-heath			r	x	
Frankenia foliosa	Leafy Sea-heath			r	x	
Frankenia serpyllifolia	Bristly Sea-heath			r	x	
Frankenia sessilis	Small-leaf Sea-heath			r	x	
Glycine canescens	Silky Glycine		f	e	x	
Hemichroa diandra	Mallee Hemichroa		f	e	x	
Isolepis australiensis	Inland Club-sedge			k	x	
Isolepis congrua	Slender Club-sedge		f	v	x	
Lepidium fasciculatum	Bundled Peppercress			k	x	
Lepidium monoplocoides	Winged Peppercress	E	f	e	x	
Lepidium papillosum	Warty Peppercress			k	x	x
Lepidium pseudohyssopifolium	Native Peppercress			k	x	

Lipocarpha microcephala	Button Rush			v	x	
Lotus australis var. *australis*	Austral Trefoil			k	x	
Maireana oppositifolia	Heathy Bluebush			r	x	
Malacocera tricornis	Goat Head			r	x	x
Mimulus prostratus	Small Monkey-flower			r	x	
Minuria integerrima	Smooth Minuria			r	x	
Muehlenbeckia horrida subsp. *horrida*	Spiny Lignum			r	x	
Myoporum montanum	Waterbush			r	x	
Ophioglossum polyphyllum	Upright Adder's-tongue			v	x	
Persicaria attenuata subsp. *attenuata*	Velvet Knotweed			k	x	
Phyllanthus lacunarius	Lagoon Spurge			v	x	
Podolepis canescens	Grey Podolepis			r	x	
Rhagodia ulicina	Spiny Goosefoot			r	x	
Rorippa eustylis	Dwarf Bitter-cress			r	x	x
Sarcozona praecox	Sarcozona			r	x	
Sclerolaena divaricata	Tangled Copperburr			k	x	
Sclerolaena lanicuspis	Woolly Copperburr			e	x	x
Sclerolaena muricata var. *muricata*	Black Roly-poly			k	x	x
Sclerolaena patenticuspis	Spear-fruit Copperburr			v	x	
Sclerolaena uniflora	Two-spined Copperburr			r	x	
Senecio cunninghamii var. *cunninghamii*	Branching Groundsel			r		x
Senecio productus subsp. *productus*	Riverina Groundsel			v	x	
Sida ammophila	Sand Sida			v	x	x
Sida intricata	Twiggy Sida			v	x	
Swainsona purpurea	Purple Swainson-pea		f	e	x	
Tecticornia lylei	Wiry Glasswort			r	x	
Tecticornia moniliformis	Ruby Glasswort			r	x	
Tecticornia nitida	Shining Glasswort			r	x	
Tecticornia pterygosperma subsp. *pterygosperma*	Whiteseed Glasswort			r	x	
Tetragonia eremaea s.s.	Desert Spinach			k	x	
Tetragonia moorei	Annual Spinach			k	x	
Triglochin dubia	Slender Water-ribbons			r	x	
Trigonella suavissima	Sweet Fenugreek			r	x	
Velleia connata	Cup Velleia			r	x	
Verbena officinalis var. *gaudichaudii*	Native Verbena			k	x	
Vittadinia condyloides	Club-hair New			r	x	

	Holland Daisy					
Wahlenbergia tumidifructa	Mallee Annual-bluebell			r	x	x

In Victoria vegetation mapping units are known as Ecological Vegetation Classes and are assigned conservation ratings within each bioregion (Table 2). Of the eight floodplain EVCs present at Hattah North six are considered depleted in the Robinvale Plains bioregion.

Table 39. Bioregional conservation status of flood-dependent Ecological Vegetation Classes in Hattah North

Ecological Vegetation Class	Bioregional Conservation Status
295 Riverine Grassy Woodland	Depleted
106 Grassy Riverine Forest	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
103 Riverine Chenopod Woodland	Depleted
818 Shrubby Riverine Woodland	Least Concern
808 Lignum Shrubland	Least Concern
104 Lignum Swamp	Vulnerable
823 Lignum Swampy Woodland	Depleted
107 Lake Bed Herbland	Depleted
813 Intermittent Swampy Woodland	Depleted

FAUNA

Nine native fish species are expected to regularly occur in Hattah Lakes and to colonise the Hattah North area when it floods (Table 3). Small fish species that inhabit localised riparian and wetland habitats include flat-headed galaxias, southern pygmy perch and hardyhead species. Large-bodied fish that specialise in deeper wetland habitat include murray cod, golden perch and silver perch.

In the Lake Boolca Area, most fish will be stranded in the lakes when water levels fall, where they will become prey for scavenging birds, mammals and reptiles. In the Chalka North Area, most fish will be conveyed to the River Murray with the draining floodwater.

Table 40. Native fish fauna of Hattah Lakes (Greenfield 2013)

Scientific Name	Common Name	Conservation Status		
		VROTS	FFG	EPBC
Bidyanus bidyanus	*silver perch*	CE		
Maccullochella peelii	*murray cod*	V		V
Macquaria ambigua	*golden perch*	V		
Melanotaenia fluviatilis	*murray-darling rainbowfish*		L	
Nematalosa erebi	*bony bream*			
Philypnodon grandiceps	*flathead gudgeon*			
Melanotaenia fluviatilis	*fly-specked hardyhead*			
Hypseleotris spp.	*carp gudgeons*			
Retropinna semoni	*australian smelt*			

The bird fauna of Hattah North comprises waterbirds associated with the floodplain and bush birds associated with the adjacent mallee habitat. A recent survey in November 2013, when the floodplain was dry, reported 107 species (Table 4) of which fifteen of these were waterbirds. The known diversity of birds in the region is very high with previous surveys reporting 172 species from the Hattah Lakes area(GHD 2012). Four species from the site are protected under migratory bird agreements.

When flooded the lakes will provide temporary habitat for large numbers of waterbirds. The lakes will provide habitat for dabbling, diving and filter feeding ducks while small fish will provide prey for piscivorous waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Table 41. Birds of conservation significance expected to occur at Hattah North (GHD 2014),(Australian Ecosystems 2014)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements		2013 Surveys	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Anas rhynchotis	australasian shoveler			V				x
Ardea intermedia	intermediate egret		L	E				x
Ardea modesta	eastern great egret		L	V		C J	x	x
Aythya australis	hardhead			V				x

Biziura lobata	musk duck			V				x
Burhinus grallarius	bush stone-curlew		L	E				x
Chlidonias hybridus javanicus	whiskered tern			NT				x
Cinclosoma castanotus	chestnut quail-thrush			NT				x
Circus assimilis	spotted harrier			NT			x	
Climacteris picumnus	brown treecreeper			NT			x	
Coracina maxima	ground cuckoo-shrike		L	V				x
Dromaius novaehollandiae	emu			NT			x	x
Gantiella picta	painted honeyeater		L	V				x
Haliaeetus leucogaster	white-bellied sea-eagle		L	V		C	x	x
Hydroprogne caspia	caspian tern		L	NT		C J		x
Leipoa ocellata	malleefowl	V	L	E				x
Lophocroa leadbeateri	major mitchells cockatoo		L	V			x	x
Lophoictinia isura	square-tailed kite		L	V				x
Melanodryas cucullata cucullata	hooded robin		L	NT			x	x
Nycticorax caledonicus hillii	nankeen night heron			NT				x
Oreoica guttaralis guttaralis	crested bellbird		L	NT			x	x
Oxyura australis	blue-billed duck		L	E				x
Phalacrocorax varius	pied cormorant			NT			x	x
Platalea regia	royal spoonbill			NT				x
Polytelis anthopeplus monarchoides	regent parrot	V	L	V			x	x
Porzna pusilla	baillon's crake		L	V				
Ptilonorhynchus maculatus	spotted bowerbird		L	CE				x
Stictonetta naevosa	freckled duck		L	E				x
Stipiturus mallee	mallee emu-wren	E	L	E				x
Struthidea cinerea	apostlebird		L				x	x
Todiramphus pyrrhopygius	red-backed kingfisher			NT				x
Tringa stagnatilis	marsh sandpiper			V	A2H	C J R		x
Turnix velox	little button-quail			NT				x

The bat fauna of Hattah North is diverse with seven taxa observed at the site. The bats roost in black box trees where they find shelter in hollows and crevices. Their diet is comprised almost entirely of insects derived from the nearby mallee vegetation. When flooded, the wetlands provide an abundant source of prey.

Hattah North supports a range of woodland mammal species including western grey kangaroo and red kangaroo that feed in grasslands and woodlands grasslands.

Table 42. Native mammal species reported from Hattah North (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	gould's wattled bat				x	
Chalinolobus morio	chocolate wattled bat				x	
Macropus fuliginosus	western grey kangaroo				x	x
Macropus giganteus	eastern grey kangaroo				x	
Macropus rufus	red kangaroo				x	x
Nyctophilus corbeni	south-eastern long-eared bat				x	
Scotorepens balstoni	inland broad-nosed bat				x	
Tachyglossus aculeatus	short-beaked echidna				x	
Tadarida australis	white-striped freetail bat				x	
Trichosurus vulpecula	common brushtail possum					x
Vespadelus regulus	southern forest bat				?	
Vespadelus vulturnus	little forest bat				?	

? Identification unconfirmed

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs (GHD 2014). Twenty three reptile species have been reported from Hattah North including four species of conservation significance (Table 6). Five frog species have been reported from Hattah North.

Table 43. Reptiles of conservation significance reported from Hattah North (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Morelia spilota metcalfei	carpet python		L	E		x
Pseudonaja aspidorhyncha	patch-nosed brown snake			NT		x
Varanus varius	lace monitor			E	x	x
Vermicella annulata	bandy bandy		L	E		x

FORMAL CONSERVATION AGREEMENTS

The Hattah Floodplain lies within the Hattah-Kulkyne National Park and Murray-Kulkyne Park, both of which are managed by Parks Victoria.

Twelve of the lakes form the Hattah Ramsar Wetland Site of International Importance.

The floodplain is a Living Murray Icon Site.

The Hattah Floodplain is protected within the Hattah-Kullkyne National Park and Murray-Kulkyne Park which area designated under the National Parks Act 1975 (Victoria).

The Hattah-Kulkyne National Park and Murray-Kulkyne Park were designated as a Biosphere Reserve in 1981 in recognition of their outstanding natural values.

Hattah Lakes is a wetland of national significance listed in the Directory of Important Wetlands in Australia (Environment Australia 2001).

VITAL HABITAT AT THE SITE

Hattah North supports plant and animal species of conservation significance under Commonwealth and Victorian frameworks.

The hollow-bearing trees and open grassland vegetation of Hattah North provide important complementary habitat components to several vertebrate fauna species of the surrounding mallee.

The linkage between Hattah-Kulkyne National Park to the broader 633,000 ha Murray-Sunset National Park represents an important biodiversity corridor. The corridor allows the movement and dispersal of biota between floodplain and terrestrial bioregions and contributes to ecosystem resilience to climate change.

4.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVES

The overall objective of water management in the Lake Boolca Area is:

"to provide important flood-dependent habitat components for terrestrial vertebrate fauna when the lakes are dry and to retain the capacity to provide a productive and diverse wetland habitat when the lakes are flooded".

The overall objective of water management in the Chalka North Area is:

"to restore the productivity and integrity of floodplain vegetation and its capacity to support floodplain fauna ".

These objectives will be achieved by:

- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats
- providing occasional breeding habitat for waterbirds
- maintaining the health and age structure of red gum and black box trees
- maintaining a plant community of drought-tolerant wetland species in infrequently flooded areas
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements in Hattah North.

Three water regime classes have been identified in the Hattah North Area (Table 44, Figure 9). Lignum Shrubland is present in the area comprises a small area (3 ha) of the inundation footprint of the proposed works.

Table 44. Hattah North Area water regime classes

Water Regime Class	Area (ha)	Ecological Vegetation Class
Red Gum Forest and Woodland	1,376	Grassy Riverine Forest Grassy Riverine Forest / Floodway Pond Herbland Complex Intermittent Swampy Woodland
Black Box Woodland	4,113	Riverine Chenopod Woodland Riverine Grassy Woodland Shrubby Riverine Woodland
Episodic Wetland	125	Lake Bed Herbland
(Plains Woodland of Forests)* *Not flood-dependent	1,908	Semi-arid Chenopod Woodland Semi-arid Woodland
(Mallee)* *Not flood-dependent	1,271	Chenopod Mallee Loamy Sands Mallee Woorinen Mallee Woorinen Sands Mallee
(Lignum Shrubland and Woodland)* *Minor component of the project area for which ecological objectives are not relevant	235	Lignum Shrubland Lignum Swamp Lignum Swampy Woodland

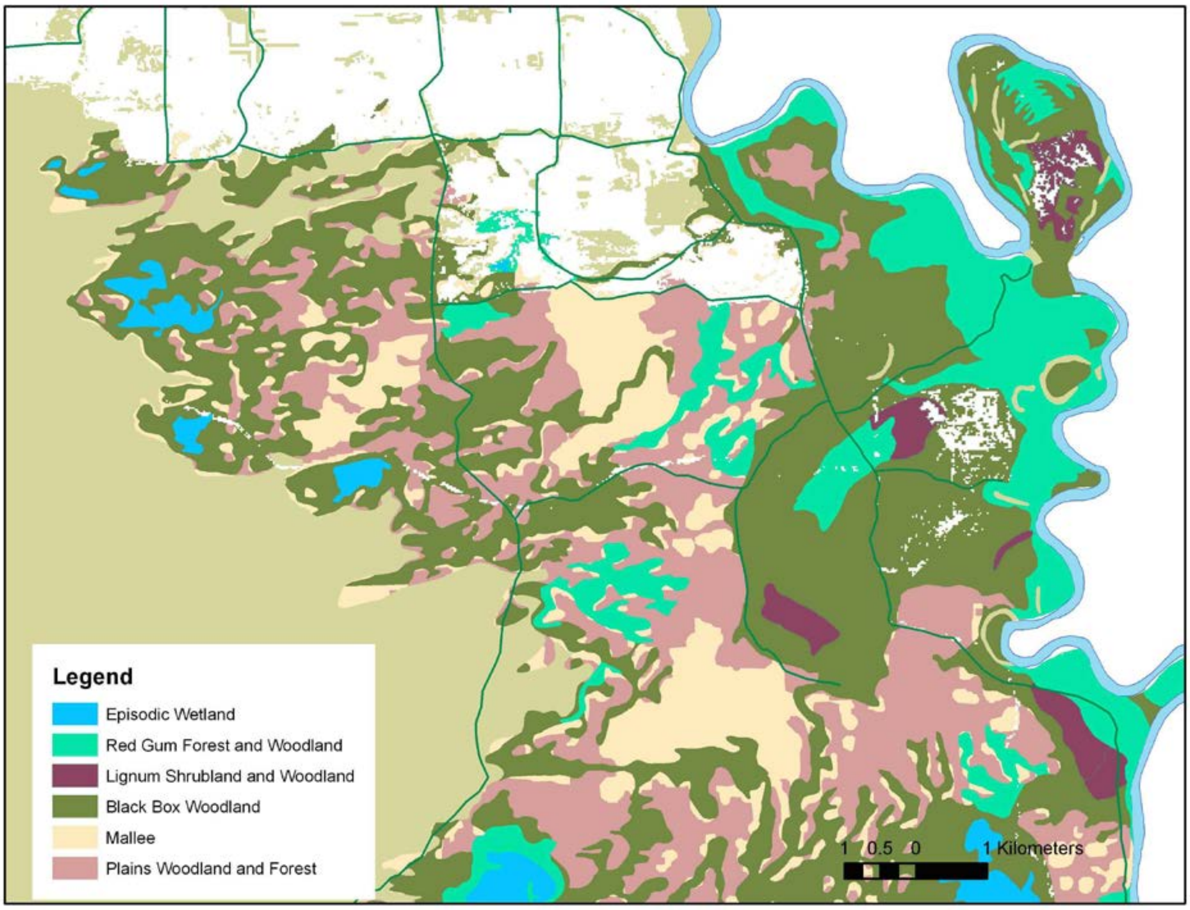


Figure 11. Hattah North Water Regime Classes

RED GUM FOREST AND WOODLAND

Ecology

Red Gum woodland occurs mainly on floodplain terraces along Chalka Creek North and Raakjlim Creek. Water spills to adjacent floodplain areas when rising creek flows exceed the capacity of the channel. Inundation occurs mostly in spring so that the ground is generally dry over summer and autumn. The community comprises species that benefit from seasonal flooding but tolerate dry conditions over summer and occasional years without any flooding. During floods aquatic plants develop from propagules including *Marsilea drummondii, Eleocharis acuta* and *Triglochin procerum.* The drier areas are dominated by grasses and sedges including *Cyperus gymnocaulos* and *Sporobolus mitchellii* and may include *Duma florulenta*. Species, which colonise the drying forest floor, include *Lachnagrostis filiformis, Glycyrrhiza acanthocarpa* and *Centipeda cunninghamii.*

Inundation of red gum woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to persistent pools along the watercourses, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

During longer flooding events red gum woodland will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as waterfowl and ibis.

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for carpet python, bats and brush-tailed possum. Red gum provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering which supports nectar-eating insects and birds and insectivorous birds.

Water Requirements

Flows exceeding 80,000 ML/d inundate red gum forest woodland in Hattah North. Under natural conditions these events occurred in 6 out of 10 years and had a median duration of 45 days.

Red gum forest and woodland has been severely degraded in Hattah North. Mean flood duration has declined to 35 days weeks while flood frequency has declined to approximately 3 events every 10 years. The health of trees has declined with low canopy density and flower production, poor understorey cover and low plant diversity. With longer intervals between floods, many trees have died from water stress and the availability of hollow-bearing trees is threatened.

Flooding in spring and early summer for one to two months will meet the seasonal requirements of understorey plants and maintain vegetation structure and diversity. Flooding at this time of year will also address the seasonal breeding requirements of native fish, frogs and waterbirds.

Long flooding events, lasting over three months, are required to support breeding by waterfowl and ibis. These events will influence the structure of the vegetation, promoting drought-tolerant wetland understorey species.

Table 45. Water management objectives for red gum forest and woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats Provide occasional breeding habitat for waterbirds Maintain the health and age structure of red gum and black box trees Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore the inundation of red gum forest and woodland
Hydrological Targets	Provide flood events 6 years in 10 to a level equivalent to flows of 75,000 ML/d - four of these events to be 1 month long - two of these events to be 3 months long

BLACK BOX WOODLAND

Ecology

Water spreading from Chalka Creek North reaches black box woodland when river flows exceed approximately 100,000 ML/d. In the Lake Boolca Area, black box woodland occurs along floodways and on the floodplain surrounding lakes.

The canopy is open and the community has a diverse, shrubby understorey that includes *Duma florulenta, Acacia stenophylla, Chenopodium nitrariaceum, Rhagodia spinescens and Enchylaena tomentosa*. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses. Some low-lying areas also support small *Eucalyptus camaldulensis* woodlands and *Callistemon brachyandrus* shrublands. *Melaleuca lanceolata* shrublands occur at the fringes of the floodplain and in some shallow wetland depressions (Ecological Associates 2007). When flooded aquatic plant species colonise the understorey including *Marselia drummondii, Asperula gemella, Eleocharis acuta* and *Sporobolus mitchellii*.

The diversity of birds is particularly high because black box woodland contributes to the habitat requirements of both riverine and dryland fauna species. The shrubby understorey and woody debris of black box woodland provides habitat for ground foraging fauna such as brown songlark, bush stone-curlew and echidna. Black box trees provide habitat for canopy feeders such as buff-rumped thornbill, musk lorikeet, white-plumed honeyeater, common brushtail possum and bats.

The hollows that develop in large, mature black box trees are important to several floodplain and dryland fauna species and contribute significantly to the fauna diversity of this community. Hollows in trees and fallen logs provide shelter for large reptiles including lace monitor and carpet python. Birds which nest in hollows include regent parrot, major mitchells cockatoo and barking owl. Common brushtail possum shelter in tree hollows and bats shelter in hollows and bark crevices.

Water Requirements

Tree recruitment and productivity is strongly linked to flooding. Flooding triggers germination events and increases tree growth. Insufficient flooding can create a population dominated by old trees, such that the habitat values of the plant community are threatened.

As a result of the depleted flooding regime, the condition of the black box woodland in Hattah North is very poor. Two surveys conducted during the millennium drought reported that tree health declined over time and that over half the trees in Hattah North were either dead or in very poor health (SKM 2006)(Sluiter 2007).

The Hattah North area is underlain by shallow, saline groundwater (Ecological Associates 2007). It is possible that in the absence of floods to recharge the shallow water table aquifer, the exposure of vegetation to high soil salinities contributes to plant stress.

Black box woodland productivity, health and age structure can be restored by restoring the natural flooding regime of inflow events 1 in 10 years with a maximum interval between events of 20 years.

Table 46. Water management objectives for black box woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats Maintain the health and age structure of red gum and black box trees Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore intermittent flooding events
Hydrological Targets	Black Box woodlands to be flooded for at least 4 weeks 1 year in 10 with a maximum interval between events of 20 years

EPISODIC WETLANDS

Ecology

Under natural conditions the wetlands of the Lake Boolca Area would have been flooded sufficiently frequently to maintain a community of drought-tolerant wetland species. *Cyperus gymnocaulos* and *Eleocharis* acuta would have been present as vegetative growth or below-ground propagules and viable seed banks of other aquatic plants would be present, enabling the rapid re-establishment of aquatic and mud-flat plants including *Glycyrrhiza acanthocarpa, Persicaria prostrata, Centipeda cunninghamii* and *Alternanthera denticulata.*

The lakes range in depth from 3 to 5.3 m and develop mature, persistent aquatic ecosystems when flooded. Decaying plants and other organic matter support microbial, algal and invertebrate production in the lakes. Flooded lake bed plants provide a substrate for biofilms on which frog larvae, fish and invertebrates graze and they also provide shelter for small fish. These in turn provide food for frogs, large-bodied fish and wading birds. Semi-emergent macrophytes such as *Myriophyllum* sp. and *Potamogeton* sp. will colonise the lakes during floods. Emergent macrophytes, such as *Cyperus gymnocaulos,* will grow at the perimeter of flooded lakes.

As the lakes dry, herbland plants such as *Lachnogrostis filiformis, Chenopodium glaucum* and *Malva australiana* would colonise the lake bed before true terrestrial plants became established. Shallow water and mud flats would have provided feeding habitat for wading birds as well as forage for terrestrial fauna including kangaroo. The beds of the lakes are prone to waterlogging and shallow flooding from rainfall. The water table aquifer, which is believed to have a salinity of 50,000 to 80,000 EC, lies within 2 m of the lake beds and contributes to waterlogging and salinisation and prevents the colonisation of tree species (Ecological Associates 2007).

The lakes are fringed by the black box woodland of the surrounding floodplain. The trees contribute to lake productivity by providing organic debris and to habitat complexity by providing the logs and snags used by fish and perching waterbirds.

Water Requirements

The lakes are threatened by the reduced flooding regime caused by blockages on Raakjilm Creek and reduced River Murray flow. The inflow frequency of the lakes has declined from approximately ten times per 100 years to three times per 100 years. Some of these events may not have been long enough to inundate the entire area, but areas that did receive water would retain water for up to three years (Ecological Associates 2007). It is estimated that some water would have been present in the system 20 to 30% of the time.

Under current conditions the lakes are normally dry. The vegetation is dominated by terrestrial plant species and the lakes rarely provide aquatic habitat. Seed banks of aquatic plants are depleted so that aquatic vegetation takes longer to re-establish during floods, while floods are shorter, providing less opportunity for a mature aquatic ecosystem to develop.

It is recommended that the natural flooding regime of the episodic wetlands is re-established by providing water to the lakes with a frequency of 1 year in 10 with a maximum interval between events of 20 years.

Table 47. Water management objectives for episodic wetlands

Objectives Addressed	Provide occasional breeding habitat for waterbirds Maintain a plant community of drought-tolerant wetland species in infrequently flooded areas
Strategy	Restore intermittent flooding events
Hydrological Targets	Wetlands to be filled to their retention level 1 year in 10 with a maximum interval between events of 20 years

4.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Hattah North Floodplain Management Project will

- maintain black box trees as an important habitat component for terrestrial fauna
- maintain the capacity of the wetlands to support productive and diverse aquatic communities when floods occur
- provide extensive inundated floodplain areas that support waterbird feeding

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Hattah North (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

Table 48. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Hattah North project.

Ecological Class	Ecological Element	Hattah North
Waterbirds	Bitterns, crakes and rails	
	General abundance and health - all waterbirds	❶❶❶
	Breeding - Colonial-nesting waterbirds	❶
	Breeding - other waterbirds	❶
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	❶❶
	Forests: river red gum (*Eucalyptus camaldulensis*)	
	Forests and woodland: black box (*Eucalyptus largiflorens*)	❶❶❶
	Shrublands	❶
	Tall grasslands, sedgelands and rushlands	
	Benthic herblands	❶
Fish	Short-lived / small-bodied fish	❶❶
	Long-lived / large-bodied fish	

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

The proposed Hattah North supply measure restores flooding to red gum woodland and lignum shrubland habitat along Chalka Creek North. These areas will provide temporary habitat to small fish and waterbirds. During sustained flood events these areas will support breeding by birds that build nests in trees and in flooded lignum including colonial nesting species.

Flooding of the Lake Boolca area will provide extensive and productive aquatic habitat. The wetlands will develop communities of aquatic vegetation when flooded and will suport large numbers of small-bodied fish and a wide variety of waterbirds. Inundation will also maintain the health and productivity of black box woodland.

4.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

The Hattah Lakes wetlands system comprises approximately 20 lakes which receive water from the River Murray via Chalka Creek (Figure 12). Following modifications under TLM works, water enters the southern branch of Chalka Creek when the River Murray reaches 20,000 ML/d at Euston and is distributed to the low-lying lakes in the central floodplain: firstly Lake Lockie, then Lake Little Hattah, Lake Hattah, Lake Yerang, Lake Mournpall then others. As River Murray levels increase water also enters the floodplain by the northern branch of Chalka Creek and by Cantala Creek. Higher river levels introduce water to additional lakes and inundate the surrounding floodplain. Chalka Creek North is the principal route for water returning to the river on the flood recession.

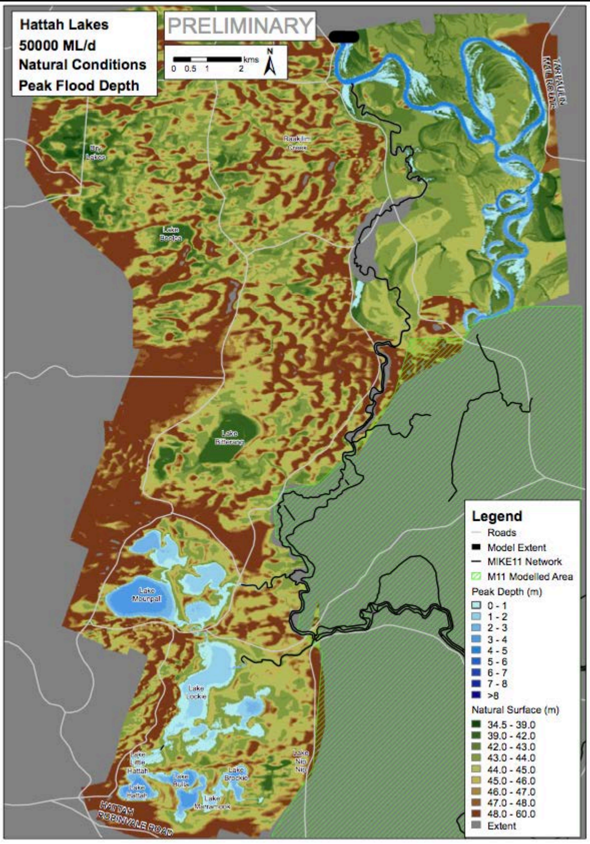
Water first backs up into Chalka Creek North at flows exceeding approximately 33,000 ML/d at and reaches the bank-full level of the creek near the River Track of 42.5 m AHD when flow at Euston exceeds 60,000 ML/d (Gippel 2008) (Jacobs 2014). The retention level of 43.5 m AHD at the proposed K10 Regulator is equivalent to a river discharge of approximately than 120,000 ML/d (Jacobs 2014).

The Lake Boolca Area is among the last parts of the Hattah floodplain to be inundated. The area comprises a mosaic of small wetlands with floodways confined between sand dunes of the Lowan and Woorinen Formations. Two floodways connect the area to the broader Hattah floodplain. Raakjlim Creek passes water from Chalka Creek North to the Lake Boolca Area and the Bitterang floodway extends north from Lake Bitterang (Ecological Associates 2007).

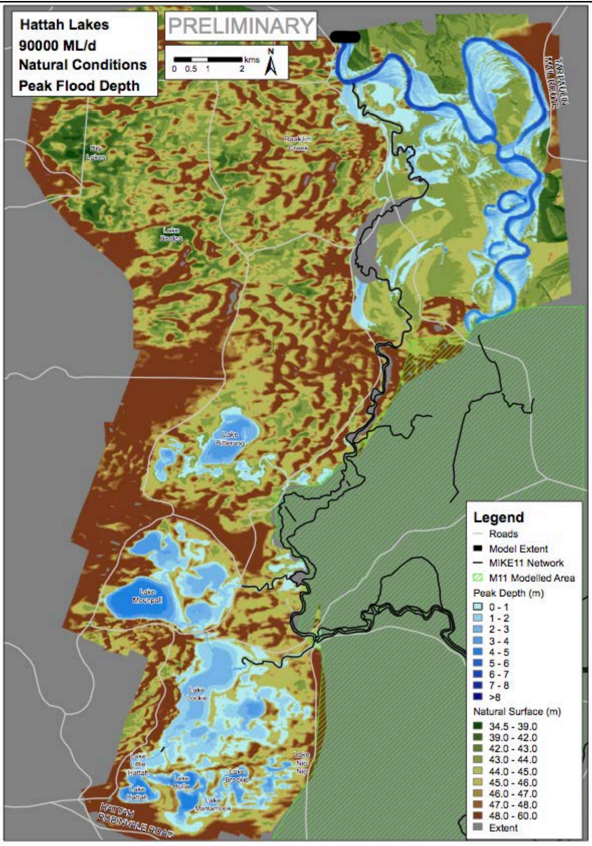
Under natural conditions water began to spread into Raakjlim Creek when River Murray discharge exceeded 100,000 ML/d and created significant inundation of lakes at flows exceeding 120,000 ML/d. Lake Boolca was filled when river flow exceeded 140,000 ML/d. However, stop banks constructed on Raakjlim Creek now block the passage of water so that flows of up to 160,000 ML/d do not enter the area (Ecological Associates 2007) (Jacobs 2014).

The Bitterang floodway has a naturally high sill level and only passes water northwards at very high flows, greater than 160,000 ML/d, that have not been determined by modelling (Jacobs 2014).

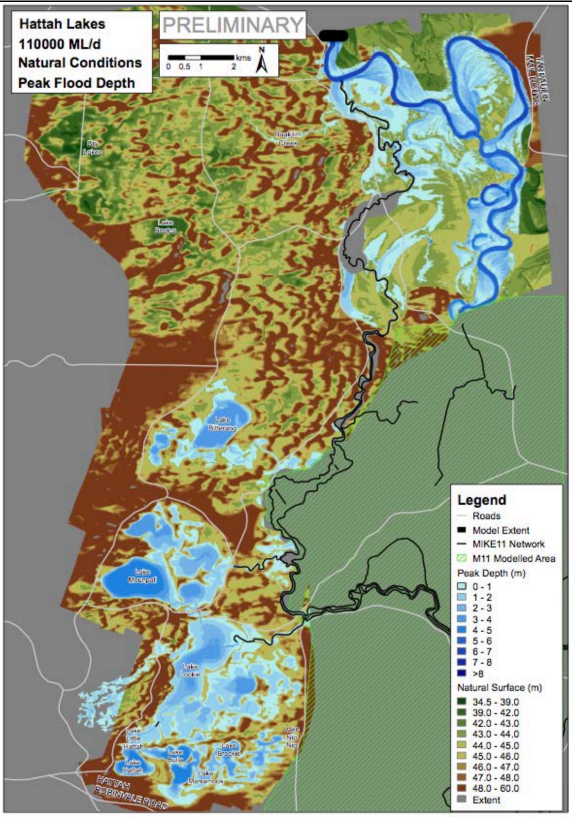
There are substantial losses to evaporation and seepage on the flow paths to the Lake Boolca Area. For the area to be effectively flooded, water levels must exceed flow thresholds for several weeks.



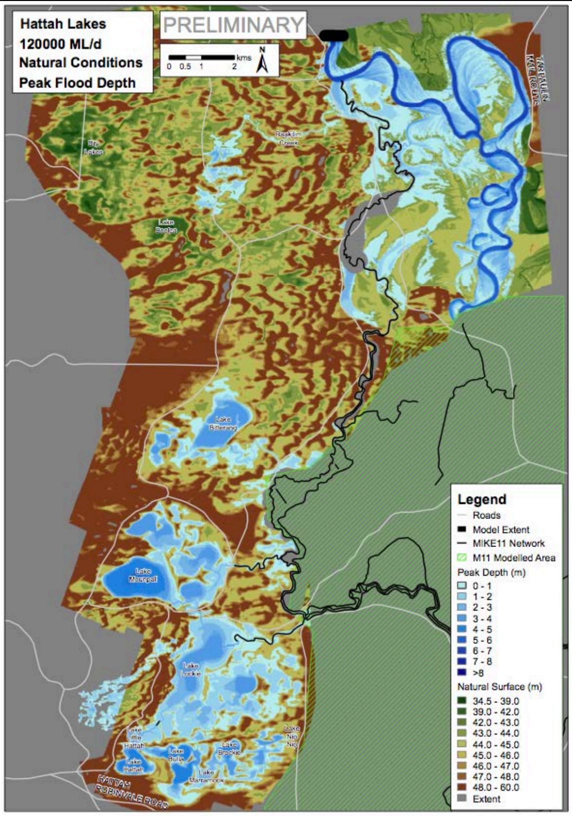
50,000



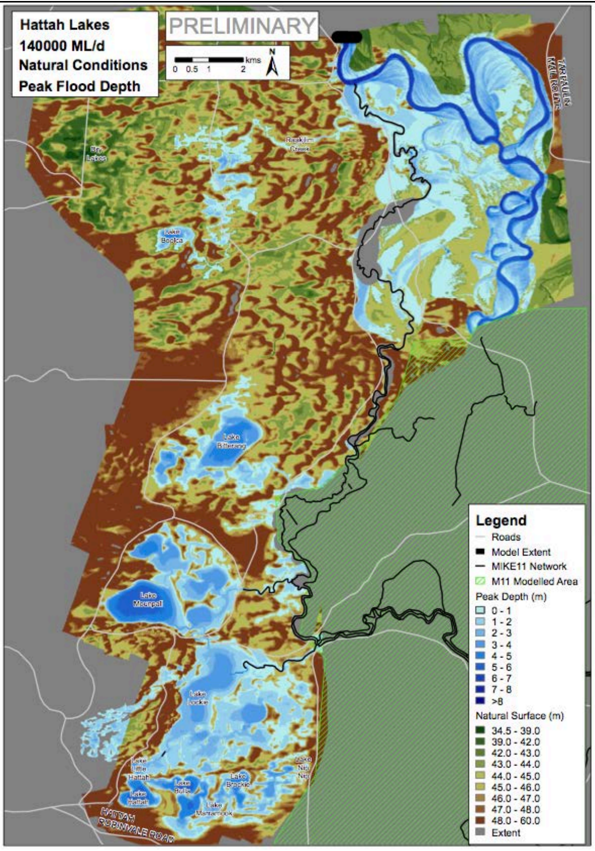
90,000



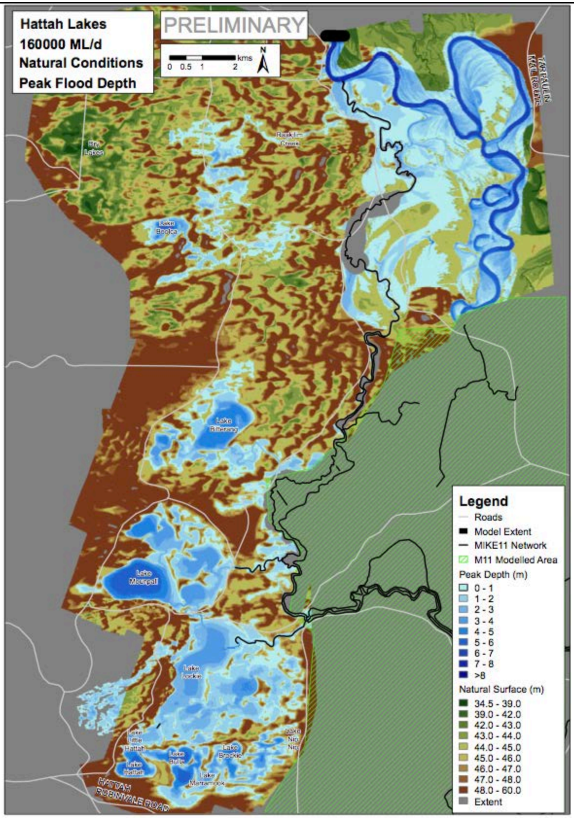
110,000



120,000



140,000



160,000

Figure 12. Hattah North floodplain inundation at flows of 50,000, 90,000 and 110,000, 120,000, 140,000 and 160,000 ML/d (Jacobs 2014).

HYDROLOGY

The hydrology of the River Murray at Euston Weir under pre-regulation and current conditions is illustrated in Figure 13. The analysis shows that regulation and diversions have less impact on river hydrology as discharge increases. However, impacts persist even at flows exceeding 180,000 ML/d.

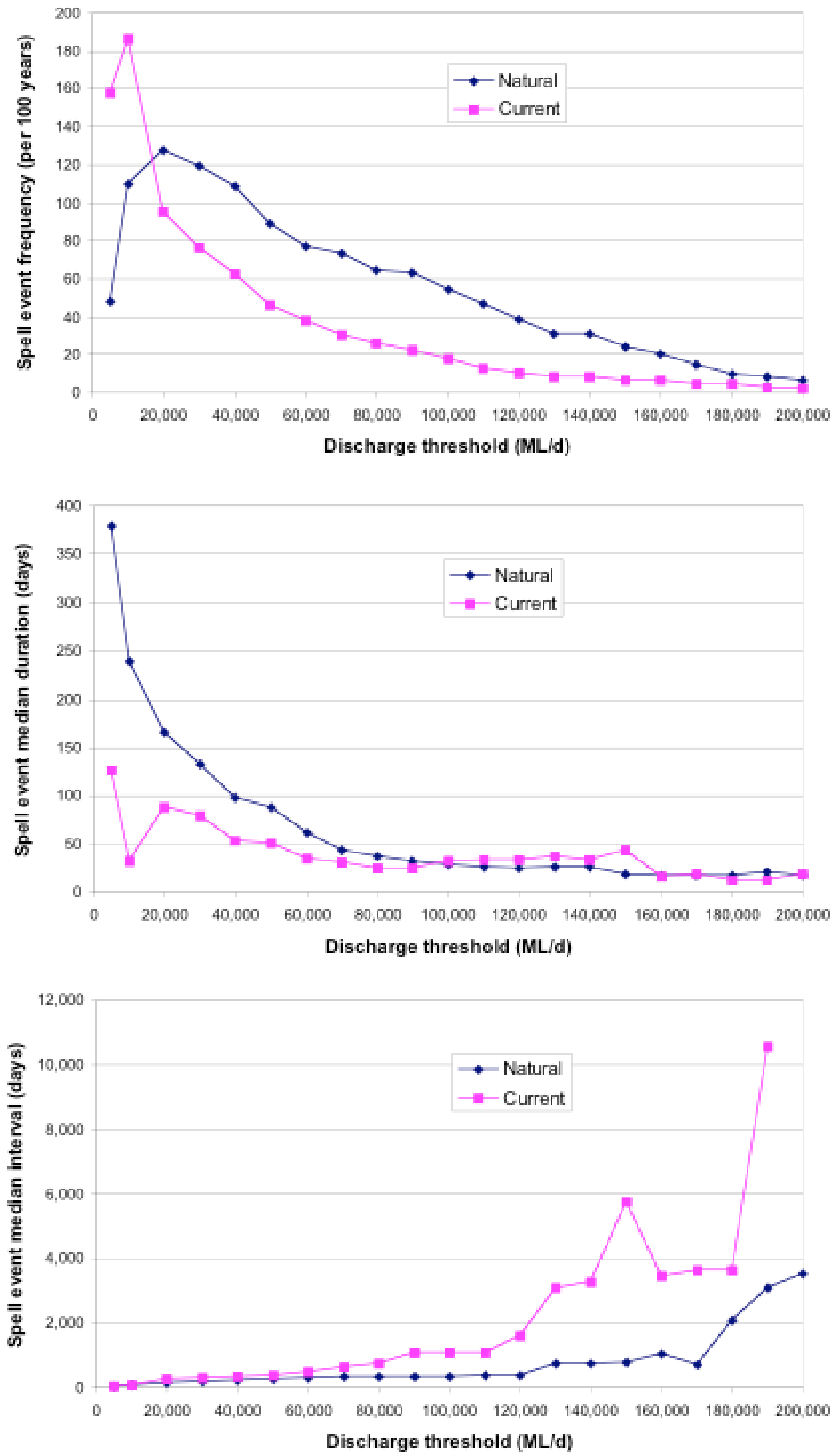


Figure 13. Hydrology of the River Murray at Euston Weir under natural and current conditions (data from MSM-Bigmod, processed courtesy of Chris Gippel, Fluvial Systems Pty Ltd)

The bank full level of the Chalka Creek North is exceeded when river discharge reaches 60,000 ML/d. These events, which initiate inundation of the nearby red gum woodland, have decreased in frequency from more 80 events in 100 years under natural conditions to 40 currently. The median duration of these events has also decreased, from 6 weeks to approximately 4 weeks. The 43.5 m AHD retention level of the proposed K10 Regulator corresponds to a discharge of approximately 120,000 ML/d. Under natural conditions these flows occurred 40 times in 100 years with a median duration of 40 days. They now occur 10 times per 100 years with a duration of 30 days.

The hydrology of the Lake Boolca Area has been impacted by both the altered hydrology of the River Murray and changes to the sill level of Raakjlim Creek. Under natural conditions River Murray flows at Euston exceeded the natural threshold of 140,000 ML/d approximately 30 times per 100 years but exceed the current modified threshold approximately 7 times per 100 years. Consequently, the interval between events has increased, from a median of approximately 2.5 years to 8 years. The duration of events is largely unchanged.

River flows are not a complete indicator of the hydrology of the Lake Boolca Area. Flows are delayed and depleted along the complex flow path connecting the river to the floodplain, resulting in smaller, less frequent and shorter flow peaks than occur in the river. SKM (2006) developed a water balance model for the entire Hattah-Kulkyne system that accounts for these processes (Table 49). The model estimated that under natural river hydrology, if the levees in Raakjlim Creek were removed, the Lake Boolca Floodplain would receive inflows approximately ten times per 100 years. Under current river hydrology inflow events occur only four times and are substantially shorter in duration.

Given an estimated annual evaporation at Mildura of 2000 mm/year, a maximum lake depth of approximately 5.3 m and losses to seepage the lakes are expected to hold water for up to two years.

Table 49. The duration of inflow events that would have occurred to the Lake Boolca Area if blockages on Raakjlim Creek were not present, under Natural and Current conditions. Model run from 1908 to 2000 (Ecological Associates 2007).

Inflow Date	Natural River Hydrology	Current River Hydrology
	Inflow Duration (weeks)	Inflow Duration (weeks)
Oct 1917	15	9
Jul 1931	4	
Oct 1940	2	
Sep 1955	2	2
Jul 1956	15	15
Sep 1974	6	
Nov 1975	5	3
Aug 1981	6	
Oct 1992	6	
Nov 1993	2	

The hydrology of the floodplain at the Bitterang floodway was investigated using a version of the SKM (2006) model modified by MDBA (Ecological Associates 2009). This model estimated weekly water levels in the lakes within the system for a 117 year period under natural conditions. The model estimated that under natural conditions, water levels at Lake Bitterang would have exceeded 45 m AHD on three occasions in 117 years, with durations of 11, 67 and 73 days. This modelling indicates that Raakjlim Creek is the lower channel and flows more frequently than the Bitterang floodway.

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

The proposed works inundate wetland and woodland areas (Table 50, Figure 14).

Table 50. Area of inundation from the proposed works at Hattah North

Water Regime Class	Area (ha)
Red Gum Forest and Woodland	125
Black Box Woodland	883
Episodic Wetlands	33
(Lignum Shrubland and Woodland)	3*
(Mallee)	30*
(Plains Woodland and Forest)	31*

*Lignum Shrubland and Woodland is a minor component areas are not relevant to the ecological objectives for Hattah North. Mallee and Plains Woodland and Forest are not flood-dependent vegetation types.

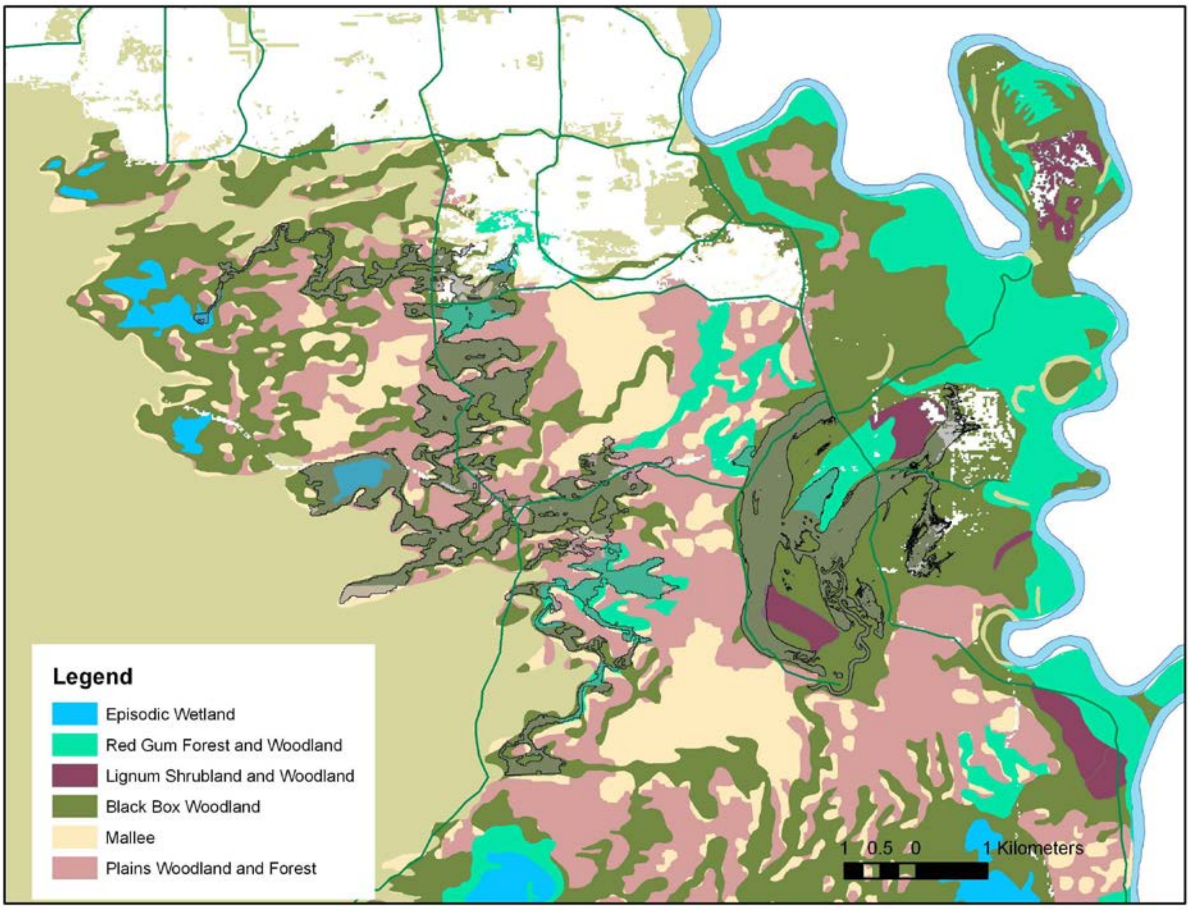


Figure 14. Water regime classes inundated by proposed works in Hattah North

LAKE BOOLCA AREA

It is proposed to restore the flooding regime of the Lake Boolca Area by increasing the frequency and duration of inflows via the Bitterang floodway. Although Raakjlim Creek is the lower of the two flow paths, TLM works provide a practical mechanism to promote inflows from Lake Bitterang.

A levee and regulator will be constructed in the existing TLM Bitterang Levee on the floodway to manage the delivery of environmental water to the Lake Boolca Area. The levee and regulator will be operated to detain water over an area as large as 710 ha, including Lake Boolca, and will address ecological targets for flooding frequency and duration. The inundated area will not extend as far as the Dry Lakes.

The Bitterang Levee was constructed in the TLM works to facilitate flooding in the central Hattah floodplain by preventing the escape of water to the north. With the addition of a regulator it could also be used to pass and detain flood water in the Lake Boolca Area. A four-bay regulator would be constructed in the existing regulator and would be designed to pass 100 ML/d.

The Bitterang Regulator will operate in conjunction with TLM works and in response to natural flooding events.

The Bitterang Levee can be operated under three scenarios (Table 51).

- natural flood events
- environmental watering - gravity releases to the northern floodplain area
- environmental watering - pumped discharge to the northern floodplain area.

In natural flood events, the regulator may be opened to allow the passage of water from Lake Bitterang to the north. Flood levels will be able to rise and fall without interference[1]. Alternatively, the regulator may be closed to prevent flood water from draining so that floods can be prolonged to meet ecological water requirements. Temporary pumps may be used to supplement floods or managed flows.

With the Bitterang Regulator in place, inundation under the TLM program (floodplain inundation scenario to 45 m AHD) may be allowed to spread into the Bitterang floodway by gravity. Under this scenario the pool will generate a flow of approximately 100 ML/d at the regulator and over 30 days will distribute water over approximately 300 ha, including Lake Boolca (GHD 2012). Under the TLM program it is planned to operate the floodplain inundation scenario to 45 m AHD approximately 1 year in 8 (Greenfield 2013).

The extent of inundation achieved by gravity feed through the Bitterang Regulator can be increased by pumping water across the levee. In this scenario, the regulator would be closed while the TLM floodplain scenario is operated (at 45 m AHD). A pump would be used to re-lift water over the levee from Lake Bitterang to the Bitterang floodway. At a flow of 300 ML/d a level of 45.11 m AHD can be achieved against the northern side of the levee which distributes water over 710 ha.

Table 51. Bitterang Levee operating scenarios

Operating Condition	Bitterang Regulator
Natural Flood Events	Stop logs are removed from the structure to allow unobstructed flow through the regulator. The levee track and structure may be inundated where flood levels exceed 45.3 m AHD.
Environmental Watering - Gravity Releases to the Northern Floodplain Area	The TLM inundation needs to be operated to 45 m AHD. The stop logs should be removed from the regulator as long as flow is required to the northern floodplain. It is expected the peak flow rate will be approximately 100 ML/d and will inundate approximately 300 ha.
Environmental Watering - Pumped Discharged to the Northern Floodplain Area	The TLM inundation needs to be operated to 45 m AHD. A temporary pump will be installed on the Bitterang Levee. Stop logs will be installed to the maximum height. Water will be pumped from Lake Bitterang to the northern side of the levee at a rate of up to 300 ML/d to provide sufficient head for

[1] The minimum design capacity adopted for the Bitterang Levee Regulator does not completely offset the reduction in flood flow capacity into the northern floodplain area resulting from the construction of the Bitterang Levee.

	water to flow north, extending over approximately 710 ha.

It is proposed to operate the levee and regulator to augment flooding to meet environmental water requirements. The decision to inundate the Lake Boolca Area will mainly be based on the duration since the last event. It is important to limit the interval between floods so that the health and age structure of black box woodland can be maintained, so that the value of these trees as habitat for terrestrial fauna and as a component of the wetland ecosystem during floods is preserved.

CHALKA NORTH FLOODPLAIN

Under the TLM works, water released from Oateys Regulator is conveyed northwards by Chalka Creek North to return to the River Murray. The Chalka North works will create a second tier of inundation using water released from the regulator. Outflows towards the River Murray will be controlled by structures at three locations to create a pool extending over 420 ha when water is stored at the maximum level of 43.5 m AHD.

The K10 Regulator will be constructed on Chalka Creek North at the existing River Track crossing. The regulator will incorporate a levee that extends 840 m across the creek and will raise water levels above the channel bank and into the adjacent the Red Gum Woodland.

At a level of 43.5 m AHD water also spreads to the east, and a second structures is required to prevent water escaping to the River Murray. The K10 Levee extends over 460 m to a height of less than 1 m high and will incorporate stop logs to allow water to move freely when the Chalka North Pool is not in operation.

A third structure is required to maintain access along the River Track when the Chalka North Pool is in operation. The River Track Causeway will raise the road level 0.3 m above the maximum pool level. It will incorporate stop log regulators to allow free passage of water when not in operation.

The area to the east of the River Track Causeway includes the private land of Kulnine Station. It is not proposed, at present, to inundate the private land between the River Track Causeway and the K10 Levee. Water may be excluded from this area using stop logs in the causeway when the Chalka North Pool is filled. Should the opportunity arise to water this area of floodplain, via a change of ownership or through negotiation with the current landowner, then the stop logs would be removed.

Most water stored in the Chalka North Pool will return to the River Murray at the conclusion of flooding events when the K10 regulator is opened. Some water retained in floodplain depressions will be lost to drainage and evaporation.

The Chalka North structures will be operated in conjunction with TLM works and in response to natural flooding events.

In natural flooding events, the structures will remain open as river levels rise and water enters the floodplain. The structures may be closed when the floodplain starts to drain in order to capture flood water and meet environmental targets for flood duration. When flooding requirements are met, the water will be released to the River Murray via Chalka Creek North.

The Oateys Regulator Pool is operated to meet the water requirements of the lakes and floodplain of the central Hattah area. The pool may be filled by pumped water or by capturing flood peaks. When flooding requirements are met, the water released from Oateys Regulator may be detained by the Chalka North structures to meet flooding requirements in this area.

In large natural flooding events, if environmental requirements have been met, the structures will remain open and will not be operated.

Table 52. Hydrological Change at Hattah North

Targeted Water Regime Classes	Hydrological Targets	Ecological Objectives
Red Gum Forest and Woodland	Provide flood events 6 years in 10 to a level equivalent to flows of 75,000 ML/d - four of these events to be 1 month long - two of these events to be 3 months long	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats Provide occasional breeding habitat for waterbirds Maintain the health and age structure of red gum and black box trees Contribute to the carbon requirements of the River Murray channel ecosystem
Black Box Woodland	Black Box woodlands to be flooded for at least 4 weeks 1 year in 10 with a maximum interval between events of 20 years	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats Maintain the health and age structure of red gum and black box trees Contribute to the carbon requirements of the River Murray channel ecosystem
Episodic Wetlands	Wetlands to be filled to their retention level 1 year in 10 with a maximum interval between events of 20 years	Provide occasional breeding habitat for waterbirds Maintain a plant community of drought-tolerant wetland species in infrequently flooded areas

ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray(Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

Table 53. Hattah North specific ecological targets

Objective	Target
Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats	Total bat abundance to increase by 25% from 2015 levels by 2030.
Provide occasional breeding habitat for waterbirds	Any species of waterfowl, crake, rail, waterhen or coot to breed in at least six seasons between 2025 and 2035.
Maintain the health and age structure of red gum and black box trees	All red gum and black box stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035.
Maintain a plant community of drought-tolerant wetland species in infrequently flooded areas	The drought-tolerant wetland species *Cyperus gymnocaulos* and *Eleocharis acuta* are to be present in vegetative form in 75% of wetlands following any filling event.
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Hattah North for the period 2025 to 2035 is double 2015 to 2020 levels.

5 BELSAR AND YUNGERA FLOODPLAIN MANAGEMENT PROJECT

5.1 PROJECT DETAILS

The Belsar and Yungera Floodplain Management Project is a Supply Measure project located on the River Murray floodplain, 17 km south east of the township of Robinvale in northwest Victoria. The project is located entirely within land managed for conservation including Crown Land and private land under conservation covenants or agreements.

The Belsar and Yungera floodplain is located on the left (southern) bank of the River Murray between 1,201 and 1,157 river km, approximately 30 km upstream of Euston Weir. The system comprises Belsar and Yungera Islands, Lakes Powell and Carpul and adjacent floodplain with a total area of 8,200 ha.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over extensive areas of the floodplain. The project provides inundation of up to 2,444 ha of intact floodplain habitat.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

Figure 15. Location of the Belsar and Yungera Floodplain Management Project

5.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

The Belsar and Yungera Islands Floodplain Management Project area lies mainly in public land managed by Parks Victoria and includes the proposed River Murray Park, River Murray Reserve and the Lakes Powell and Carpul Wildlife Reserve. Some land in the southern part of the system is private land managed for conservation purposes.

Narcooyia Creek defines the southern side of Belsar and Yungera Islands. Flowing over 17 km, the creek diverges from the River Murray upstream of Yungera Island and returns to the river downstream of Belsar Island. Bonyaricall Creek branches from Narcooyia Creek near its downstream end. It is 6 km in length and forms the southern boundary of Tonsing Island. The islands and adjacent floodplain cover 8,200 ha and extend 14 km from east to west.

Lying near the western limit of the Murray Fans bioregion, the floodplain is one of the most-downstream areas to feature frequently flooded low-lying river red gum forest and woodland. Meander loops along the River Murray support wetland and forest complexes which provide complex habitat for woodland and wetland fauna including small native fish species, frogs, turtles and, to some extent, breeding colonies of great egret (McNee 1996). With complex understorey vegetation and abundant woody debris, the forest along the river bank is an important habitat component for carpet python and lace monitor.

Yungera Island, together with Peacock Creek on the NSW side of the River Murray, is one of the most important breeding sites for EPBC endangered regent parrot (GHD 2009). The birds utilise areas of river red gum forest and woodland that are close to waterways and contain large numbers of large, old, healthy, hollow-bearing trees (Webster 2004).

The floodplain provides semi-permanent wetland habitat in a number of deep, frequently flooded wetlands which include Yungera Creek and the Carp Hole. These wetlands received inflows almost annually under natural conditions and remained flooded most of the time. A variety of wetland plants depend on sustained seasonal flooding including spiny mudgrass (McKane 1992). Reliably flooded habitat provides a refuge from which species such as growling grass frog can disperse to other floodplain habitat during flood, and provide reliable breeding sites for waterfowl and other wetland birds.

Belsar and Yungera Islands have an important fish fauna. Although isolated from the River Murray by banks and weirs, Narcooyia Creek provides high quality fish habitat with deep holes and complex woody debris. The creek supports populations of murray cod, freshwater hardyhead and golden perch (GHD 2009). Bonyaricall Creek supports a number of small fish species including carp gudgeon speces, bony bream and murray-darling rainbowfish (Ho, et al. 2004).

The central areas of Belsar and Yungera Islands are vegetated by extensive lignum shrubland and shrubby black box woodland. Flooded lignum shrublands provide nesting platforms for waterbirds including ibis, cormorants, pelicans and freckled duck. Flooded lignum is a highly productive aquatic habitat, providing abundant food and physical habitat for small native fish species and frogs. In the dry phase between flooding events, lignum and woodland habitat is important for terrestrial fauna for bush birds, reptiles and small mammals.

Two large ephemeral wetlands, Lakes Powell and Carpul, are located at the southern limit of the floodplain. The lakes are infrequently filled by large, sustained peaks in river flow. They retain water to a depth of several metres and can remain flooded for more than a year. Deepwater habitat, occurring in combination with lignum and woodland vegetation, is important to breeding by a number of birds of conservation significance including blue-billed duck, musk duck and hard head. Lake Powell is one of only seven recorded breeding sites in Victoria for freckled duck. The vegetation of the lakes and surrounding woodland is diverse and intact, featuring at least 35 plant species of conservation significance including the endangered hoary scurf-pea and woolly scurf pea(VEAC 2008).

WATER DEPENDENT FLORA AND FAUNA

FLORA

The vegetation of Belsar and Yungera Islands is dominated by lignum shrublands and black box woodlands. River red gum woodland and forest is present along watercourses and in meander loops along the River Murray. The vegetation of Lakes Powell and Carpul is distinctive, supporting lake bed herblands on the lake floor and mallee and woodland vegetation present at the lake fringes.

The flora of the system is diverse, with over 630 native plant species known to occur near the site and 124 of these having conservation significance. The high diversity of plants is related to the close proximity of contrasting mallee and floodplain vegetation. A recent survey in November 2013 recorded 207 native species at the site (Table 1). Of these 57 are floodplain species that are rare or threatened under the Advisory List of Rare or Threatened Plants in Victoria.

Table 54. Plant species of conservation significance reported from Belsar Yungera (Australian Ecosystems 2014)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Alternanthera nodiflora	Common Joyweed			k	x	x
Alternanthera sp. 1 (Plains)	Plains Joyweed			k	x	x
Asperula gemella	Twin-leaf Bedstraw			r	x	x
Asperula wimmerana	Wimmera Woodruff			r		x
Atriplex paludosa subsp. *paludosa*	Marsh Saltbush			r	x	
Atriplex papillata	Coral Saltbush			r	x	
Atriplex rhagodioides	Silver Saltbush		L	v	x	
Atriplex spinibractea	Spiny-fruit Saltbush			e	x	
Bergia ammannioides	Jerry Water-fire			v	x	
Cardamine moirensis	Riverina Bitter-cress			r	x	
Centipeda crateriformis subsp. compacta	Compact Sneezeweed			r	x	
Centipeda nidiformis	Cotton Sneezeweed			r	x	
Centipeda thespidioides s.l.	Desert Sneezeweed			r	x	
Centipeda thespidioides s.s.	Desert Sneezeweed			r	x	
Ceratophyllum demersum	Hornwort			k	x	
Craspedia haplorrhiza	Plains Billy-buttons			k	x	x

Cullen cinereum	Hoary Scurf-pea		L	e	x	
Cynodon dactylon var. *pulchellus*	Native Couch			k	x	x
Cyperus nervulosus	Annual Flat-sedge		L	e	x	
Cyperus rigidellus	Curly Flat-sedge		L	e	x	
Dianella porracea	Riverine Flax-lily			v	x	
Eleocharis pallens	Pale Spike-sedge			k	x	
Eragrostis lacunaria	Purple Love-grass			v	x	
Eragrostis setifolia	Bristly Love-grass			v	x	
Eremophila divaricata subsp. *divaricata*	Spreading Emu-bush			r	x	x
Eremophila maculata subsp. *maculata*	Spotted Emu-bush			r	x	
Eryngium paludosum	Long Eryngium			v		x
Frankenia crispa	Hoary Sea-heath			r	x	
Frankenia foliosa	Leafy Sea-heath			r	x	
Frankenia serpyllifolia	Bristly Sea-heath			r	x	x
Heliotropium asperrimum	Rough Heliotrope			v	x	
Isolepis australiensis	Inland Club-sedge			k	x	
Isolepis congrua	Slender Club-sedge		L	v	x	
Lepidium papillosum	Warty Peppercress			k	x	x
Lepidium phlebopetalum	Veined Peppercress			e	x	
Lepidium pseudohyssopifolium	Native Peppercress			k	x	x
Lepidosperma canescens	Hoary Rapier-sedge			r		x
Lipocarpha microcephala	Button Rush			v	x	
Lotus australis var. *australis*	Austral Trefoil			k	x	
Malacocera tricornis	Goat Head			r	x	x
Minuria integerrima	Smooth Minuria			r	x	x
Muehlenbeckia horrida subsp. *horrida*	Spiny Lignum			r	x	x
Ophioglossum polyphyllum	Upright Adder's-tongue			v	x	x
Rorippa eustylis	Dwarf Bitter-cress			r	x	x
Sarcozona praecox	Sarcozona			r	x	
Sclerolaena muricata var. *muricata*	Black Roly-poly			k	x	x
Sclerolaena patenticuspis	Spear-fruit Copperburr			v	x	
Senecio campylocarpus	Floodplain Fireweed			r		x
Sida ammophila	Sand Sida			v	x	x
Stemodia glabella s.s.	Smooth Blue-rod			k	x	
Templetonia egena	Round Templetonia			v	x	
Tetragonia moorei	Annual Spinach			k	x	
Teucrium albicaule	Scurfy Germander			k	x	
Trigonella suavissima	Sweet Fenugreek			r	x	
Vittadinia australasica var.	Sticky New Holland			k	x	

oricola	Daisy					
Vittadinia condyloides	Club-hair New Holland Daisy			r	x	

In Victoria vegetation mapping units are known as Ecological Vegetation Classes and are assigned conservation ratings within each bioregion (Table 2). Of the twelve EVCs present at Belsar-Yungera, one is considered endangered six are considered vulnerable in the Murray Fans Bioregion.

Table 55. Bioregional conservation status of Belsar Yungera Ecological Vegetation Classes

Ecological Vegetation Class	**Bioregional Conservation Status**
103 Riverine Chenopod Woodland	Endangered
104 Lignum Swamp	Vulnerable
106 Grassy Riverine Forest	Depleted
107 Lake Bed Herbland	Vulnerable
200 Shallow Freshwater Marsh	Vulnerable
295 Riverine Grassy Woodland	Vulnerable
808 Lignum Shrubland	Least Concern
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
813 Intermittent Swampy Woodland	Depleted
818 Shrubby Riverine Woodland	Least Concern
819 Spike Sedge Wetland	Rare
823 Lignum Swampy Woodland	Vulnerable

FAUNA

Belsar Yungera has a diverse fish fauna with eight native species reported from Narcooyia Creek and Bonyaricall Creek (Table 3). Bonyaricall Creek provides slow-flowing, shallow water with fringing reed beds which supports a number of small fish species (Ho, et al. 2004). Narcooyia Creek is permanently flooded and provides complex habitat including deep holes and woody debris over a length of 17 km. The creek supports populations of murray cod and golden perch (SKM 2006)(GHD 2009).

Table 56. Native fish fauna of Belsar Yungera (Ho, et al. 2004)(SKM 2006),(GHD 2009)

Scientific Name	Common Name	Conservation Status		
		VROTS	FFG	EPBC
Maccullochella peelii	*murray cod*	V	L	V
Macquaria ambigua	*golden perch*	V		
Melanotaenia fluviatilis	*murray-darling rainbowfish*		L	
Nematalosa erebi	*bony bream*			
Melanotaenia fluviatilis	*fly-specked hardyhead*			
Hypseleotris spp.	*carp gudgeons*			
Retropinna semoni	*australian smelt*			
Craterocephalus stercusmescarum fulvus	*freshwater hardyhead*		L	

The bird fauna of Belsar Yungera includes waterbirds and bushbirds with 118 species recorded in the vicinity of the site. A recent survey in November 2013 reported 87 species of which 22 have conservation significance at the state or national level (Table 4). The diversity of birds is promoted by the close proximity of the contrasting floodplain and mallee environments. Three species are protected under international migratory bird agreements.

Yungera Island supports one of the largest breeding colonies for Regent Parrot with birds nesting in red gum trees near the River Murray at Gearbox Loop and Peacock Creek in NSW (GHD 2009).

Grey-crowned babbler has been reported from Belsar Yungera. These birds are insectivores that build stick nests in saplings, shrubs and the lower canopy of trees. Their favoured habitat is black box and red gum woodland where they forage partly on the ground and partly on the trunks and branches of trees and shrubs.

The large lakes of Powell and Carpul can support large numbers of waterbirds when flooded and breeding by birds of conservation significance such as blue-billed duck and freckled duck (VEAC 2008). The smaller, semi-permanent wetlands of Yungera Creek and the Carp Hole provide reliable breeding sites for waterfowl.

Table 57. Birds of conservation significance expected to occur at Belsar Yungera (GHD 2014)(Australian Ecosystems 2014)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements		2013 Surveys	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Anas rhynchotis	australasian shoveler			V			x	x
Ardea intermedia	intermediate egret		L	E				x
Ardea modesta	eastern great egret		L	V		C J		x
Ardeotis australis	australian bustard		L	CE				x
Aythya australis	hardhead			V				x
Biziura lobata	musk duck			V				x
Calidris ferruginea	curlew sandpiper			E	A2H	C J R		x
Chlidonias hybridus javanicus	whiskered tern			NT			x	
Climacteris picumnus	brown treecreeper			NT			x	
Dromaius novaehollandiae	emu			NT			x	x
Gelochelidon nilotica macrotarsa	gull-billed tern		L	E				x
Haliaeetus leucogaster	white-bellied sea-eagle		L	V		C	x	x
Lophocroa leadbeateri	major mitchells cockatoo		L	V				x
Lophoictinia isura	square-tailed kite		L	V			x	
Nycticorax caledonicus hillii	nankeen night heron			NT				x
Oxyura australis	blue-billed duck		L	E				x
Phalacrocorax varius	pied cormorant			NT				x
Platalea regia	royal spoonbill			NT			x	x
Polytelis anthopeplus monarchoides	regent parrot	V	L	V			x	x
Pomatostomus temporalis temporalis	grey-crowned babbler		L	E				x
Stictonetta naevosa	freckled duck		L	E				x
Struthidea cinerea	apostlebird		L					x

The bat fauna of Belsar Yungera is diverse with eight taxa observed at the site (Table 5). The bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey, while trees provide roosting habitat in bark, crevices and hollows.

Belsar Yungera supports a number of woodland mammal species western grey kangaroo, short-beaked echidna, sugar glider and common brushtail possum. The recent observations of sugar glider in November 2014 is a range extension represents the most-downstream population of this species (GHD 2014).

Table 58. Native mammal species reported from Belsar Yungera (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	gould's wattled bat				x	
Chalinolobus morio	chocolate wattled bat				x	
Macropus fuliginosus	western grey kangaroo				x	x
Macropus rufus	red kangaroo					x
Mormopterus ridei (species 2)	southern freetail bat				x	
Nyctophilus corbeni	south-eastern long-eared bat				x	
Petaurus breviceps	sugar glider				x	
Scotorepens balstoni	inland broad-nosed bat				x	
Tachyglossus aculeatus	short-beaked echidna				x	
Tadarida australis	white-striped freetail bat				x	
Trichosurus vulpecula	common brushtail possum				x	x
Vespadelus regulus	southern forest bat				?	
Vespadelus vulturnus	little forest bat				?	

? Identification uncertain

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs. Fifteen reptile species have been reported from Belsar Yungera including three species of conservation significance (Table 6). Tesselated gecko has not been reported from the site but would be expected to occur in Lakes Powell and Carpul and other wetland beds which provide shelter in cracking clays. Carpet python and lace monitor both depend on high levels of floodplain productivity to provide a supply of vertebrate prey within dense understorey vegetation, tree hollows and hollow logs to provide shelter.

Six frog species have been reported from the site, including the nationally vulnerable growling grass frog (GHD 2014).

Table 59. Reptiles and amphibians of conservation significance reported from Belsar Yungera (GHD 2014)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Morelia spilota metcalfei	carpet python		L	E		x
Lampropholis delicata	delicate skink			DD	x	
Varanus varius	lace monitor			E		x
Litoria raniformis	growling grass frog	V	L	E		x

FORMAL CONSERVATION AGREEMENTS

The Belsar and Yungera Floodplain lies mainly within Crown Land managed for conservation purposes including River Murray Reserve, the Lakes Powell and Carpul Wildlife reserve, public land water frontage. The former Belsar Island and Yungera Island state forests are now proposed to be reclassified as Murray River Park.

Part of the floodplain is private land but managed for conservation under covenants and other binding agreements.

Belsar Island is a wetland of national significance listed in the Directory of Important Wetlands in Australia (Environment Australia 2001).

VITAL HABITAT AT THE SITE

Yungera Island and adjacent Peacock Creek (NSW) is one of the largest known breeding locations for the regent parrot (*Polytelis anthopeplus monarchioides*) (vulnerable EPBC) (GHD 2009). The main breeding colony exists along Gearbox Loop on Yungera Island and Peacock Creek in New South Wales.

Lakes Powell and Carpul are important intermittent breeding sites for waterbirds of conservation including blue-billed duck, musk duck and hard head. Lake Powell is one of only seven recorded breeding sites in Victoria for freckled duck (VEAC 2008).

5.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVES

The overall objective of water management at Belsar Yungera is:

"to restore the key species, habitat components and functions of the Belsar Yungera ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- restoring habitat linkages between the river and Narcooyia Creek for murray cod and other native fish
- enhancing native fish habitat by improving the productivity of riparian zones and wetlands
- restoring semi-permanent wetlands capable of supporting growling grass frog
- maintaining lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats
- intermittently providing productive lake habitat for hundreds of waterbirds
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements in key areas of the Belsar and Yungera floodplain. Six water regime classes have been identified at Belsar and Yungera (Table 60). The following describes their ecology and water requirements.

Table 60. Belsar Yungera Water Regime Classes

Water Regime Class	Area (ha)	Ecological Vegetation Class
Watercourses	72	Waterbody Fresh
Semi-permanent Wetlands	132	Floodway Pond Herbland Shallow Freshwater Marsh Spike Sedge Wetland
Red Gum Forest and Woodland	613	Grassy Riverine Forest / Floodway Pond Herbland Complex Intermittent Swampy Woodland Grassy Riverine Forest
Lignum Shrubland and Woodland	4085	Lignum Swamp Lignum Shrubland Lignum Swampy Woodland
Black Box Woodland	2056	Riverine Grassy Woodland Riverine Chenopod Woodland Shrubby Riverine Woodland
Floodplain Lake	130	Lake Bed Herbland

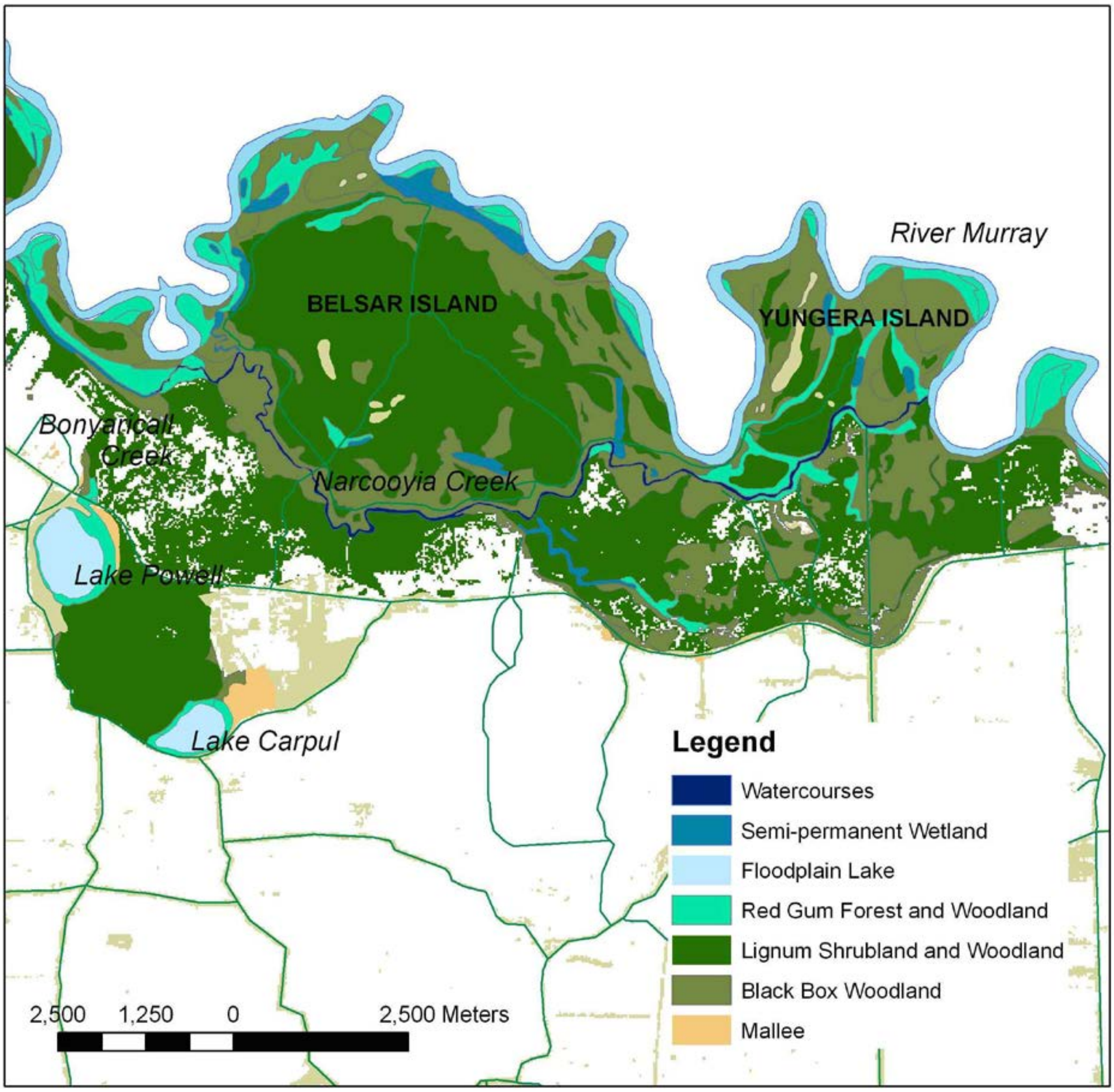


Figure 16. Belsar and Yungera Island Water Regime Classes

WATERCOURSES

Ecology

Narcooyia Creek is a deeply incised anabranch of the River Murray flowing over 17 km through the Belsar Yungera floodplain. The creek conveys fast-flowing water when river levels are high. The creek is an important habitat for native fish, supporting murray cod and golden perch. Deep holes and large woody debris which provide resting areas for fish and sources of prey. Several low-lying wetlands are connected to the creek, including Yungera Creek, and provide a more extensive aquatic habitat for creek fauna when water levels are high.

The food resources available to native fish, turtles and other fauna are limited by the stable of water levels in the creek. The creek is blocked at each end with water pumped into the creek to supply irrigators. Variation in water level promotes a complex and productive food web by mineralising organic matter, promoting bacterial biofilms and promoting the growth of aquatic plants over a broad area of the creek banks and connected wetlands.

Variation in flow is important to the productivity and habitat value of the creek. Increasing discharge in spring is associated with spawning in golden perch, smelt and silver perch (Lake 1967, King et al. 2007). It is believed to act as a reliable indicator of the imminent availability of productive floodplain habitat to support juvenile fish recruitment.

Flowing water habitat is important to a number of native fish species fish. Flowing watercourses provides attractant flows for fish, encouraging their upstream migration (Leigh and Zampatti 2005). Streams that include fast- and slow-flowing water are associated with large, viable populations of murray cod (Saddlier and O'Mahony 2007). Flowing water provides an important breeding habitat for australian smelt (Sheldon and Lloyd 1990, Boulton and Brock 1991).

Water Requirements

Modifications to structures are required to allow fish to move between the creek and the River Murray while maintaining the creek as a permanent aquatic habitat. This can be achieved by constructing a fish passage on the downstream structure. This will allow adult and juvenile fish to migrate and disperse, providing fish with access to a greater range of food sources and habitat components and increase the resilience of the population to local disturbance.

The regulating structures could also be modified to allow through-flow to occur more frequently in the creek. The banks could be removed whenever river flow is high enough to meet irrigator requirements. This would increase connectivity and the frequency and duration of fast-flowing habitat.

The productivity and habitat value of the creek is limited by the stability of water levels. High creek benches and adjacent wetlands, including Yungera Creek are rarely connected to the Narcooyia Creek. Seasonally elevated water levels would promote the productivity of these wetlands and provide a more extensive aquatic habitat for fish. Access to these habitats will be most important during the spawning season, from mid spring to early summer.

Table 61. Water management objectives for watercourses

Objectives Addressed	Restore habitat linkages between the river and Narcooyia Creek for murray cod and other native fish Enhance native fish habitat by improving the productivity of riparian zones and wetlands
Strategy	Provide a fishway in the downstream regulating structure on Narcooyia Creek Open Narcooyia Creek to through-flow whenever river discharge provides levels in Narcooyia Creek that exceed pump requirements Pump water into Narcooyia Creek system to provide seasonal connections to adjacent wetlands
Hydrological Targets	Open, through-flowing habitat in Narcooyia Creek for 2 to 3 months annually in spring and early summer Water levels in the creek raised by 0.5 to 1.5 m for 3 to 6 months between August and February 8 years in 10.

SEMI-PERMANENT WETLANDS

Ecology

Semi-permanent wetlands are present on the Belsar and Yungera floodplain where there are deep depressions with low thresholds to river inflows. These sites include the Carp Hole on Belsar Island and several wetlands associated with Yungera Creek.

Under natural conditions water was almost always present in these wetlands due to frequent inflows and the capacity of wetlands to retain water for long periods. The wetlands would only dry out during rare, prolonged periods of low flow. Water levels would vary seasonally such that wetlands would tend to be flooded most deeply and frequently in spring and would tend to have lowest water levels in summer and autumn.

Persistent, deep flooding will exclude emergent macrophytes from the central wetland bed, which will instead have either open water or semi-emergent vegetation of *Pseudoraphis spinescens, Myriophyllum* spp., *Vallisneria americana* and *Potamogeton* spp. When dry the bed will be bare or provide habitat for lake bed herbs such as *Alternanthera denticulata, Eleocharis acuta* and *Centipeda cunninghamii.*

Seasonal inundation of the wetland fringe provides habitat for emergent macrophytes such as *Phragmites australis* and *Juncus spp..* Vegetation at the perimeter grades into the grass and sedge-rich understorey of red gum forest and woodland.

Regular drying and re-flooding of the fringe is important to wetland productivity. Flooding of the reed zone mineralises organic matter and promotes microbial, algal and macro-invertebrate production.

Persistent flooding of the wetland bed allows the development of a community of large zooplankton, shrimp (*Paratya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. These animals provide prey for fish such as smelt, bony bream and hardyhead, while flying adult insects contribute to the food requirements of bats and birds. Persistent flooding would also support resident populations of tortoise. Frogs such as growling grass frog occupy semi-permanent wetlands as a refuge, and disperse to seasonal aquatic habitat during inundation events.

Dabbling ducks such as freckled duck, australasian shoveler and pink-eared duck feed on soft-leaved aquatic plants and aquatic macro-invertebrates. Semi-permanent wetlands provide reliable breeding habitat for bird species which build nests using reeds on scrapes in and around fringing vegetation and require water to be present for at least three months in winter and spring. Grazing waterfowl including black swan, australian shelduck and wood duck will also be favoured by semi-emergent vegetation and will regularly breed.

Inundation of the forest or woodland adjacent to semi-permanent wetlands for periods of three to six months will provide nesting habitat for colonial nesting waterbirds. These birds will nest in the flooded trees and seek food in nearby wetlands and flooded vegetation.

Water Requirements

In order to maintain resident populations of aquatic fauna, semi-permanent wetlands may only dry out on rare occasions, in 5 to 10 % of years. The wetland should retain more than 1 m of water 80% of the time to provide effective refuge habitat. Inflows are required in more than 80% of years to provide seasonal inundation of the littoral zone, which will maintain broad, dense macrophyte beds and provide aquatic fauna with access to flooded vegetation in spring and summer. These events should last for 3 months to maintain the vegetation structure and to allow breeding by waterfowl and growling grass frog. Events of 6 months will support breeding by colonial nesting waterbirds.

Table 62. Water management objectives for semi-permanent wetlands

Objectives Addressed	Restore semi-permanent wetlands capable of supporting growling grass frog Enhance native fish habitat by improving the productivity of riparian zones and wetlands
Strategy	Capture peaks in river flow in Yungera Creek wetlands and wetlands associated with Narcooyia Creek by closing regulators on the flood recession. Pump water into wetlands if peaks in river flow are not available.
Hydrological Targets	Wetlands completely dry 1 year in 10 Wetland depth to exceed 1 m 80% of the time Water depth to exceed retention level of wetland in 8 years in ten - 4 of these events to last more than 3 months - 4 of these events to last more than 6 months

RED GUM FOREST AND WOODLAND

Ecology

At Belsar Yungera river red gum forest and woodland occurs mainly adjacent to wetlands and in meander loops along the banks of the River Murray. The density of the red gum overstorey is limited in low-lying areas by frequent, sustained flooding which allows more light to the forest floor and supports an understorey of aquatic plants which grades into wetland vegetation in open areas. Perennial understorey plants include *Cyperus gymnocaulos* and *Phragmites australis* while flooding will promote the growth of seasonal species such as *Marsilea drummondii, Eleocharis acuta* and *Triglochin procerum*. The understorey becomes sparse as canopy density increases until, at higher elevations on the river levee, a shrubby understorey is present which includes *Exocarpus aphyllus, Acacia stenophylla* and *Senecio cunninghammii.* Species, which colonise the drying forest floor include *Lachnagrostis filiformis, Paspalidium jubiflorum* and *Senecio campylocarpus.*

Inundation of red gum forest and woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

During longer flooding events red gum woodland will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as nankeen night heron, cormorant and australasian darter. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for nesting wood duck, carpet python, bats and brush-tailed possum. Red gum growing close to water provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering which supports nectar-eating insects and birds and insectivorous birds.

Water Requirements

Flows exceeding 40,000 ML/d inundate red gum forest and woodland at Belsar Yungera. Under natural conditions these events occurred with frequency of approximately 10 times in 10 years and a median duration of 3 months. Under current conditions the duration and frequency of flow peaks above 40,000 ML/d have both declined by approximately 50%. In many areas the health, extent and species diversity of inundation dependent vegetation at Belsar Yungera is poor due to insufficient flooding (Australian Ecosystems 2009).

Flooding in between August and December for two months is required to maintain tree health and meet the seasonal requirements of many understorey plants. Longer events, of four months duration, are recommended to provide breeding opportunities for waterbirds, particularly in trees that fringe wetlands.

Table 63. Water management objectives for red gum forest and woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore the inundation of red gum forest and woodland
Hydrological Targets	Provide flood events 8 years in 10 to a level equivalent to flows of 40,000 ML/d - four of these events to be 3 months long - four of these events to be 4 months long

LIGNUM SHRUBLAND AND WOODLAND

Ecology

Lignum shrubland and woodland occurs in the central parts of Belsar and Yungera Islands where it occupies extensive shallow depressions and freely-draining areas. It also occupies a significant area between Lakes Powell and Carpul. Lignum is the dominant species in the shrublands and, when flooded frequently, forms extensive, dense thickets with an understorey of wetland herbs. Other shrubby species such as *Chenopodium nitrariaceum* can co-occur with lignum. In the dry phase the understorey can include grasses, herbs and sub-shrubs such as *Einada nutans* and *Paspalidium jubiflorum*. Black box, red gum and *Acacia stenophylla* can form a sparse emergent overstorey which becomes denser as the community grades into woodland vegetation.

Inundation of lignum shrubland represents an extension of the habitat for aquatic floodplain fauna such as fish, reptiles and frogs. Their bushy structure and debris provides a productive substrate for epiphytes that supports high macroinvertebrate productivity and also provides shelter from predators. Flooded lignum is also used as a platform by nesting waterbirds including ibis and spoonbill. Floodwater draining from lignum will carry dissolved and particulate carbon as well as algae and invertebrates which will contribute to the food web of the river channel.

Between flood events, lignum is an important habitat for terrestrial vertebrate fauna including snakes and lizards.

Water Requirements

Flows from 45,000 ML/d to 70,000 ML/d inundate lignum shrubland and woodland at Belsar and Yungera. Under natural conditions river flow exceeded 50,000 ML/d in approximately 80% of years, with half these events exceeding 3 months duration.

A range of flooding frequencies is required to achieve the ecological objectives. Lower-lying shrublands, equivalent to 50,000 ML/d flow threshold, should be flooded in 80% of years. Events of 2 months duration will maintain ecosystem structure and productivity and will provide seasonal habitat for aquatic fauna. Longer floods, of 4 months duration, should be provided in 4 of these years to support waterbird breeding.

Higher areas, equivalent to 70,000 ML/d flow threshold, should be flooded in 7 years in 10. Four of the events should be of 3 weeks duration to maintain vegetation structure. Three of the events should be 9 weeks duration to support breeding by fish, frogs and waterbirds.

Table 64. Water management objectives for lignum shrubland and woodland

Objectives Addressed	Maintain lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to lignum shrubland and woodland
Hydrological Targets	For areas above an inundation threshold equivalent to 50,000 ML/d - provide flooding 8 times in 10 years - four of these events to be 2 months long - four of these events to be 4 months long For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 7 times in 10 years - four of these events to be 3 weeks long - three of these events to be 9 weeks long

BLACK BOX WOODLAND

Ecology

Black box woodland occurs mostly on high floodplain terraces. The canopy is open and the community has a diverse, shrubby understorey that includes lignum, Chenopodium nitrariaceum, Rhagodia spinescens and Enchylaena tomentosa. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses.

Tree recruitment and the productivity of the vegetation is strongly linked to flooding. Flooding maintains a diverse tree age structure and a complex understorey plant community that is required by carpet python and other vertebrate fauna. The diversity of birds is particularly high because black box woodland contributes to the habitat requirements of both riverine and dryland species. Black box woodland supports a high proportion of ground foragers and hollow-nesting species. Black box woodlands are important for canopy feeding bush birds such as superb fairy-wren, little friarbird and blue-faced Honeyeater. Black box woodland also supports seasonal migrants normally associated with higher rainfall areas such as grey fantail and white-bellied cuckoo-shrike. Black box is an important habitat component for insectivorous bats.

Flood events that inundate black box woodland contribute to the carbon requirements of the River Murray. Receding flood water conveys organic debris to the river channel where it promotes macro-invertebrate productivity and maintains the riverine food web.

Water Requirements

Flows from 60,000 to more than 100,000 ML/d inundate black box woodland at Belsar and Yungera. Under natural conditions these events occurred in approximately 6 times in 10 years with duration of 1 to two months. In the more frequently flooded part of this range the woodland supports an understorey of lignum while chenopods and other shrubs dominate in less frequently flooded habitat.

While the duration of flood events is similar under the current flow regime, the frequency of events has declined to less than 3 in 10 of years.

The overall structure of black box woodland has been maintained, but tree recruitment and productivity has declined, threatening the long-term viability of vertebrate fauna populations. Resilience to prolonged drought events, where understorey vegetation becomes sparse and food resources diminish, is poor.

Black box woodland productivity can be restored by increasing the frequency of floods equivalent to 60,000 ML/d to 6 years in 10 for with events lasting 2 months and floods equivalent to 100,000 to 5 years in 10 with events lasting 1 month.

Table 65. Water management objectives for black box woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Restore flooding to black box wetland
Hydrological Targets	Provide flood events 6 years in 10 for a duration of 2 months to a level equivalent to flows of 60,000 ML/d Provide flood events 5 years in 10 for a duration of 1 month to a level equivalent to 100,000 ML/d

FLOODPLAIN LAKES

Ecology

Lakes Powell and Carpul are extensive floodplain lakes that are intermittently filled by high river flows. Lake Powell has a lower inflow threshold and under natural conditions would have filled approximately 3 times in 10 years. When full, the lake took up to a year to dry out and would sometimes have remained flooded between years. Lake Carpul has a higher inflow threshold and received significant inflows 1 year in 10. Lake Carpul would normally dry completely between filling events.

The lakes alternate between flooded and dry states. When flooded, soft-leaved semi-emergent vegetation will colonise the deeper parts of the lake bed including *Myriophyllum sp.* and *Potamogeton* sp. Open water may be present in the central part of the wetlands where water is too deep to support these species. Emergent macrophytes such as *Cyperus gymnocaulos* and *Eleocharis acuta* will occupy the fringe of the wetland.

Flooded wetlands will be colonised by the larvae of flying insects and by invertebrates released from resting stages on the lake bed. Over several weeks the wetlands will provide productive food sources for small fish, waterbirds, frogs and turtles. Lakes Powell and Carpul are important waterbird habitat and support breeding by blue-billed duck, musk duck, hard head and freckled duck.

The drying wetland bed will support a range of wetland herbs such as *Centipeda cunninghamii, Persicaria lapathifolia, Alternanthera* sp. *Glossostigma elatinoides* and *Heliotropum* sp. Between flood events the wetland bed will develop a community of lake bed herbs and grasses such as *Persicaria lapathifolia.* These plants, together with colonising *Eucalyptus camaldulensis*, will die during subsequent sustained flood events.

In sustained dry periods the wetland water levels will expose a muddy herbland on the lake bed. Small wading birds such as ruddy turnstone and red-necked stint will feed on macro-invertebrates in shallow water and mud. Fish-eating birds and carrion feeders, including white-bellied sea-eagle, will feed on stranded fish.

Water Requirements

Flows exceeding 90,000 ML/d are required to introduce water to Lake Powell, but these must be sustained for more than one month to effectively fill the lakes and inundate the surrounding woodland and lignum shrubland. Under natural conditions events exceeding 90,000 ML/d occurred in 60% of years. Fifty percent of these events lasted longer than 40 days, so effective inundation can be estimated to have occurred in approximately 20 to 30% of years.

Flood events in Lake Powell of 40 to 60 days in 25% of years are recommended, extending into the vegetation surrounding the lake. These events will maintain the structure and productivity of flood-dependent vegetation around the lake that includes river red gum, black box and lignum. The lake will remain flooded for more than six months after flood water recedes to the retention level and it will provide feeding and breeding habitat for waterbirds.

Flows exceeding 170,000 ML/d are required to substantially flood Lake Carpul. Events of this magnitude occurred in less than 20% of years under natural conditions, with 50% of these exceeding 20 days in duration.

Flood events in Lake Carpul of 30 days duration are recommended in 10% of years. These events will maintain the condition of flood-dependent vegetation near the lake and will provide a significant waterbird habitat.

Table 66. Water management objectives for floodplain lakes

Objectives Addressed	Intermittently provide productive lake habitat for hundreds of waterbirds
Strategy	Restore flooding to floodplain lakes
Hydrological Targets	Fill Lake Powell and flood surrounding woodland vegetation up to a level of 52 m AHD in 25% of years for duration of 40 to 60 days. Fill Lake Carpul and flood surrounding vegetation up to a level of 53 m AHD in 10% of years for duration of 30 days.

5.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Belsar and Yungera Floodplain Management Project will

- improve the viability and resilience of murray cod and golden perch fish populations in Narcooyia Creek and the local reach of the River Murray
- restore a local population of growling grass frogs and breeding by colonial nesting waterbirds in semi-permanent wetlands
- frequently support breeding by hundreds waterbirds in flooded lignum and lakes
- improve the viability and resilience of terrestrial fauna populations on the floodplain including carpet python, lace monitor and bats

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Belsar and Yungera (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

The proposed Belsar and Yungera supply measure promotes flooding in diverse floodplain habitats including permanent watercourses, semi-permanent wetlands, lignum shrubland, forest, woodland and large floodplain lakes. Consequently the project contributes to the habitat requirements of diverse fauna groups.

Improving water regimes in wetlands and watercourses will benefit large-bodied and small-bodied fish and promote both submerged and emergent aquatic macrophyte beds. These areas are important to resident waterbirds such as bitterns, crakes and rails, and also to visiting waterbirds that feed or breed seasonally, including colonial nesting species.

Floodplain inundation, particularly of lignum and woodland habitat provides productive temporary habitat for small fish species and waterbirds. Long flood events will provide opportunities for platform-building species to breed.

The Belsar and Yungera project inundates substantial open-water habitat in Lakes Powell and Carpul which have the potential to provide feeding habitat for large numbers of waterbirds.

Table 67. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Belsar and Yungera project.

Ecological Class	Ecological Element	Belsar and Yungera
Waterbirds	Bitterns, crakes and rails	❶❶
	General abundance and health - all waterbirds	❶❶
	Breeding - Colonial-nesting waterbirds	❶❶
	Breeding - other waterbirds	❶❶
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	❶❶
	Forests: river red gum (*Eucalyptus camaldulensis*)	❶
	Forests and woodland: black box (*Eucalyptus largiflorens*)	❶❶
	Shrublands	❶❶
	Tall grasslands, sedgelands and rushlands	❶❶
	Benthic herblands	❶❶
Fish	Short-lived / small-bodied fish	❶❶
	Long-lived / large-bodied fish	❶❶

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

5.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

The Belsar and Yungera floodplain system comprises Belsar, Yungera and Tonsing Islands, the adjacent floodplain and Lakes Powell and Carpul.

Narcooyia Creek defines the southern side of Belsar and Yungera Islands. Flowing over 17 km, it diverges from the river at 1195 river km, upstream of Yungera Island, and returns to the river at 1168 river km downstream of Belsar Island. Bonyaricall Creek branches from Narcooyia Creek near its downstream end. It is 6 km in length and joins the River Murray at 1163 river km to create Tonsing Island.

Euston Weir influences river levels in the eastern part of the system. The weir maintains a normal operating level of 47.6 m AHD which pools water in Bonyaricall Creek and reduces the variation in water level as river discharge rises and falls.

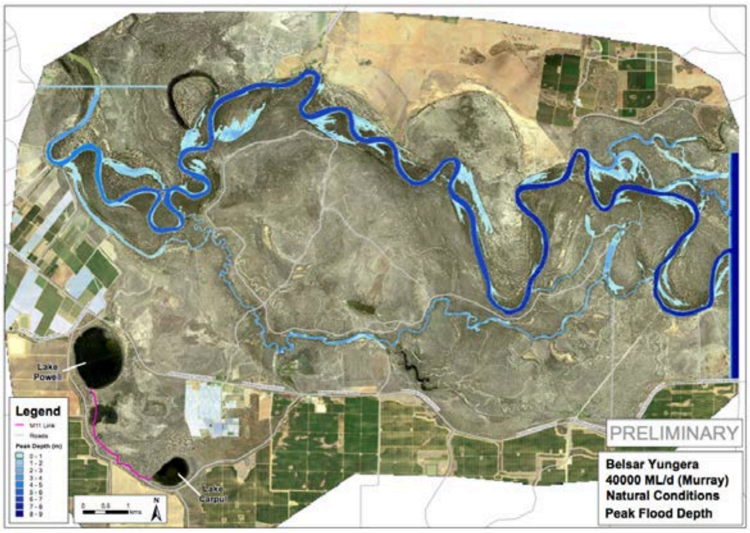
Narcooyia Creek has been significantly modified to allow its use as a delivery channel for irrigation water. The channel is impounded between a bank where it branches from the River Murray and a weir just above Bonyaricall Creek. Water is pumped from the River Murray into the creek to meet irrigation demand and to maintain a water level of 48.51 m AHD. Water is extracted from the creek just above the downstream weir(GHD 2011). These operations maintain constant flooding in the creek and near-constant flow (Ecological Associates 2006).

Excess water flows over the weir in Narcooyia Creek and enters Bonyaricall Creek rather than the final reach of Narcooyia Creek. Both creeks are subject to siltation and encroachment by *Typha* sp. (Ecological Associates 2006), (GHD 2011). The velocity in Bonyaricall Creek is negligible due to the width and depth of the channel. Intensive irrigation diversions from Bonyaricall Creek may draw water into the creek from downstream, reversing the flow.

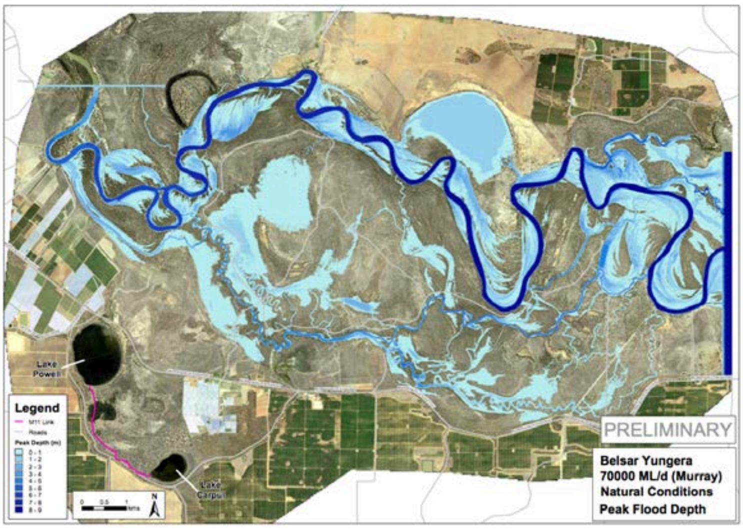
Lakes Powell and Carpul are large floodplain lakes located south of Bonyaricall Creek. Lake Powell naturally fills at its northern end when high flows spill from Bonyaricall Creek into along a narrow floodway. The channel passes under the Murray Valley Highway where the invert of the pipe culverts matches the maximum thalweg of the channel: 51.2 m AHD. The bed of Lake Powell is generally flat and has an invert of 49.75 m AHD, so that the lake stores water at a depth of 1.45 m after flood water recedes. Lake Powell has an approximate area of 115 ha and a volume of 1.5 GL (GHD 2012).

Lake Carpul fills primarily from overflows from Lake Powell when water levels exceed 52.3 m AHD. The lake has an approximate invert of 49.3 m AHD and retains water to a depth of up to 3 m. It has an area of 115 ha and a volume of 1.5 GL (GHD 2012).

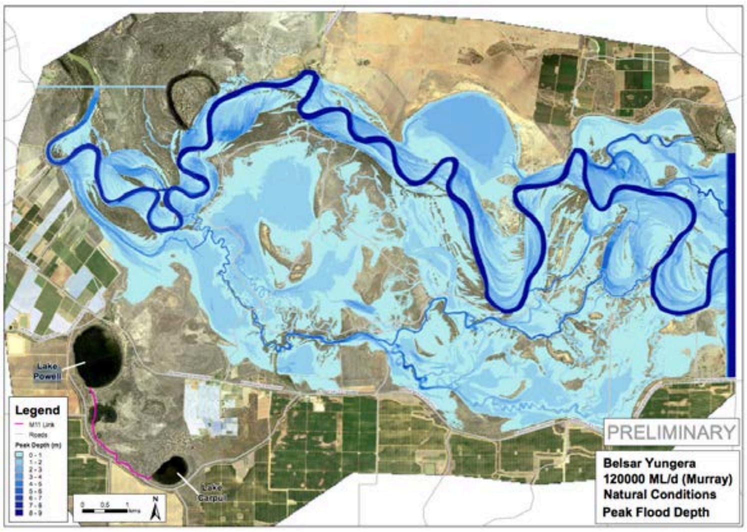
Generalised thresholds for floodplain inundation have been determined for the Belsar and Yungera using descriptions of floodplain hydraulics and published thresholds(Ecological Associates 2006) (GHD 2011); (GHD 2012) with reference the Predictor hydologic/hydraulic model (Gippel 2008) and lidar data (Table 68).



40,000 ML/d



70,000 ML/d



120,000 ML/d

Figure 17. Belsar Yungera floodplain inundation at flows of 40,000, 70,000 and 120,000 ML/d (data supplied by Water Technology).

Due to the effect of Euston Weir, rising river flows inundates upstream areas of the Belsar-Yungera floodplain before the downstream areas. Water first enters the floodplain at the downstream connection of Yungera Creek when river discharge exceeds 16,000 ML/d. Pools and wetlands near the creek are more than 2 m deep. They are readily filled by small peaks in river flow and can retain water for up to a year. Significant inundation of the surrounding areas occurring at flows exceeding 20,000 ML/d. Higher flows activate upstream connections and create through-flow.

Low floodplain terraces on meander loops of the River Murray commence when river levels exceed 20,000 ML/d with significant inundation occurring at flows over 27,000 ML/d. The Carp Hole is the largest wetland in the meander loops.

Lignum shrubland occupies a broad, shallow basin in central Belsar Island and is significantly inundated by flows exceeding 70,000 ML/d. Inundation is largely complete at flows of 120,000 ML/d. Black box woodland has a similar flooding pattern with flooding initiated at flows over 70,000 ML/d and mostly complete at flows of 120,000 ML/d (Jacobs 2014).

The flow threshold for significant flooding in Lake Powell is in the order of 140,000 ML/d and 170,000 for Lake Powell (Jacobs 2014).

Table 68. Inundation thresholds and hydrology under current conditions for key floodplain features (Gippel 2008)(Jacobs 2014)

Site	Generalised Flow Threshold (ML/d)
Yungera Creek and associated wetlands	20,000 - 30,000
River Murray meander loops	25,000 - 40,000
Lignum Shrubland	70,000 - 120,000
Black Box Woodland	70,000 - 120,000
Lake Powell	140,000
Lake Carpul	170,000

HYDROLOGY

The hydrology of the River Murray at Belsar Yungera under natural and current conditions was analysed by Ecological Associates (2006).

Median monthly and 90th percentile flows have declined substantially under current conditions, with the greatest impacts in the high flow months from June to December (Figure 18). The impacts on flows in autumn are relatively minor. There has been a slight shift in the seasonality of median daily discharge, with the highest flows occurring in September under benchmark (current) conditions and in October under natural conditions (Figure 18).

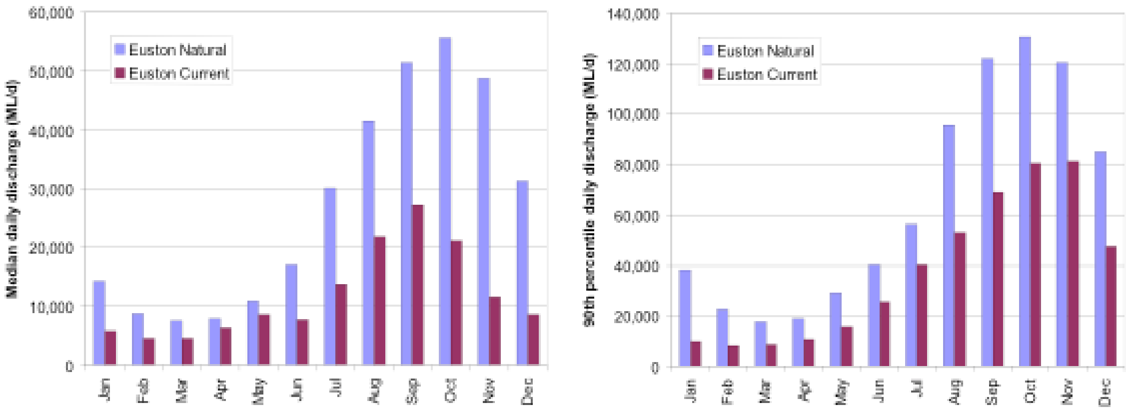


Figure 18. Distribution of median flows and 90th percentile flows for each month in the River Murray for natural and current (benchmark) conditions (Ecological Associates 2006)

For flows greater than 20,000 ML/d, event frequency has reduced significantly under regulated conditions. Current event frequency is in the order of 50% to 70% less than pre-regulation frequency, even for flows exceeding 140,000 ML/d.

The duration of spells is also lower for intermediate events: spells are 50% shorter for events 20,000 to 60,000 ML/d. However for high flows, greater than 90,000 ML/d, the duration of spells under natural and benchmark scenarios is similar.

The river is in a low-flow state for a greater proportion of time under current conditions as it is managed to deliver water to downstream consumers efficiently. Events of 5,000 ML/d occur 1.6 times per year with a median duration of 130 days. Under natural conditions river discharge exceeded 5,000 ML/d for most of the year (Figure 19).

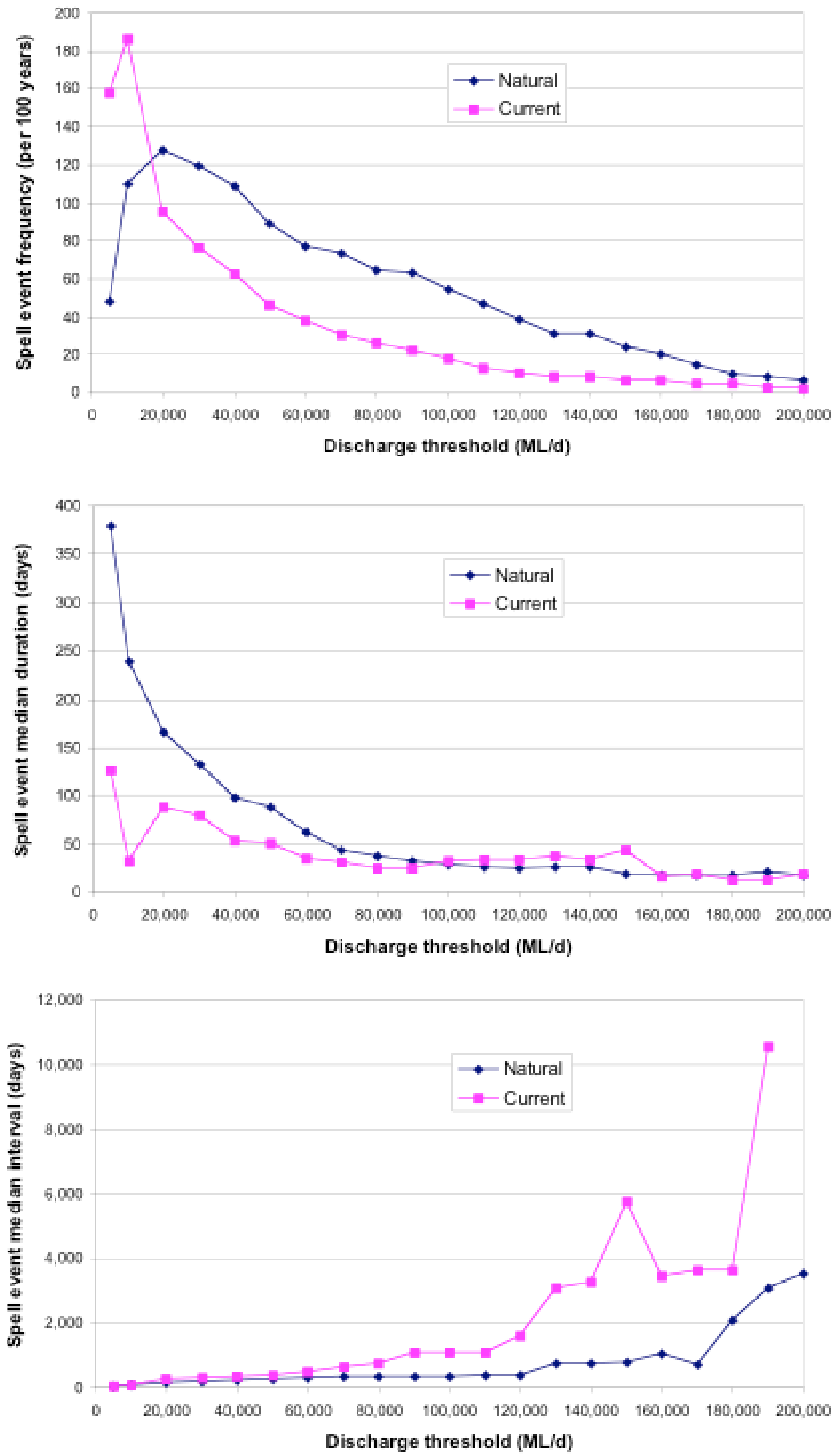


Figure 19. Spell event frequency, median duration and median interval for natural and current conditions at Euston Weir. Source: derived from MDBC MSM-Bigmod data processed by Chris Gippel of Fluvial Systems (Ecological Associates 2007)

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

The proposed works inundate a range of water regime classes at Belsar and Yungera ranging from watercourses to black box woodlands (Table 69, Figure 20).

Table 69. Area of inundation of proposed works at Belsar and Yungera

Water Regime Class	Area (ha)
Watercourse	59
Semi-permanent Wetland	55
Red Gum Forest and Woodland	128
Lignum Shrubland and Woodland	1546
Black Box Woodland	405
Floodplain Lake	130
(Mallee)*	0.02
(Plains Forest and Woodland)*	0.06

*Not flood-dependent

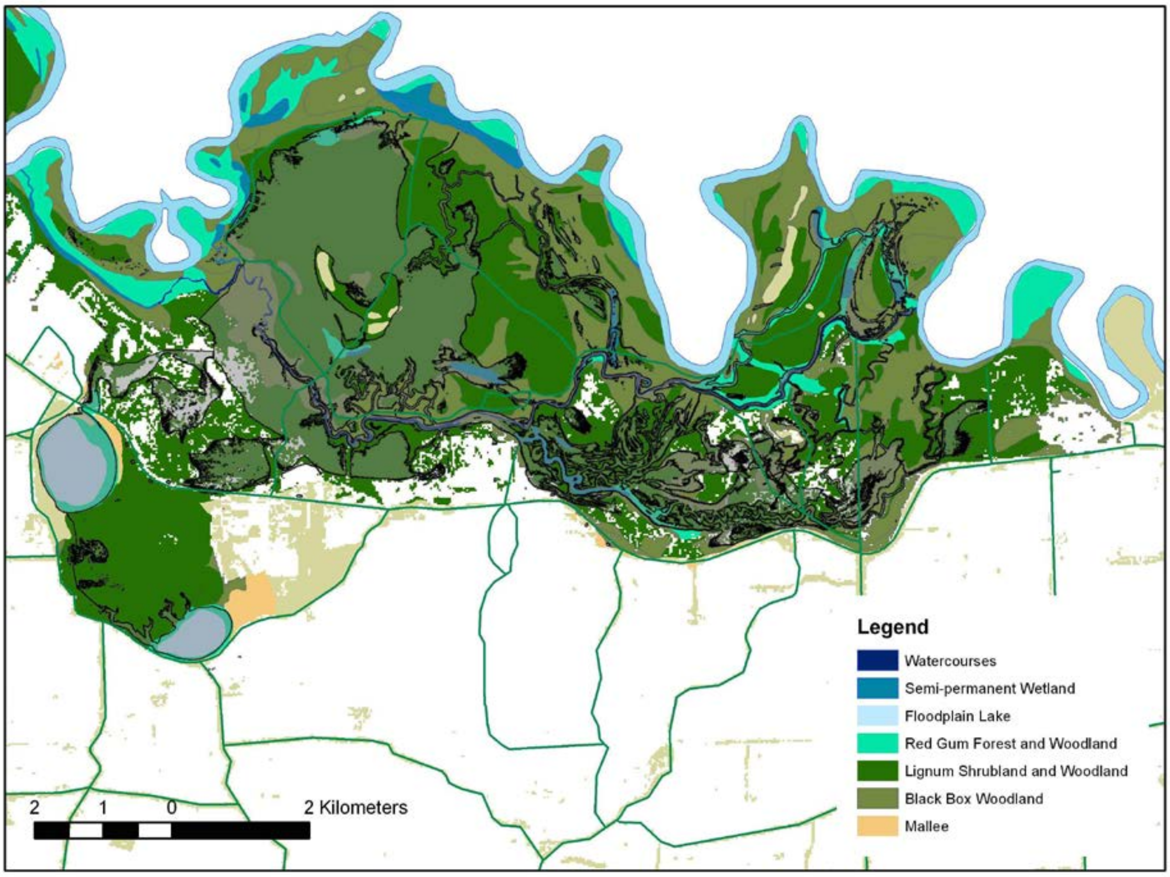


Figure 20. Water regime classes inundated by the proposed works at Belsar and Yungera

DESIGN

It is proposed to meet targets for flood duration and frequency by promoting floodplain inundation with a system of flow detention and regulating structures. The system creates three tiers of inundation that can utilise peaks in river flow, pumped water or a combination of the two.

The primary component of the works is the detention of water upstream of a levee bank and regulator at the western end of Belsar Island, near the confluence of Narcooyia Creek and the River Murray. This structure, ER1, will store water up to a level of 52.3 m AHD and will inundate most of central Belsar Island. The water body will extend to the floodplain south of Belsar Island and upstream to channels and low-lying wetlands in Yungera Island. Minor regulators and banks will be constructed on floodplain effluents to control outflows to the River Murray, including regulators S7 on Yungera Creek and ER3 at the upstream river connection of Narcooyia Creek. Flow in the channel from Narcooyia Creek to Lake Powell will be improved through excavation and levee bank construction to inundate Lake Powell, part of Lake Carpul and, importantly, the high value river red gum and black box woodland between the two lakes (Mallee CMA 2013) (GHD 2012).

These works inundate an area of 2,093 ha (Mallee CMA 2013).

The downstream regulator will incorporate a fishway. When not being used in environmental watering events, the regulator will hold Narcooyia Creek at levels required to support existing irrigation diversions. However by replacing the weir, the regulator and fishway will provide connection between the Narcooyia Creek and River Murray habitats.

Supplementary works are proposed to complement these works. Two additional water storage tiers will be created in the J1 Creek system to the south of Yungera Island. Minor stop log structures will pond water in the second tier at 52.9 m AHD and in the third tier at 53.3 m AHD. The supplementary works also include a new, lower 600 mm pipe culvert in the Murray Valley Highway to reduce the commence to flow to Lake Powell. Regulators will be constructed on the pipes to allow floodwater to be held in the lakes . Some excavation will be required to improve flow along the channel between Lake Powell and Carpul (Mallee CMA 2013) (GHD 2012).

The supplementary works inundate an area of 351 ha (Mallee CMA 2013).

Initial analysis of flood flow equivalence shows that :

- the proposed works achieve an inundation extent in the central part of Belsar Island is equivalent to a 70,000 ML/d flow at Euston
- the inundation extent in the northern parts of Yungera Island is equivalent to a flow of 100,000 ML/d at Euston
- the inundation extent achieved in Lake Carpul is equivalent to a flow of 170,000 ML/d at Euston. (Mallee CMA 2013)

OPERATION

The Belsar Yungera Floodplain Management Project will be operated to augment the frequency and duration of floodplain inundation to meet environmental watering targets.

The structures will be operated to achieve environmental watering targets under four scenarios.

- Under normal flow conditions (when no environmental watering is occurring) ER3 will be closed to regulate water levels in Narcooyia Creek according to existing arrangements, maintaining a level that supports irrigation diversions from the channel (48.51 m AHD) (GHD 2012). The fishway will operate continuously in this phase. All other regulators will be open.

- Under conditions of a minor peak in river flow, the Narcooyia / Bonyaricall Creek system will be operated as a through-flow system. When river levels exceed 48.51 m AHD (approximately 7,000 ML/d) the Narcooyia Creek inlet and outlet regulators will be opened. This will meet the water level requirements of the Narcooyia Creek diverters while increasing channel velocity and providing free movement of aquatic fauna between the creek and the river.

- When a moderate to large flood occurs, the system will be operated to increase the duration of wetland floodplain inundation. Regulators at the perimeter of the ponded areas, including ER1, S1, S7 and ER3, will remain open on the rising hydrograph to allow the system to fill. The regulators will be closed when river levels start to fall to store water at the target level, up to limits of the regulators: 52.3 m AHD at ER1 and 52.9 and 53.3 m AHD in the J1 Creek system. Water will be detained to meet the duration requirements of environmental targets, then returned to the River Murray by opening regulators. ER3 will be close to restore the regulated pool in Narcooyia Creek.

- If peaks in river flow are too infrequent to meet environmental targets, part or all of the system may be inundated by pumped water. Temporary pumps will be installed on the river bank to fill the primary waterbody and may be relifted to fill the lakes or J1 Creek system. Pumping rates of 500 to 800 ML/d are proposed.

It is proposed to operate the system to augment flooding to meet environmental water requirements Table 70Table 70. Decisions to operate the system will mainly be based on the duration since the last event.

Table 70. Hydrological targets and ecological objectives

Thresholds	Hydrological Targets	Ecological Objectives
Watercourse	Open, through-flowing habitat in Narcooyia Creek for 2 to 3 months annually in spring and early summer Water levels in the creek raised by 0.5 to 1.5 m for 3 to 6 months between August and February 8 years in 10.	Restore habitat linkages between the river and Narcooyia Creek for murray cod and other native fish Enhance native fish habitat by improving the productivity of riparian zones and wetlands
Semi-permanent Wetlands	Wetlands completely dry 1 year in 10 Wetland depth to exceed 1 m 80% of the time Water depth to exceed retention level of wetland in 8 years in ten - 4 of these events to last more than 3 months - 4 of these events to last more than 6 months	Restore semi-permanent wetlands capable of supporting growling grass frog Enhance native fish habitat by improving the productivity of riparian zones and wetlands
Red Gum Forest and Woodland	Provide flood events 8 years in 10 to a level equivalent to flows of 40,000 ML/d - four of these events to be 3 months long - four of these events to be 4 months long	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Lignum Shrubland	For areas above an inundation threshold equivalent to 50,000 ML/d - provide flooding 8 times in 10 years - four of these events to be 2 months long - four of these events to be 4 months long For areas above an inundation threshold equivalent to 70,000 ML/d - provide flooding 7 times in 10 years - four of these events to be 3 weeks long - three of these events to be 9 weeks long	Maintain lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Black Box Woodland	Provide flood events 6 years in 10 for a duration of 2 months to a level equivalent to flows of 60,000 ML/d Provide flood events 5 years in 10 for a duration of 1 month to a level equivalent to flows of 100,000 ML/d	Provide flood events 6 years in 10 for a duration of 2 months to a level equivalent to flows of 60,000 ML/d Provide flood events 5 years in 10 for a duration of 1 month to a level equivalent to 100,000 ML/d
Lake Powell	Fill Lake Powell and flood surrounding vegetation up to a level of 52 m AHD in 25% of years for a duration of 40 to 60 days	Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats Contribute to the carbon requirements of the River Murray channel ecosystem
Lake Carpul	Fill Lake Carpul and flood surrounding vegetation up to a level of 53 m AHD in 10% of years for a duration of 30 days	

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011). To evaluate the target for murray cod movement PIT (Passive Inductive Transponder) tagging would be required.

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray(Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

Table 71. Belsar and Yungera specific ecological targets

Objective	Target
Restore and enhance habitat linkages between the river and Narcooyia Creek for murray cod and other native fish	More than 10 adult murray cod in Narcooyia Creek migrate to and from the River Murray channel at least once per year.
Restore and enhance native fish habitat by improving the productivity of riparian zones and wetlands	The average lateral extent of aquatic macrophyte vegetation on the banks of Narcooyia Creek will increase by 100% from 2015 to 2030 The December projected plant cover exceeds 50% in at least 30 ha of wetland habitat connected to Narcooyia Creek by 2030
Restore and enhance semi-permanent wetlands capable of supporting growling grass frog	More than 1 ha of dense sedgeland is present in at least 2 wetland sites by 2030. These sedgelands are completely dry no more than 6 months in the period from 2020 to 2030.
Maintain lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds	Platform-building waterbirds to breed in lignum shrublands on at least four occasions between 2025 and 2035.
Restore and enhance floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats	Total bat abundance to increase by 25% from 2015 levels by 2030.
Intermittently provide productive lake habitat for hundreds of waterbirds	Total summer waterbird abundance at Lake Powell Island to exceed 500 on at least two occasions between 2025 and 2035 Total summer waterbird abundance at Lake Carpul to exceed 500 on at least one occasion between 2025 and 2035
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Belsar and Yungera for the period 2025 to 2035 is double 2015 to 2020 levels.

6 BURRA CREEK FLOODPLAIN MANAGEMENT PROJECT

6.1 PROJECT DETAILS

The Burra Creek Floodplain Management Project is a Supply Measure project located on the River Murray floodplain, 63 km southeast of Robinvale in northwest Victoria. The project is located entirely within Crown Land.

The Burra Creek floodplain is located on the left (west) bank of the River Murray between 1287 and 1323 river km. This project addresses flooding requirements in the northern section of the floodplain. The floodplain includes wetland, forest and woodland areas.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to remove blockages to flow and to use structures to retain and regulate water over the floodplain. The project inundates up to 340 ha of intact floodplain habitat.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

Figure 21. Location of the Burra Creek Floodplain Management Project

6.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

The Burra North area of the Burra Creek project area lies entirely within the River Murray Reserve. The reserve is managed for conservation and sustainable recreation by Parks Victoria.

Burra Creek is an anabranch of the River Murray that diverges from the river near Piangil at 1320 river km and rejoins the river 15 km north (in a direct line) at 1296 river km. The area enclosed between the creek and the river is known as Macreadie Island.

Burra North represents the downstream part of the island. The landscape in Burra North is largely unmodified and comprises wetlands, forest and woodland. The southern part of the island is mainly freehold land and is developed for agriculture.

Burra North is one of the best-preserved floodplain woodland and shrubland communities in the western Murray Fans bioregion. The system has intact vegetation strata with an overstorey of black box, a mid storey of lignum and a complex ground layer with high levels of organic litter, logs and understorey grasses and shrubs(Lumsden, et al. 2007).

The complex habitat supports a diverse bird community with over 130 bird species reported from the site and local vicinity. The bird fauna is dominated by species that depend on woodland and shrubland vegetation such as grey-crowned babbler, brown treecreeper and red-capped robin. The bat fauna is also diverse with twelve species reported from the site. Bats are largely insectivorous and depend on high levels of floodplain productivity to provide prey.

Burra North supports fourteen terrestrial reptile species including the large predators lace monitor and curl snake. The presence of these species indicates the availability of vertebrate prey species such as frogs, birds and small reptiles and that sheltering habitat is available in the form of logs, litter and tree hollows.

Burra Creek provides a strongly contrasting habitat to the surrounding floodplain woodland. Under natural conditions the creek flowed almost every year for about four months. When flowing, the creek would have supported large channel-specialist fish such as murray cod. Deep, permanent pools would have supported resident populations of small fish such as gudgeon species and murray-darling rainbowfish.

WATER DEPENDENT FLORA AND FAUNA

FLORA

The Victorian Flora Information System indicates 129 native vascular flora species have been recorded in the vicinity of Burra North (GHD 2013). The database and recent field surveys report nine rare or threatened floodplain species in or close to Burra North (Table 1).

The vegetation of Burra North is dominated by lignum shrubland and swampy woodland. Higher ground on the natural river levee supports red gum woodland with a grassy understorey. Higher ground on the terrestrial side of the floodplain supports black box woodland with a chenopod understorey.

Table 72. Plant species of conservation significance reported from Burra North(GHD 2013)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Amaranthus macrocarpus var. macrocarpus	dwarf amaranth			V		x
Asperula gemella	twin-leaf bedstraw			R		x
Atriplex rhagodioides	silver saltbush			V		x
Centipeda nidiformis	cotton sneezeweed			R		x
Cynodon dactylon var. pulchellus	native couch			K		x
Cyperus pygmaeus	dwarf flat-sedge			V		x
Cyperus victoriensis	yelka			K		x
Eremophila divaricata	spreading emu-bush			R	x	
Senecio cunninghamii var. cunninghamii	branching groundsel			R	x	x

In Victoria, vegetation mapping units, known as Ecological Vegetation Classes, are assigned conservation ratings within each bioregion (Table 2). Of the ten EVCs present at Burra North one is considered endangered and four are considered vulnerable.

Table 73. Bioregional conservation status of Burra North Ecological Vegetation Classes

Ecological Vegetation Class	Bioregional Conservation Status
103 Riverine Chenopod Woodland	Endangered
104 Lignum Swamp	Vulnerable
106 Grassy Riverine Forest	Depleted
295 Riverine Grassy Woodland	Vulnerable
808 Lignum Shrubland	Vulnerable
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
818 Shrubby Riverine Woodland	Least Concern
823 Lignum Swampy Woodland	Vulnerable

FAUNA

Ten native fish species are encountered regularly in the River Murray near Burra North (Table 74). Under natural conditions, seasonal flow in Burra Creek would have provided habitat for large channel-specialist fish such as murray cod and golden perch. Small, vegetation-dependent fish such as murray-darling rainbowfish would have dispersed through the creek during flow events and retreated to deep pools when flow ceased.

Flooded lignum and woodland provide habitat for a range of small fish that benefit from submerged aquatic vegetation, woody debris and plant, biofilm and invertebrate food sources . The restoration of floodplain habitat would provide feeding and breeding opportunities for murray-darling rainbowfish, carp gudgeon, flathead gudgeon and australian smelt.

Carbon generated on the floodplain is conveyed to the river channel by floodwater. This material contributes to the productivity of the riverine ecosystem on which channel-specialist fish depend, including murray cod, silver perch and golden perch.

Table 74. Native fish species expected to occur at Burra North (Davies, et al. 2008)

Scientific name	Common Name	Conservation Status		
		EPBC	FFG	VROTS
Bidyanus bidyanus	silver perch		L	V
Craterocephalus stercusmuscarum fulvus	fly-specked hardyhead			
Hypseleotris klunzingeri	carp gudgeon			
Maccullochella peelii peelii	murray cod	V	L	V
Macquaria ambigua	golden perch		I	NT
Melanotaenia fluviatilis	murray-darling rainbowfish		L	V
Nematalosa erebi	bony herring			
Phylipnodon grandiceps	flathead gudgeon			
Retropinna semoni	australian smelt			
Tandanus tandanus	freshwater catfish		L	E

Burra North has a diverse bird fauna with over 130 bird species reported from the site and the local vicinity. Of these, 16 have conservation significance in Victoria or under the EPBC Act and two are protected under intational migratory bird agreements (Table 4).

The bird fauna is dominated by species that depend on forest and woodland habitat. Species such as grey-crowned babbler, brown treecreeper and red-capped robin forage on the ground and on the trunks and branches of trees and shrubs. These species are insectivores and benefit from the high levels of insect productivity associated with flooding.

Waterbirds do not represent a large component of the fauna, which is dominated by species that depend on forest and woodland habitat. However, Burra North has significant areas of Lignum Swamp which are potentially nesting habitat for a range of platform-building waterbirds such as ibis and cormorants and waterfowl such as freckled duck.

Table 75. Birds of conservation significance reported at or near Burra North (Brown, Bryant and Horrocks 2013),(Lumsden, et al. 2007)

Species	Common Name	Conservation Status			Migratory Bird Agreements		2007 and 2013 Surveys	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Ardea modesta	eastern great egret			V		C J	x	x
Burhinus grallarius	bush stone-curlew		L	E			x	x
Cacatua leadbeateri	major mitchell's cockatoo		L	V			x	x
Circus assimilis	spotted harrier			NT			x	x
Climatcteris picumnus	brown treecreeper			NT			x	x
Dromaius novaehollandiae	emu			NT			x	x
Egretta garzetta	little egret		L	E			x	x
Geopelia cuneata	diamond dove		L	NT			x	x
Haliaeetus (Pontoaetus) leucogaster	white-bellied sea-eagle		L	V		C	x	x
Lophoictinia isura	square-tailed kite		L	V			x	x
Melanodryas cucullata	hooded robin		L	NT			x	x
Nycrticorax caledonicus	nankeen night heron			NT			x	
Polytelis anthopeplus	regent parrot	V	L	V			x	x
Pomatostomus temporalis	grey-crowned babbler		L	E			x	
Stagonopleura guttata	diamond firetail		L	NT			x	x
Sterna nilotica	gull-billed tern		L	E			x	

Burra North has a highly diverse bat fauna with twelve species reported from the site (Table 5). The bats are largely insectivorous and depend on high levels of forest productivity to provide prey. They roost in the crevices and hollows of *Eucalyptus camaldulensis* and *E. largiflorens* trees.

Shrubby woodland vegetation provides shelter and a productive habitat for sugar glider and black wallaby. These mammals are at the western limit of their range at Burra North. Feathertail glider is restricted to the River Murray corridor in north-western Victoria where it depends on hollows provided by large trees.

Black wallaby is present. This species prefers thick the forest undergrowth that is often found near wetlands and forest watercourses. It feeds on native shrubs, sedges, rushes, grasses and ferns. Typically patches of dense vegetation provide refuges during the day from which swamp wallabies emerge at dusk to feed on more open vegetation and grassland.

Table 76. Native mammal species reported from Burra North (Brown, Bryant and Horrocks 2013),(Lumsden, et al. 2007)

Species	Scientific Name	Conservation Status			2007 and 2013 Surveys	Data-bases
		EPBC	FFG	VROT		
Acrobates pygmaeus	feathertail glider				x	
Chalinolobus gouldii	gould's wattled bat				x	
Chalinolobus morio	chocolate wattled bat				x	
Macropus fuliginosus	western grey kangaroo				x	
Macropus giganteus	eastern grey kangaroo				x	
Mormopterus sp.	freetail bat (female)				x	
Mormopterus sp. (sp. 2)	eastern freetail bat				x	x
Mormopterus sp. (sp. 4)	southern freetail bat				x	x
Nyctophilus geoffroyi	lesser long-eared bat				x	x
Nyctophilus gouldi	gould's long-eared bat				x	x
Petaurus breviceps	sugar glider				x	
Scotorepens balstoni	inland broad-nosed bat				x	
Tachyglossus aculeatus	short-beaked echidna				x	x
Tadarida australis	white-striped freetail bat				x	x
Trichosurus vulpecula	common brushtail possum				x	x
Vespadelus darlingtoni	large forest bat				x	x
Vespadelus regulus	southern forest bat				x	x
Vespadelus vultumus	little forest bat				x	x
Wallabia bicolor	black wallaby				x	x

The forest provides a variety of complex habitats in understorey vegetation, litter, woody debris, shrubby vegetation tree bark, crevices and hollows. Flooding maintains the structure of these habitat components and high levels of productivity which provide food for reptiles and amphibians in the form of vegetation, invertebrates and small birds and mammals (Table 6).

Table 77. Reptiles and amphibians reported from Burra North (Brown, Bryant and Horrocks 2013)(Lumsden, et al. 2007)

Species	Scientific Name	Conservation Status			2007 and 2013 Surveys	Data-bases
		EPBC	FFG	VROT		
Reptiles						
Chelodina expansa	broad-shelled tortoise				x	
Chelodina longicollis	common long-necked tortoise			DD	x	
Christinus marmoratus	marbled gecko				x	x
Cryptoblepharus carnabyi	carnaby's wall skink				x	x
Diplodactylus tessellatus	tessellated gecko				x	
Egernia striolata	tree skink				x	
Lerista punctatovittata	spotted burrowing skink				x	x
Menetia greyii	grey's skink				x	
Morethia boulengeri	boulenger's skink				x	x
Pogona barbata	eastern bearded dragon			V	x	
Pseudonoja testilis	eastern brown snake				x	x
Ramphotyphlops bicolor	west australian blind snake				x	
Suta suta	curl snake			V	x	
Tiliqua rugosa	stumpy-tailed lizard					x
Varanus gouldii	sand goanna				x	
Varanus varius	lace monitor			E	x	
Amphibians						
Crinia parasignifera	plains froglet				x	x
Crinia signifera	common froglet				x	x
Limnodynastes dumerilii	southern bullfrog				x	x
Limnodynastes fletcheri	barking marsh frog				x	x
Limnodynastes tasmaniensis	spotted marsh frog				x	x
Litoria peronii	peron's tree frog				x	x

FORMAL CONSERVATION AGREEMENTS

Burra North lies entirely on public land within River Murray Reserve. The reserve is managed for conservation and sustainable recreational use.

VITAL HABITAT AT THE SITE

Burra North is one of the best-preserved examples of floodplain woodland and shrubland habitat in this reach of the River Murray. The site has an intact and diverse plant community which provides habitat complexity for woodland fauna in grasses and sub-shrubs, lignum and rough-barked and hollow-bearing trees. The quality of habitat supports a diverse fauna of woodland mammals, birds and reptiles.

6.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVE

The overall objective of water management at Burra North is:

"to restore the key species, habitat components and functions of the Burra North ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- restoring seasonal aquatic habitat to Burra Creek
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements of the Burra North floodplain. Three water regime classes have been identified at Burra North (Table 7). The following describes their ecology and water requirements.

Table 78. Burra North Water Regime Classes

Water Regime Class	Area (ha)	Ecological Vegetation Class
Seasonal Anabranch and Billabongs	100	Waterbody - Fresh Floodway Pond Herbland
Lignum Shrubland and Woodland	687	Lignum Shrubland Lignum Swamp Lignum Swampy Woodland
Black Box and Red Gum Woodland	417	Riverine Chenopod Woodland Shrubby Riverine Woodland Riverine Grassy Woodland Grassy Riverine Forest Grassy Riverine Forest / Floodway Pond Herbland Complex
(Plains Woodland and Forest)* *Not flood-dependent	11	Semi-arid Chenopod Woodland Semi-arid Woodland
(Mallee)* *Not flood-dependent	1.4	Chenopod Mallee Woorinen Mallee

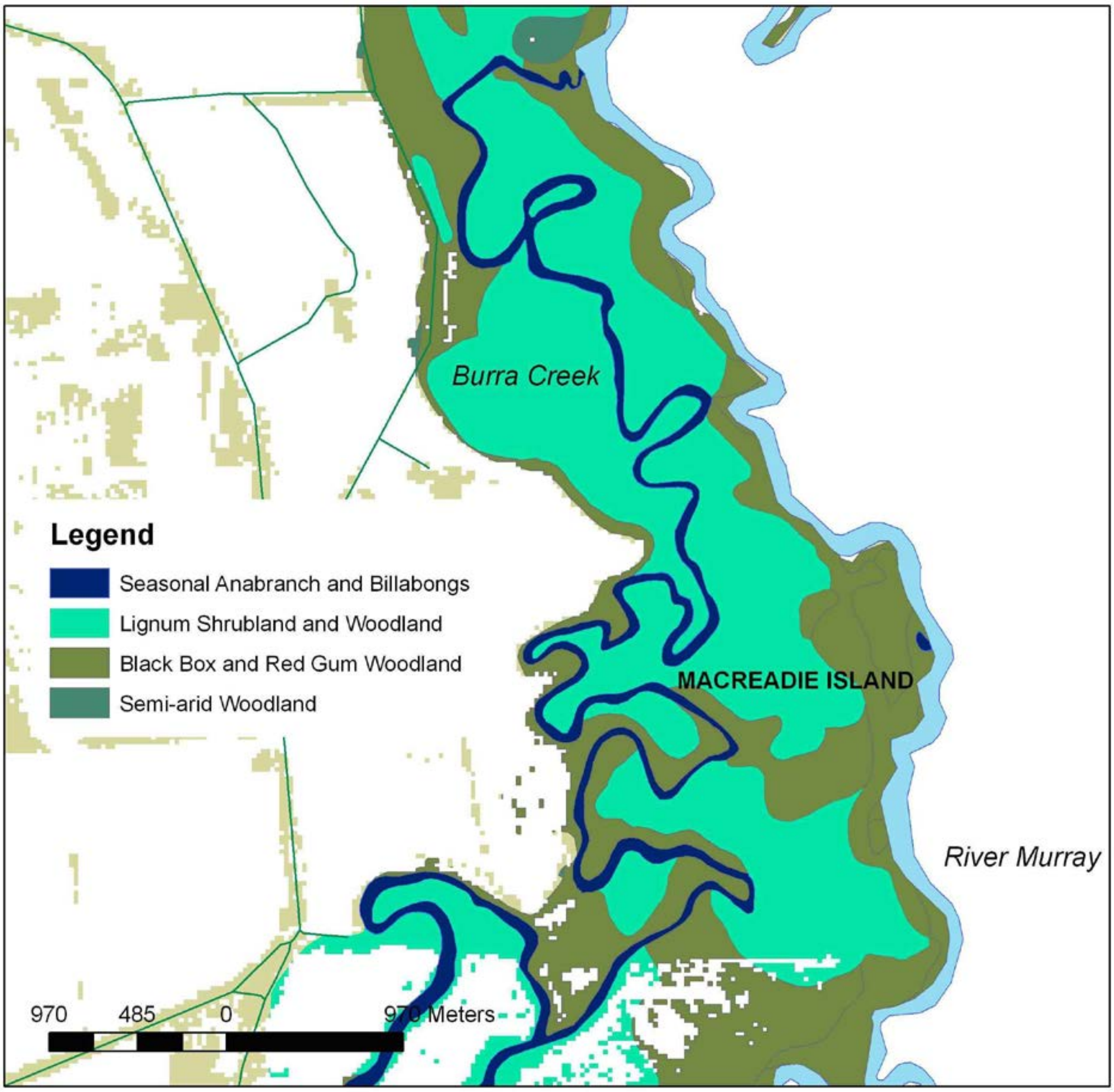


Figure 22. Burra North Water Regime Classes

SEASONAL ANABRANCH AND BILLABONGS

Ecology

Burra Creek is a deeply incised anabranch of the River Murray flowing over 54 km through the Burra Creek floodplain. Under natural conditions the creek flowed in most years for several months. Deep pools within the creek would have rarely dried out.

Originally the creek would have provided a continuous corridor of riparian vegetation. Semi-emergent macrophytes such as *Triglochin multifructum* and *Vallisneria americana* were present in the channel while emergent macrophytes such as *Bolboschoenus medianus* and *Phragmites australis* would have lined the banks under a canopy of red gum and black box.

Permanent pools would have supported resident populations of small-bodied native fish such as murray-darling rainbow fish while large-bodied fish such as murray cod would have accessed the channel during periods of seasonal high flow.

The creek provides a complimentary environment to surrounding floodplain woodland. Snakes, lizards and waterbirds would find prey in vegetation along the creek. Dense riparian vegetation provides shelter to several waterbird species and provides seasonal forage for large herbivores such as western grey kangaroo and black wallaby.

Water Requirements

Under natural conditions, high river levels created sustained and almost annual flow in Burra Creek during winter and spring. Artificial blockages have raised the flow threshold from 20,000 ML/d to over 30,000 ML/d so that through-flow now occurs with a frequency of 1 in 10 years and with a median duration of less than one month.

The condition of flood-dependent vegetation along the creek is poor. Large red gum and black box trees are in poor health from lack of flooding. Riparian and aquatic macrophytes are largely absent and aquatic fauna such as fish, frogs and tortoise are rarely present.

Seasonal aquatic habitat may be restored to the lower section of Burra Creek by providing flooding of 1 to 3 months duration 9 years in 10, between July and November. This will promote the growth of in-stream and riparian aquatic macrophytes. If deep pools are present, a resident population of small-bodied native fish will establish, migrating between pools and the River Murray when water levels are high in spring.

Table 79. Water management objectives to restore seasonal anabranch

Objectives Addressed	Restore seasonal aquatic habitat to Burra Creek
Strategy	Remove blockages in the Burra North section of Burra Creek Regulate the channel to capture peaks in flow or to store pumped water
Hydrological Targets	Inundate Burra Creek 9 years in 10 for a median duration of 2 months

LIGNUM SHRUBLAND AND WOODLAND

Ecology

The majority of Burra North is vegetated by lignum shrubland and woodland. This community occupies the central floodplain area between the natural river levee to the east and the terrestrial landscape to the west.

Lignum shrublands at Burra North are rarely flooded and experience long dry periods between inundation events. When flooded the shrubs grow quickly and form dense, continuous thickets. Other large shrubby species such as *Chenopodium nitrariaceum* and *Eragrostis australasica* can co-occur with lignum. The ground layer supports a range of wetland herbs. When flooding is less frequent the shrubs are smaller and more widely spaced allowing the groundlayer vegetation to become more dense and diverse, supporting shrubs, grasses and herbs including *Dysphyma crassifolium, Atriplex leptocarpa, A. lindleyi, Sclerolaena tricuspis* and *Austrodanthonia* sp.

Inundation of lignum shrubland represents an extension of the habitat for aquatic floodplain fauna such as fish, reptiles and frogs. Their bushy structure and debris provides a productive substrate for epiphytes that supports high macroinvertebrate productivity and also provides shelter from predators. Floodwater draining from lignum will carry dissolved and particulate carbon as well as algae and invertebrates which will contribute to the food web of the river channel.

Between flood events, lignum is an important habitat for terrestrial vertebrate fauna including snakes and lizards.

Water Requirements

Flows over 30,000 ML/d inundate the lignum shrubland and woodland at Burra North. These events occur approximately 1 year in 10 with a median duration of 20 days. The frequency and duration of these flow events has not been significantly affected by river regulation.

Table 80. Water management objectives for lignum shrubland and woodland

Objectives Addressed	Restore floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	Maintain the existing flooding regime of 1 event every 10 years with a median duration of 20 days

BLACK BOX AND RED GUM WOODLAND

Ecology

Black box and red gum woodland is present on high ground along the river levee and near the terrestrial boundary of the floodplain. The canopy is open and the community has a diverse, shrubby understorey that includes lignum, *Chenopodium nitrariaceum, Rhagodia spinescens* and *Enchylaena tomentosa*. The ground layer comprises low shrubs, herbs and a range of terrestrial grasses.

Tree recruitment and the productivity of the vegetation is strongly linked to flooding. Flooding maintains a diverse tree age structure and a complex understorey plant community that is required by carpet python and other vertebrate fauna. The diversity of birds is particularly high because black box woodland contributes to the habitat requirements of both riverine and dryland species. Black box woodland supports a high proportion of ground foragers and hollow-nesting species. Black box woodlands are important for canopy feeding bush birds such as superb fairy-wren, little friarbird and blue-faced Honeyeater. Black box woodland also supports seasonal migrants normally associated with higher rainfall areas such as grey fantail and white-bellied cuckoo-shrike. Black box is an important habitat component for insectivorous bats.

Flood events that inundate black box woodland contribute to the carbon requirements of the River Murray. Receding flood water conveys organic debris to the river channel where it promotes macro-invertebrate productivity and maintains the riverine food web.

Water Requirements

Flows 30,000 to 35,000 ML/d inundate black box and red gum woodland at the edges of the floodplain. These events occur approximately 1 year in 10 with a median duration of 20 days. The frequency and duration of these flow events has not been significantly affected by river regulation.

Table 81. Water management objectives for black box and red gum woodland

Ecological Objective	Restore floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	Maintain the existing flooding regime of 1 event every 10 years with a median duration of 20 days

6.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Burra Creek Floodplain Management Project will

- restore seasonal flooding to the lower reach of Burra Creek
- improve the viability and resilience of terrestrial fauna populations on the floodplain including carpet python, lace monitor and bats
- supply organic matter to the River Murray channel ecosystem

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Burra Creek (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

Table 82. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Burra Creek project.

Ecological Class	Ecological Element	Burra Creek
Waterbirds	Bitterns, crakes and rails	
	General abundance and health - all waterbirds	
	Breeding - Colonial-nesting waterbirds	
	Breeding - other waterbirds	
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	
	Forests: river red gum (*Eucalyptus camaldulensis*)	
	Forests and woodland: black box (*Eucalyptus largiflorens*)	❶❶
	Shrublands	❶
	Tall grasslands, sedgelands and rushlands	
	Benthic herblands	
Fish	Short-lived / small-bodied fish	❶
	Long-lived / large-bodied fish	

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

The proposed Burra Creek supply measure addresses deficiences in the water regime of the northern section of Burra Creek and adjacent lignum and black box floodplain vegetation. When flooded the creek would provide seasonal aquatic habitat for small fish. Flooding of the adjacent floodplain will improve vegetation health and productivity but will generally be too brief to contribute to the habitat requirements of waterbirds or aquatic fauna.

6.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

Burra Creek diverges from the River Murray downstream of Piangil at 1320 river km and rejoins the river at 1296 river km. The area between the creek and the River Murray forms Macreadie Island.

The southern part of the island is largely freehold and has been developed for agriculture. The creek is Crown Land (proposed Murray River Park) but has been modified at several locations. Banks are used to provide road crossings and to store water for irrigation. The road culverts generally have a small capacity and impede the flow of water. Levee banks at some locations confine water in the creek and reduce floodplain inundation.

In the Burra North the floodplain is protected in the River Murray Reserve and is largely unmodified. However blockages are present in Burra Creek.

Under natural conditions water would have first entered the Burra Creek at the downstream river connection when River Murray discharge exceeded about 17,500 ML/d (pers. comm. Malcolm Thompson Mallee CMA 14/8/14) (Jacobs 2014).

At flows exceeding 27,500 ML/d water spills into low-lying floodplain areas from Burra Creek and from River Murray effluents. These areas are mainly vegetated by Lignum Swamp.

Very high flows of 30,000 ML/d inundate additional low-lying areas including black box and lignum vegetation.

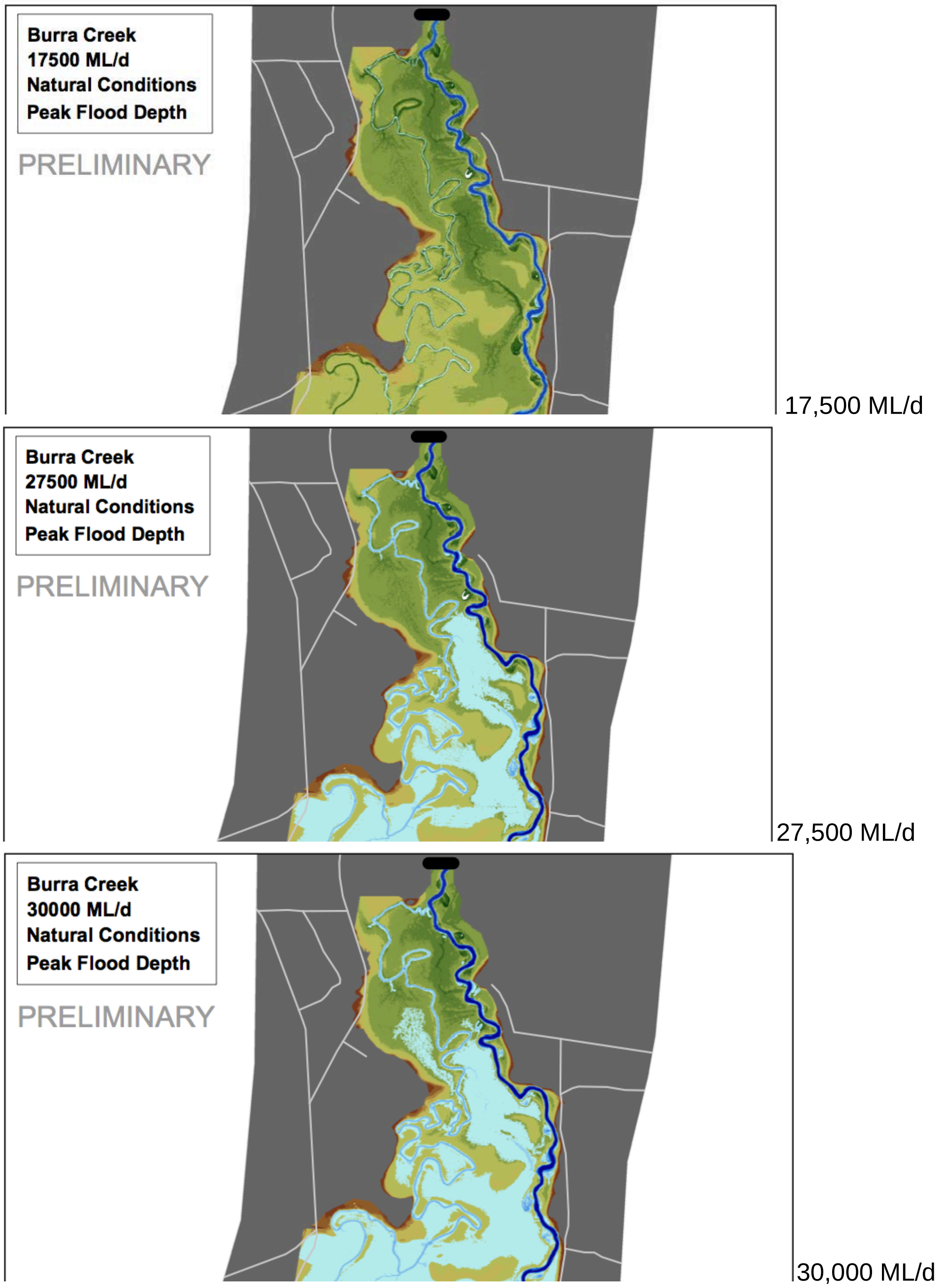


Figure 23. Burra North floodplain inundation at flows of 17,500, 27,500 and 30,000 ML/d (Jacobs 2014).

HYDROLOGY

The hydrology of the River Murray at Swan Hill was analysed under natural and current conditions by Ecological Associates (2006).

Median monthly and 90th percentile flows have declined substantially under current conditions with the greatest impacts in the high flow months from June to January (Figure 24). The impacts on median flows in autumn are relatively minor. However a reduction on high flow events in summer and autumn is illustrated by the 90th percentile flows.

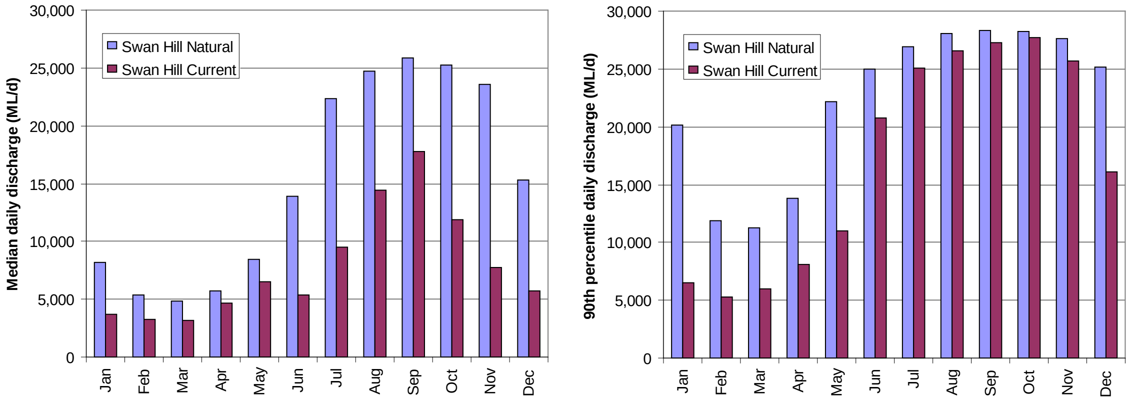


Figure 24. Distribution of median flows (left) and 90th percentile flows (right) for each month in the River Murray for natural and current (benchmark) conditions. Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006).

The natural hydrology of the river at Burra Creek is characterised by frequent and sustained flow events. Flow was initiated by river levels exceeding 17,500 ML/d and occurred with a frequency of more than 130 events every 100 years. The median duration of these events was approximately three months. The current threshold to create through-flow of 22,500 ML/d occurs 7 years in 10 with a median duration of approximately than 40 days (Figure 25).

To inundate the floodplain in Burra North river discharge must exceed 27,500 ML/d. The frequency of these events has halved from 50 to 25 events in 100 years. However the duration is relatively unimpacted having declined from approximately 30 days to 25 days median event duration.

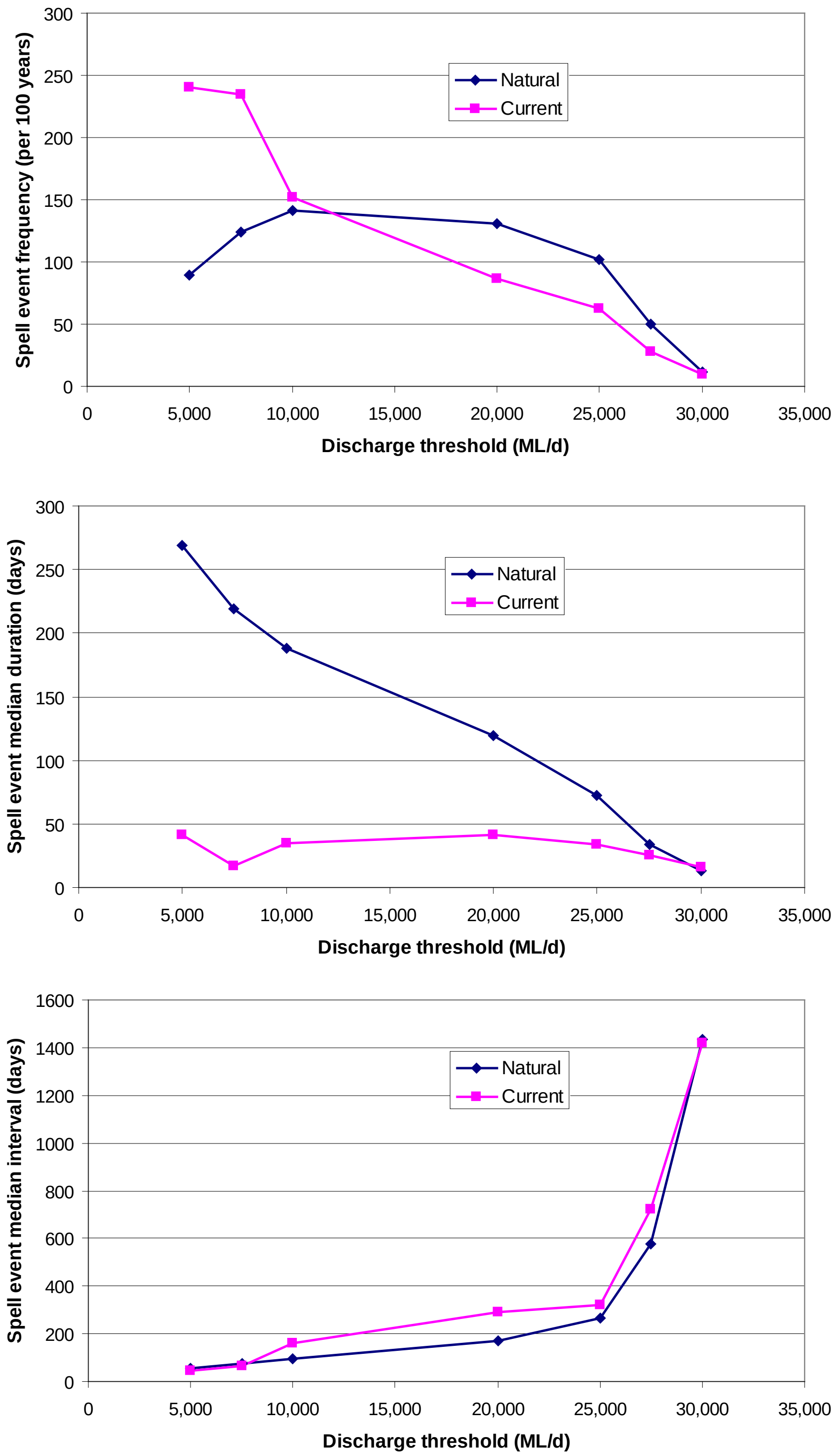


Figure 25. Spell event frequency, median duration and median interval for natural and current conditions (Swan Hill gauge). Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006)

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

The proposed works inundate the three water regime classes in Burra North (Table 83, Figure 26).

Table 83. Area of inundation from proposed works at Burra North

Water Regime Class	Area (ha)
Seasonal Anabranch and Billabongs	55
Lignum Shrubland and Woodland	221
Black Box and Red Gum Woodland	52

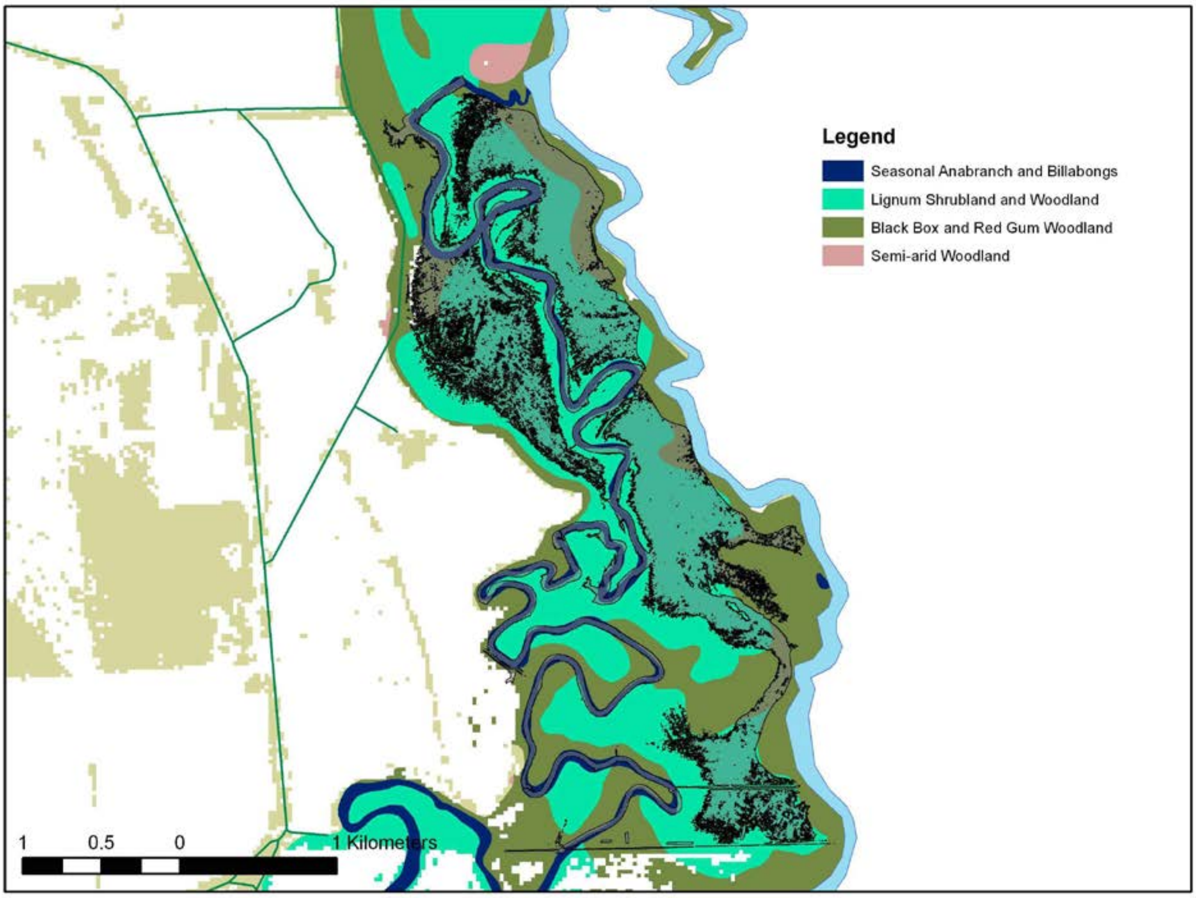


Figure 26. Inundation of water regime classes in Burra North from the proposed works

DESIGN

It is proposed to meet targets for flood duration and frequency by removing barriers to flow and using new structures to detain water on the floodplain.

Two barriers in Burra Creek will be removed to allow the Burra North section of the channel to completely fill with water when River Murray flows exceed 20,000 ML/d.

To promote floodplain inundation, a regulator will be constructed on the creek near the junction with the River Murray to control outflows. Existing tracks will be raised and to enclose the flooded area up to a level of 58.7 m AHD. The works will promote flooding over an area of 325 ha.

OPERATION

The Burra North Floodplain Management Project will be operated to augment the frequency and duration of floodplain inundation to meet environmental targets.

The structures will be operated to achieve environmental watering targets under three scenarios.

- Under normal flow conditions (when no environmental watering is occurring) regulator on Burra Creek will be open.
- When a flow peak is anticipated, the regulator will remain open to allow floodwater to enter and to allow movement of aquatic fauna between the river and floodplain. As river levels fall, the regulators will be closed to store flood water. The level at which water is stored will depend on the ecological objectives of the event. When the hydrological targets of the watering event are met, water will be released back to the river.
- If peaks in river flow are too infrequent to meet environmental watering targets, part or all of the system may be flooded by temporary pumps installed on the river bank.

Table 84. Environmental water requirements

Threshold	Hydrological Targets	Ecological Objectives
20,000 ML/d	Inundate Burra Creek 9 years in 10 for a median duration of 2 months	Restore seasonal aquatic habitat to Burra Creek
30,000 ML/d	Maintain the existing flooding regime of 1 event every 10 years with a median duration of 20 days	Restore floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor Contribute to the carbon requirements of the River Murray channel ecosystem
35,000 ML/d	Maintain the existing flooding regime of 1 event every 10 years with a median duration of 20 days	Restore floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor Contribute to the carbon requirements of the River Murray channel ecosystem

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

Table 85. Burra North specific ecological targets

Objective	Target
Restore seasonal aquatic habitat to Burra Creek	At least two frog species and two vegetation-dependent fish species are present in Burra Creek in spring annually between 2025 and 2035.
Restore floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor	All red gum and black box stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035. The total abundance of bats in Burra North increases by 25% from 2015 levels by 2030.
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Burra North for the period 2025 to 2035 is double 2015 to 2020 levels.

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al.

1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray(Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

7 NYAH FLOODPLAIN MANAGEMENT PROJECT

7.1 PROJECT DETAILS

The Nyah Floodplain Management Project is a Supply Measure project located in Nyah Park on the River Murray floodplain, 30 km north of Swan Hill in northwest Victoria. The project is located entirely within Crown Land.

The Nyah floodplain is located on the left (west) bank of the River Murray between 1341 and 1356 river km. The floodplain includes wetland, forest and woodland areas and the Parnee Malloo anabranch.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over the floodplain. The project inundates up to 476 ha of intact floodplain habitat.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

Figure 27. Location of the Nyah Floodplain Management Project

7.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

The Nyah floodplain lies within the proposed Nyah Park, which was formerly a state forest. Reclassification of the site was recommended by the Victorian Environmental Assessment Council in recognition of its conservation values and its outstanding range and concentration of Aboriginal cultural heritage sites (VEAC 2008).

The Nyah floodplain forms an elongate basin aligned parallel to the River Murray. The basin is bounded by the terrestrial landscape to the west and the natural levee of the River Murray to the east. The basin is drained by a central watercourse, Parnee Malloo Creek, into which River Murray water backs at moderate river flows. At higher river flows the upstream connection of the creek becomes active and through-flow commences. The floodplain has an area of 907 ha.

Lying near the western limit of the Murray Fans bioregion, the floodplain is one of the most downstream areas of the central river red gum forests which include Barmah-Millewa, Gunbower-Koondrook-Perricoota, Werai, Campbell Island, Guttrum and Benwell. These communities provide complex physical habitat and are highly productive. Several fauna species common in this bioregion are at the downstream limit of their range at Nyah, including sugar glider and black wallaby. The forests support breeding by colonial nesting waterbirds and provide habitat for woodland fauna that require dense and productive understorey.

Regent parrot nest at Nyah. These birds feed in nearby mallee woodland and depend on large, healthy river red gum near the River Murray to provide nesting hollows. Other parrot species that also feed in the mallee but depend on tree hollows on the floodplain include major mitchell cockatoo, scarlet-chested parrot and elegant parrot.

Nyah Park supports an important population of grey-crowned babbler. These birds depend on large, rough-barked trees in a forest community with a complex understorey of shrubs and timber. Flooding maintains the productivity of the ecosystem, including the insect fauna on which grey-crowned babbler depend.

The floodplain includes wetlands in floodplain depressions adjacent to Parnee Malloo Creek. Under a natural flow regime, these wetlands would have been flooded almost annually and frequently remained flooded throughout the year. Persistent annual flooding would have excluded trees and supported a community of marshland plants including spiny mudgrass. Growling grass frog, murray-darling rainbow fish and other aquatic species that depend on permanent aquatic habitat would have expanded from these refuges into the forest understorey during spring floods.

WATER DEPENDENT FLORA AND FAUNA

FLORA

Nyah Park is located in a floodplain area of high plant diversity. The Victorian Flora Information System indicates 394 vascular flora species have been recorded in the vicinity of Nyah Park, of which 277 are indigenous (Cook 2012). The database together with recent field surveys (Cook 2012)(GHD 2013) report 15 rare or threatened floodplain species in or close to Nyah Park (Table 1).

The vegetation of Nyah Park is dominated by river red gum forest. The central basin of the floodplain has a dense overstorey and very sparse ground layer. Near Parnee Malloo Creek, where the canopy is more open, aquatic macrophytes are present, including *Ludwigia peploides, Eleocharis acuta and Marsilea drummondii.* Higher ground along the river levee has a shrubby understorey that includes pale-fruit ballart. On the western side of forest, near the boundary of the floodplain, the understorey becomes more terrestrial and includes a greater proportion of grasses and chenopods.

Table 86. Plant species of conservation significance reported from Nyah forest systems (Cook 2012)(GHD 2013).

Scientific Name	Common Name	Conservation Status			2012 and 2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Asperula gemella	twin-leaf bedstraw			R		
Cardamine moirensis	riverina bitter-cress			R	x	x
Cuscuta australis	australian dodder			K	x	x
Cynodon dactylon var. pulchellus	native couch			V		x
Cyperus pygmaeus	dwarf flat-sedge			V		x
Dianella porracea	riverine flax-lily			V	x	x
Glossostigma drummondii	desert mud-mat			K	x	
Haegiela tatei	small nut-heads			V		x
Nymphoides crenata	wavy marshwort		L	V		x
Ranunculus pumilio var. politus	ferny small-flower buttercup			K		x
Ranunculus undosus	swamp buttercup			V		x
Rutidosis helichrysoides	grey wrinklewort			E		x
Senecio campylocarpus	floodplain fireweed			R	x	
Senecio cunninghamii var. cunninghamii	branching groundsel			R	x	x
Templetonia rossii	flat templetonia			V		x

In Victoria, vegetation mapping units, known as Ecological Vegetation Classes, are assigned conservation ratings within each bioregion (Table 2). Of the nine EVCs present at Nyah Park seven are considered depleted in the Murray Fans bioregion and two, Spike-sedge Wetlands and Grassy Riverine Woodland are considered Vulnerable.

Table 87. Conservation status of Nyah Ecological Vegetation Classes in the Murray Fans Bioregion

Ecological Vegetation Class	Bioregional Conservation Status
106 Grassy Riverine Forest	Depleted
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
812 Grassy Riverine Forest / Riverine Swamp Forest Complex	Depleted
814 Riverine Swamp Forest	Depleted
816 Sedgy Riverine Forest	Depleted
817 Sedgy Riverine Forest / Riverine Swamp Forest Complex	Depleted
819 Spike-sedge Wetlands	Vulnerable
103 Riverine Chenopod Woodland	Endangered
295 Riverine Grassy Woodland	Vulnerable

FAUNA

Ten native fish species are encountered regularly in the River Murray near Nyah Park and would be expected to occur on the floodplain. Wetlands and flooded forest provide habitat for a range of small fish that benefit from submerged aquatic vegetation, woody debris and plant, biofilm and invertebrate food sources (Table 3). The restoration of wetland habitat would potentially support resident populations include murray-darling rainbowfish, carp gudgeon, flathead gudgeon and australian smelt. Freshwater catfish may use both wetland and creek habitat. Seasonal fast-flowing habitat in Parnee Malloo Creek will provide habitat for large-bodied channel specialists, specifically murray cod, golden perch and silver perch.

Table 88. Native fish species expected to occur at Nyah Park (Davies, et al. 2008)

Scientific name	Common Name	Conservation Status		
		EPBC	FFG	VROTS
Bidyanus bidyanus	silver perch		L	V
Craterocephalus stercusmuscarum fulvus	fly-specked hardyhead			
Hypseleotris klunzingeri	carp gudgeon			
Maccullochella peelii peelii	murray cod	V	L	V
Macquaria ambigua	golden perch		I	NT
Melanotaenia fluviatilis	murray-darling rainbowfish		L	V
Nematalosa erebi	bony herring			
Phylipnodon grandiceps	flathead gudgeon			
Retropinna semoni	australian smelt			
Tandanus tandanus	freshwater catfish		L	E

River murray crayfish (*Euastacus armatus*), is a detritivore favoured by the relatively cool temperatures and high oxygen levels of fast-flowing watercourses (McCarthy 2005). This species is listed under the FFG Act (Vic) and is present in the River Murray in the vicinity of Nyah Park. The restoration of wetland and fast-flowing habitat would support this species on the floodplain.

Nyah Park has a diverse bird fauna with over 140 bird species reported from the site and the local vicinity. Of these, 20 have conservation significance in Victoria or under the EPBC Act (Table 4). Two birds subject to migratory bird agreements have been reported from Nyah.

An important population of grey-crowned babbler is present at Nyah. These birds are insectivores that build stick nests in saplings, shrubs and the lower canopy of trees. Their favoured habitat is black box and red gum woodland where they forage partly on the ground and partly on the trunks and branches of trees and shrubs.

The floodplain provides breeding habitat for regent parrot, which nests in red gum trees near the River Murray.

Wetlands provide habitat for dabbling, diving and filter feeding ducks while fish provide prey for waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Semi-permanent wetlands, such as Green Swamp in Nyah Park, that are surrounded by frequently flooded red gum forest provide breeding habitat for colonial nesting waterbirds.

Other woodland birds of conservation significance include the granivorous diamond firetail, insectivorous hooded robin and frugivorous emu.

Table 89. Birds of conservation significance expected to occur at Nyah Park (Brown, Bryant and Horrocks 2013)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements		2013 Survey	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Anas rhynchotis	australasian shoveler			V				x
Ardea modesta	eastern great egret			V		C J		x
Aythya australis	hardhead			V				x
Biziura lobata	musk duck			V				x
Cacatua leadbeateri	major mitchell's cockatoo		L	V			x	x
Circus assimilis	spotted harrier			NT				x
Climacteris picumnus	brown treecreeper			NT				x
Dromaius novaehollandiae	emu			NT				x
Egretta garzetta	little egret		L	E				x
Geopelia cuneata	diamond dove		L	NT				x
Haliaeetus (Pontoaetus) leucogaster	white-bellied sea-eagle		L	V		C	x	x
Melanodryas (Melanodryas) cucullata	hooded robin		L	NT				x
Nycticorax caledonicus	nankeen night heron			NT			x	x
Phalacrocorax (Phalacrocorax) varius	pied cormorant			NT				x
Platalea regia	royal spoonbill			NT				x
Polytelis anthopeplus	regent parrot	Vul	L	V				x
Pomatostomus temporalis	grey-crowned babbler		L	E				x
Stagonopleura guttata	diamond firetail		L	NT				x
Sterna nilotica	gull-billed tern		L	E				x
Turnix (Alphaturnia) velox	little button-quail			NT				x

Nyah Forest has a diverse bat fauna with ten species reported from the site. One of the species, yellow-bellied sheathtailed bat, is listed under the Victorian FFG Act (Table 5). The bats are largely insectivorous and depend on high levels of forest productivity to provide prey. They roost in the crevices and hollows of *Eucalyptus camaldulensis* and *E. largiflorens* trees.

Water rat is present at Nyah Park. It is a rodent that inhabits watercourses and wetlands. It has a largely carnivorous diet mostly comprised of aquatic insects. Birds, mammals, frogs, reptiles, mussels, spiders and plants are occasionally taken. Plants are an important part of the diet in winter and when food is scarce.

Black wallaby is present. This species prefers thick the forest undergrowth that is often found near wetlands and forest watercourses. It feeds on native shrubs, sedges, rushes, grasses and ferns. Typically patches of dense vegetation provide refuges during the day from which swamp wallabies emerge at dusk to feed on more open vegetation and grassland.

Table 90. Native mammal species reported from Nyah Park (Brown, Bryant and Horrocks 2013)

Scientific Name	Species	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Acrobates pygmaeus	Feathertail glider					x
Chalinolobus gouldi	Gould's wattled bat				x	x
Chalinolobus morio	Chocolate wattled bat				x	x
Hydromus chrysogaster	Water rat				x	
Macropus fuliginosus	Western grey kangaroo					x
Macropus giganteus	Eastern grey kangaroo				x	x
Mormopterus sp. 2	Eastern freetail bat				x	x
Mormopterus sp. 4	Southern freetail bat				x	x
Nyctophilus geoffroyi	Lesser long-eared bat					x
Nyctophilus gouldi	Gould's long-eared bat					x
Ornithorhynchus anatinus	Platypus					x
Petaurus breviceps	Sugar glider					x
Phascolarctos cinereus	Koala					x
Saccolaimus flaviventris	Yellow-bellied sheathtailed bat		L	DD	x	
Scotorepens balstoni	Inland broad-nosed bat					x
Scotorepens greyii	Little broad-nosed bat					x
Tachyglosssus aculeatus	Short-beaked echidna				x	x
Tadarida australis	White-striped freetail bat					
Trichosurus vulpecula	Common brushtail possum				x	x
Vespadelus darlingtoni	Large forest bat				x	x
Vespadelus regulus	Southern forest bat				x	x
Vespadelus vulturnus	Little forest bat				x	x
Wallabia bicolor	Black wallaby				x	x

Nyah Park supports the threatened reptiles carpet python and lace monitor. High levels of forest productivity are required to provide the birds, frogs, rabbits and other small vertebrate prey on which these predators depend. Refuge habitat is provided by tree hollows and logs on the forest floor.

Table 91. Reptiles and amphibians reported from Nyah Park (Brown, Bryant and Horrocks 2013)

Scientific Name	Species	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chelodina expansa	Broad-shelled tortoise					x
Chelodina longicollis	Common long-necked tortoise			DD	x	x
Christinus marmoratus	Marbled gecko				x	x
Crinia parasignifera	Plains frotlet				x	
Crinia signifera	Common froglet				x	
Cryptoblepharus carnabyi	Carnaby's wall skink				x	x
Delma inornata	Olive legless lizard					x
Diplodactylus tessellatus	Tessellated gecko					x
Egernia striolata	Tree skink					x
Lampropholis guichenoti	Garden skink				x	
Lerista punctatovittata	Spotted burrowing skink					x
Limnodynastes dumerilii	Southern bullfrog				x	
Limnodynastes fletcheri	Barking marsh frog					x
Limnodynastes tasmaniensis	Spotted marsh frog				x	
Litoria peronii	Peron's tree frog				x	
Menetia greyii	Grey's skink				x	x
Morelia spilota metcalfei	Carpet python		L	E	x	x
Morethia boulengeri	Boulenger's skink				x	x
Pogona barbata	Eastern bearded dragon			V		x
Pseudonaja textilis	Eastern brown snake				x	
Ramphotyphlops bicolor	West australian blind slnake					x
Suta suta	Curl snake					x
Tiliqua rugosa	Stumpy-tailed lizard					x
Varanus gouldii	Sand goanna					x
Varanus varius	Lace monitor			E	x	

FORMAL CONSERVATION AGREEMENTS

The Nyah project area lies entirely on public land within the proposed Nyah Park. It is a former forestry reserve that is now managed to protect conservation and aboriginal heritage values.

Nyah Park is an important cultural site for the Wadi Wadi Aboriginal people and there are numerous burial sites, earth ovens middens and scarred trees. The earthen ovens and middens are listed under the National Estate (VEAC 2008).

VITAL HABITAT AT THE SITE

Nyah Forest supports important populations of grey-crowned babbler, regent parrot and carpet python. It supports a diverse bat fauna of ten species, which includes the FFG listed yellow-bellied sheathtailed bat.

Nyah is a low-lying floodplain area that is reliably inundated in spring by elevated river flows. Under a restored water regime, the wetland and flooded forest areas would provide reliable refuge and breeding habitat for aquatic fauna and waterbirds.

7.3 ECOLOGICAL OBJECTIVES

GOAL

The overall objective of water management at Nyah Park is:

"to restore the key species, habitat components and functions of the Nyah Park ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- restoring the vegetation structure of wetland plant communities
- re-establishing resident populations of frogs and small fish
- providing seasonal feeding and reproductive opportunities for riverine fish species
- providing reliable breeding habitat for waterbirds, including colonial nesting species
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements of the Nyah Park floodplain. Four water regime classes have been identified at Nyah Park (Table 7). The following describes their ecology and water requirements.

A fifth water regime class, Black Box Woodland, occurs at high elevations at the perimeter of the floodplain and is outside the scope of the proposed works.

Table 92. Nyah Park Water Regime Classes

Water Regime Class	Area (ha)	Origin of Data
Seasonal Anabranch	58	Parnee Malloo Creek mapped by Murray Wetlands Working Group "Wetlands54"
Seasonal Wetland	45	819 Spike-sedge Wetlands 810 Floodway Pond Herbland
Red Gum Swamp Forest	168	814 Riverine Swamp Forest
Red Gum Forest and Woodland	576	106 Grassy Riverine Forest 811 Grassy Riverine Forest / Floodway Pond Herbland Complex 812 Grassy Riverine Forest / Riverine Swamp Forest Complex 816 Sedgy Riverine Forest 817 Sedgy Riverine Forest / Riverine Swamp Forest Complex
(Black Box Woodland)	64	103 Riverine Chenopod Woodland 295 Riverine Grassy Woodland

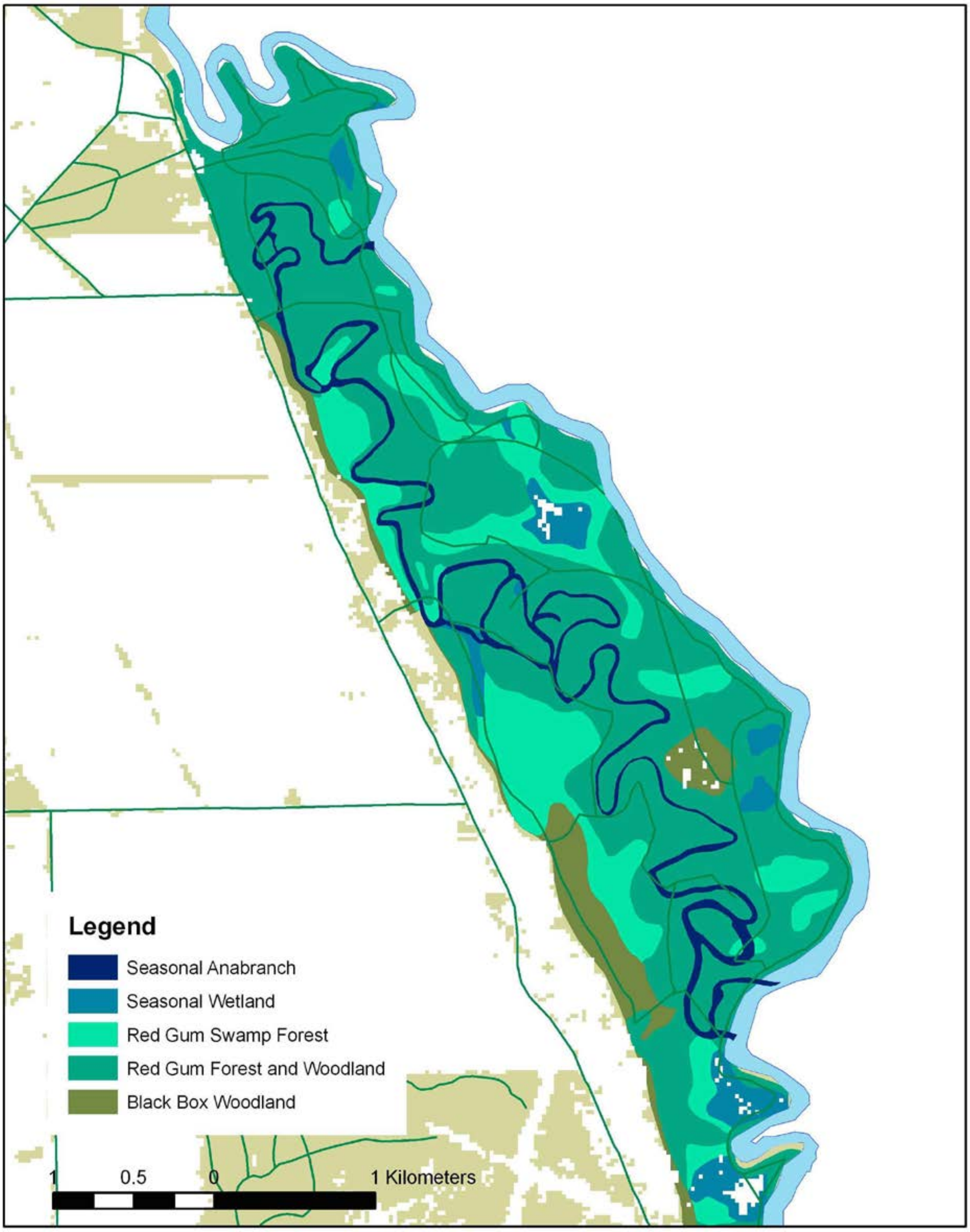


Figure 28. Nyah Park Water Regime Classes

SEASONAL ANABRANCH

Ecology

Parnee Malloo Creek is a seasonal anabranch of the River Murray flowing over 16 km through the Nyah floodplain. Water backs into the creek from the downstream end during small peaks in river flow. Larger flows, exceeding 15,000 ML/d introduce water to the channel from upstream and create a fast-flowing habitat.

High water velocities and sustained inundation keep the channel largely clear of aquatic macrophytes and trees. The channel is fringed by emergent macrophytes such as *Eleocharis acuta* and *Cyperus gymnocaulos* that benefit from seasonal waterlogging and shading. Red gum forms a closed overstorey along the edge of the watercourse. At the upstream end, where the channel is more incised and the banks are flooded less frequently, the understorey includes *Exocarpus strictus* and *Acacia stenophylla* (White, et al. 2003).

The creek provides an alternative, fast-flowing habitat to the main channel of the River Murray. Under natural conditions the creek would have flowed in winter through to summer in most years. The creek would have provided habitat to large channel-dependent fish species such as murray cod, silver perch and golden perch during their spawning seasons. It would have supported aquatic species that depend on fast flowing water such as murray crayfish. These fauna could move between wetland, anabranch and main channel habitats which were connected by Parnee Malloo Creek. Water rat, which occurs at Nyah, would have been present in the creek.

Water Requirements

Parnee Malloo Creek has been degraded by changes to the river flow regime. Under natural conditions events that would inundate the creek and activate through-flow (12,500 ML/d) had a median duration of more than 5 months and occurred almost every year. Under current flow conditions in the River Murray, these events remain frequent but now have a median duration of 6 weeks.

To meet the water requirements of channel specialist fish species and murray crayfish, flowing habitat should be provided in between later winter and early summer (July to December) with the highest priority period from October to November. These flows will also promote flow-tolerant aquatic plants such as *Triglochin procerum* and help exclude river red gum from the channel. To maintain local populations and successful recruitment of juvenile fauna, these flows should be provided in eight out of ten years.

Table 93. Water management objectives to restore seasonal anabranch habitat

Objectives Addressed	Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities
Strategy	Increase through-flow in Parnee Malloo Creek by increasing River Murray flow in spring and early summer
Hydrological Targets	Seasonal flow in Parnee Malloo Creek for 4 to 6 months annually

Complementary works are required to restore flowing habitat. A large bank constructed across the creek near the downstream end has been used to store water and requires the river to reach high flows before water can flow effectively through the creek. A road crossing near the downstream river connection conveys low flows through a small pipe culvert which impedes the movement of fish. These structures should be removed.

SEASONAL WETLANDS

Ecology

The Nyah floodplain features broad wetland depressions that retain water to a depth of 1 m or more on the flood recession. While shallow, the wetlands experienced persistent and frequent flooding under natural flow conditions and frequently remained flooded throughout the year. The largest wetland is Green Swamp.

Frequent and persistent flooding promotes an emergent sedgeland dominated by *Eleocharis acuta* and excludes *Eucalyptus camaldulensis* trees. The wetlands would support a range of species adapted to variable water levels including *Myriophyllum crispatum, Ottelia ovalifolia* ssp. *ovalifolia, Azolla filiculoides, Ludwigia peploides* and *Callitriche* spp. As the wetlands dry out,(Young 2001) the herbs *Marsilea drummondii, Pratia concolor* and *Persicaria prostrata* will become more abundant (White, et al. 2003). Taller reedy vegetation, such as *Phragmites australis,* may be present at the wetland fringes.

Dense aquatic vegetation, algae and biofilms are a productive food source and provide physical habitat for zooplankton, macroinvertebrates and small fish such as gudgeon, smelt and hardyhead. Soft leaved vegetation and aquatic macro-invertebrates will provide food for dabbling and grazing ducks such as grey teal, pacific black duck and australian shelduck. The wetlands will provide reliable breeding habitat for waterfowl which build nests using reeds on scrapes in and around reedy vegetation. Reeds will provide terrestrial frogs with abundant aquatic invertebrates and flying insects, a substrate for eggs and shelter from predators. Wading birds such as royal spoonbill and intermediate egret will prey on invertebrates and small fish.

Seasonal inundation is important to wetland productivity. The plant matter that is exposed on the drying wetland bed in summer and autumn is readily mineralised when reflooded in winter. This supports a productive food web of algae and zooplankton and bacterial biofilms (Young 2001) which in turn provides prey for larger fauna including fish and waterbirds.

The wetlands are a refuge habitat for frogs such as southern bullfrog and spotted marsh frog. Reliable flooding in the wetlands maintains the population, which expands to flooded red gum understorey during floods.

Dense reedy vegetation near the wetlands provides shelter for black wallaby.

Water Requirements

Under natural conditions, high river levels provided sustained, almost annual, inflows to the shallow wetlands on the Nyah floodplain from winter to summer. Flooding persisted for four to eight months in most years and frequently lasted throughout the year.

Seasonal wetland habitat has been lost from Nyah Park through a reduction in the duration of spring flow peaks. High river levels now inundate wetlands only briefly, and have promoted the establishment of river red gum on former wetland beds. Flood duration is too short to support aquatic marshland vegetation and the understorey is now dominated by grasses and seasonal floodplain herbs. The decline in wetland habitat means the floodplain now only provides opportunistic habitat for aquatic fauna that recolonise the system when water is available. The encroachment by trees now excludes many waterbirds that rely on open water.

Seasonal wetland habitat may be restored to Nyah Park by providing flooding of 9 to 12 months duration in 90% of years, between winter and summer. This will provide regular breeding habitat for waterbirds and will support the seasonal requirements of aquatic wetland fauna including native fish. Water levels should fall over summer and autumn to promote macrophyte growth over broad areas of the wetland bed and to promote mineralisation of organic matter.

Table 94. Water management objectives to restore seasonal wetlands

Ecological Objective	Restore resident populations of frogs and small fish Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into wetlands if peaks in river flow are too infrequent
Hydrological Targets	Wetlands completely dry 1 year in 10 Wetland depth to exceed retention level of wetland 9 years in 10 - 6 of these events to last more than 9 months - 3 of these events to last more than 12 months Wetland depth to be less than 50% of retention level in May 5 years in 10

RED GUM SWAMP FOREST

Ecology

In low-lying areas, frequent and sustained inundation limits tree density to an open forest structure. The understorey comprises obligate wetland plant species which require regular spring and summer flooding. This stratum is dominated by *Eleocharis acuta* and *Triglochin multifructum* and includes also *Myriophyllum* spp. *Pseudoraphis spinescens, Ranunculus* spp. Prolonged seasonal flooding provides little opportunity for understorey plants to establish between flood events and the ground layer in late summer and autumn will be largely bare.

The swamp forest represents an extension of the seasonal wetland habitat with a similar understorey and similar habitat values for aquatic fauna.

Inundation of red gum forest and woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

Flooding events will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as little egret, white-necked heron, white-faced heron, great cormorant and little black cormorant. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

Water Requirements

Flows of 17,500 to 20,000 ML/d inundate the low-lying river red gum forest. Under natural conditions these flows occurred approximately 130 times every 100 years and lasted over 4 months. Frequent and sustained flooding limited the density of red gum trees, creating and open canopy with a diverse and productive ground layer of amphibious plants. Forest flooding provides an extension of aquatic habitat from the seasonal wetlands and Parnee Malloo Creek.

Red gum forest has been severely degraded at Nyah Park. Median flood duration has declined to less than 6 weeks. However flood frequency has remained high, which has led to higher tree density and increased shading of the understorey. Flood durations are too low to sustain perennial aquatic macrophytes and more drought-tolerant species are now more abundant. Flooding is generally too brief to contribute significantly to the breeding requirements of native fish or waterbirds.

The habitat values of red gum forest can be restored by increasing the duration of flooding events while maintaining a high flooding frequency. Flooding should commence in late winter or early spring and be sustained until summer. Longer events will contribute to the breeding requirements of waterbirds while shorter events will provide foraging habitat and breeding opportunities for resident aquatic fauna. A higher density of vegetation on the forest floor will contribute to the habitat requirements of terrestrial fauna. It will provide forage and shelter for swamp wallaby and a source of prey and physical habitat for carpet python. High levels of insect productivity will sustain local bat populations.

Table 95. Water management objectives to restore red gum swamp forest

Ecological Objective	Provide reliable breeding habitat for waterbirds, including colonial nesting species Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	For areas above an inundation threshold equivalent to 17,500 ML/d - provide flooding 9 times in 10 years - five of these events to be 5 months long - four of these events to be 7 months long

RED GUM FOREST AND WOODLAND

Ecology

The density of red gum trees increases outside of the swampy forest areas. The understorey is more sparse and has a broader mix of sedges and rushes that benefit from drier conditions over summer including *Carex tereticaulis, Bolboschoenus medianus, Phragmites australis* and *Eleocharis acuta*. During floods *Triglochin multifructum* is present. Following the flood recession a number of ground-layer species grow including the grasses *Paspalidium jubiflorum* and *Lachnagrostis filiformis* and a range of herbs including *Pratia concolor, Brachyscome basaltica, Brachyscome basaltica, Calotis* spp., *Wahlenbergia luminaries, Senecio quadridentatus* and *Euphorbia drummondii* (White, et al. 2003).

Red gum woodland is present on higher ground near the terrestrial boundary of the floodplain and on local rises within the forest. Red gum trees forms an open woodland canopy while the understorey is dominated by tussock grasses that respond to winter and spring rain but do not depend on flooding. The ground layer is grassy and dominated by *Austrodanthonia* spp. and *Austrostipa* spp. There is generally a sparse scattering of low shrubs frequently including *Einadia nutans, Atriplex semibaccata, Atriplex eardleyae, Sclerolaena muricate* var. *villosa, Enchylaena tomentosa, Maireana decalvans, Chenopodium curvispicatum* and *Salsola kali* (White, et al. 2003).

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for nesting wood duck, carpet python, bats and brush-tailed possum. Red gum growing close to water provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. Dense understorey vegetation provides habitat for grey-crowned babbler, swamp wallaby and carpet python.

The grassy understorey provides seeds and forage for granivores such as finches, cockatoos, galah, lorikeet and budgerigar, the frugivorous emu and large herbivores including western grey kangaroo and swamp wallaby. The trees directly support insectivorous and omnivorous birds such as honeyeaters and wattlebird. Both overstorey and understorey vegetation support insect production on which a wide range of insectivorous birds and bats depend.

Water Requirements

Flows 25,000 ML/d inundate red gum woodland at the edges of the floodplain. Under natural conditions these flows occurred approximately 100 years in 100 and lasted approximately six weeks. The duration of these flood events has halved to a median of 40 days and the freqency has declined to 60 events in 100 years.

While the overall health and integrity of red gum woodland at Nyah has been maintained, productivity has declined. The understorey vegetation growth has reduced, providing less physical habitat and contributing less to ecosystem carbon requirements. The food resources and structural habitat carpet python, swamp wallaby, grey-crowned babbler and other woodland species have reduced.

The ecological values of woodland can be restored by increasing the frequency of floods exceeding 25,000 ML/d to 8 events in 10 years. Providing events of 4 weeks duration will maintain woodland productivity while longer events of 12 weeks will provide breeding opportunities for fish and waterbirds. Flooding should take place in winter and spring to support tree and the growth of trees and understorey grasses and shrubs over late spring and summer.

Table 96. Water management objectives for red gum forest and woodland

Ecological Objective	Provide reliable breeding habitat for waterbirds, including colonial nesting species Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	For areas above an inundation threshold equivalent to 25,000 ML/d - provide flooding 8 times in 10 years - four of these events to be 6 weeks long - four of these events to be 12 weeks long

7.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Nyah Floodplain Management Project will

- provide reliable breeding habitat for waterfowl
- restore frequent breeding opportunities for colonial nesting waterbirds
- restore the productivity and structure of floodplain forest, increasing the viability of vertebrate fauna populations including carpet python, grey-crowned babbler and sugar glider
- supply organic matter to the River Murray channel ecosystem

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Nyah Park (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

The wetlands set within red gum forest at Nyah Park provide important habitat for aquatic fauna. The recommended flooding regime aims to restore open wetland habitat with emergent and submerged aquatic beds. These will provide habitat for small fish species and potentially significant colonial nesting waterbird breeding habitat. Other waterbird species are likely to use the site for feeding and breeding.

Inundation of the red gum forest will improve floodplain productivity and provide seasonal aquatic habitat for fish and waterbirds.

Parnee Malloo Creek would provide a refuge habitat for small-bodied fish species. When flowing, the channel will provide seasonal habitat for channel-specialist fish species.

Table 97. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Nyah Park project.

Ecological Class	Ecological Element	Nyah Park
Waterbirds	Bitterns, crakes and rails	❶❶
	General abundance and health - all waterbirds	❶❶
	Breeding - Colonial-nesting waterbirds	❶❶
	Breeding - other waterbirds	❶❶
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	❶
	Forests: river red gum (*Eucalyptus camaldulensis*)	❶❶
	Forests and woodland: black box (*Eucalyptus largiflorens*)	
	Shrublands	
	Tall grasslands, sedgelands and rushlands	❶❶
	Benthic herblands	❶
Fish	Short-lived / small-bodied fish	❶❶
	Long-lived / large-bodied fish	❶

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

7.1 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

FLOODPLAIN HYDRAULICS

The Nyah floodplain is a shallow basin aligned parallel to the River Murray. It is formed between the high ground of natural levee along the river bank in the east and the terrestrial landscape to the west. Parnee Malloo Creek is an intermittently flowing anabranch that meanders through the floodplain over a distance of 16 km. The creek departs from the River Murray near Nyah at 1353 river km and rejoins the river near Wood Wood at 1346 river km. Shallow wetland depressions adjacent to the creek are filled by water spilling from the creek and by minor effluents in the river levee (Ecological Associates 2006).

Water first enters Nyah Park at the downstream end of Parnee Malloo Creek. The upstream connection of the channel is connected soon after with through-flow occurring at river discharges approaching 12,500 ML/d.

As river levels continue to rise above 17,500 ML/d, water spills from Parnee Malloo Creek to adjacent wetlands. Effluents along the river bank also introduce water to wetlands, the most important of which is Green Swamp which is flooded at river levels over 20,000 ML/d.

Water spreads through the forest understorey as river levels rise and at river discharges exceeding 25,000 ML/d approaches the higher ground along the river levee and terrestrial boundary of the floodplain.

On the falling hydrograph, water remains pooled Green Swamp and other wetland areas (Ecological Associates 2006). A deep billabong just north of the Parnee Malloo Creek confluence is filled by water spilling from the creek at river discharges exceeding 20,000 ML/d. This wetland retains water to a depth of more than 2 m.

At present the spread of water in the creek is blocked. Two earthen banks form a storage in the creek that is filled by water pumped from the River Murray. A former water supply for the now defunct Nyah Golf Club, the storage is now used as a fire water supply by two landholders.

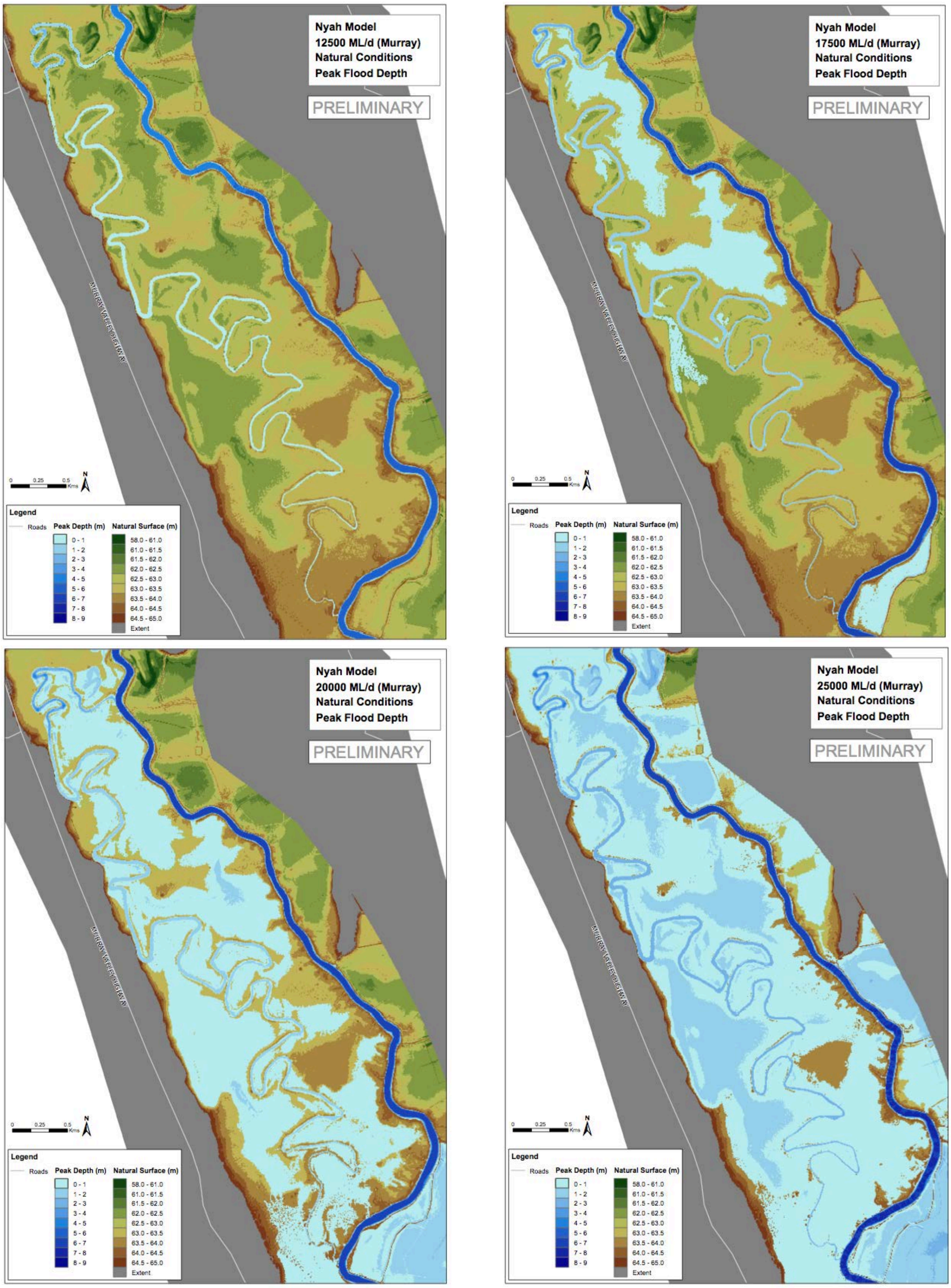


Figure 29. Nyah floodplain inundation at flows of 12,500, 17,500, 20,000 and 25,000 ML/d (Jacobs 2014).

HYDROLOGY

The hydrology of the River Murray at Swan Hill was analysed under natural and current conditions by Ecological Associates (2006).

Median monthly and 90th percentile flows have declined substantially under current conditions with the greatest impacts in the high flow months from June to January (Figure 24). The impacts on median flows in autumn are relatively minor. However a reduction on high flow events in summer and autumn is illustrated by the 90th percentile flows.

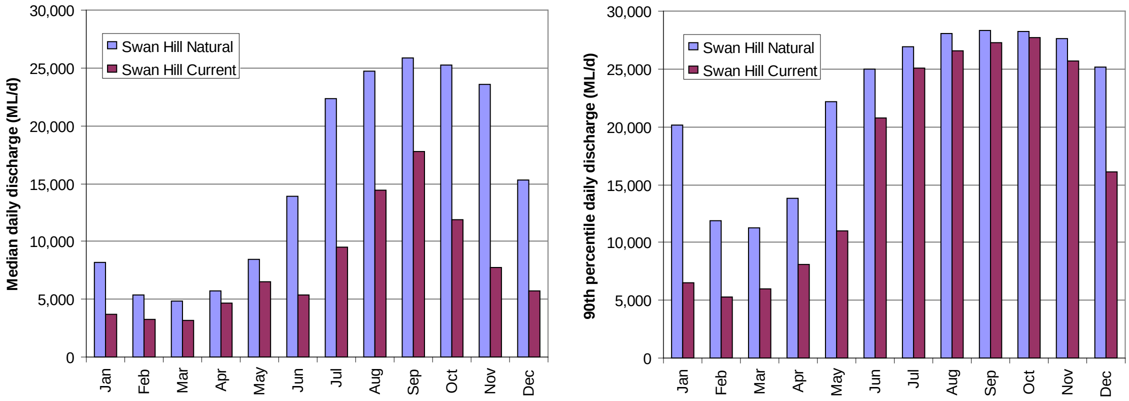


Figure 30. Distribution of median flows (left) and 90th percentile flows (right) for each month in the River Murray for natural and current (benchmark) conditions. Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006).

The natural hydrology of the river at Nyah Park is characterised by very frequent and sustained floodplain inundation events. Events between 12,500 ML/d and 22,500 ML/d, which inundate wetland and forest areas, occurred with a frequency of more than 10 events every 10 years. The duration of these events was substantial. Events that would inundate wetlands and activate through-flow in Parnee Malloo Creek (12,500 ML/d) had a median duration of more than 5 months while the median duration of forest flooding events (20,000 to 25,000 ML/d) was than 2 to 3 months. Most floodplain depressions at Nyah are shallow and retain little water, but under this flow regime they would have frequently remained flooded throughout the year.

Under current conditions, the frequency of flow peaks greater than 10,000 ML/d has declined somewhat but the median duration of these events has declined even more. Flows of 10,000 to 15,000 ML/d, which would have occurred almost 15 times every 10 years under natural conditions, last only 5 weeks rather than the 5 month median duration under natural conditions. The duration of events which reach the upper extent of red gum forest communities (25,000 ML/d) has almost halved from 75 days to 30. The frequency of these events has also declined significantly from 10 events every 10 years to only 6.

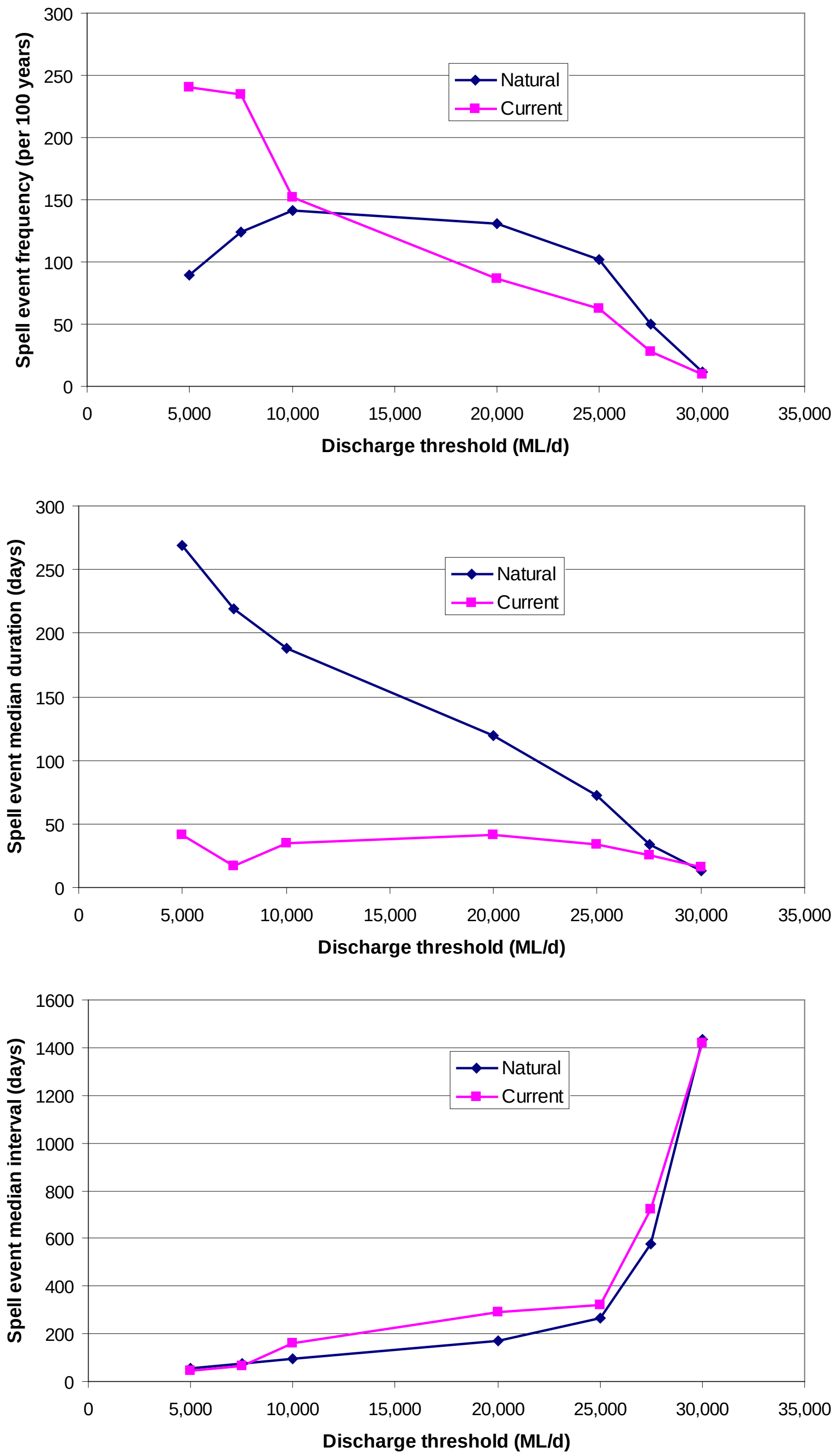


Figure 31. Spell event frequency, median duration and median interval for natural and current conditions (Swan Hill gauge). Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006)

Very high flows of 30,000 ML/d rarely occur in this reach and remain relatively unimpacted by regulation.

The river is managed in a low-flow state for a greater proportion of time in order to deliver water efficiently to downstream consumers. The low-flow component of the hydrology is characterised by a high frequency of brief flow peaks less than 10,000 ML/d.

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

The proposed works affect the majority of the Nyah floodplain including watercourse, wetland and forest habitats (Table 98, Figure 32).

Table 98. Area of Water Regime Classes inundated by the proposed works at Nyah Park

Water Regime Class	Area (ha)
Seasonal Anabranch	37
Seasonal Wetland	23
Red Gum Swamp Forest	128
Red Gum Forest and Woodland	293
(Black Box Woodland)	3.7

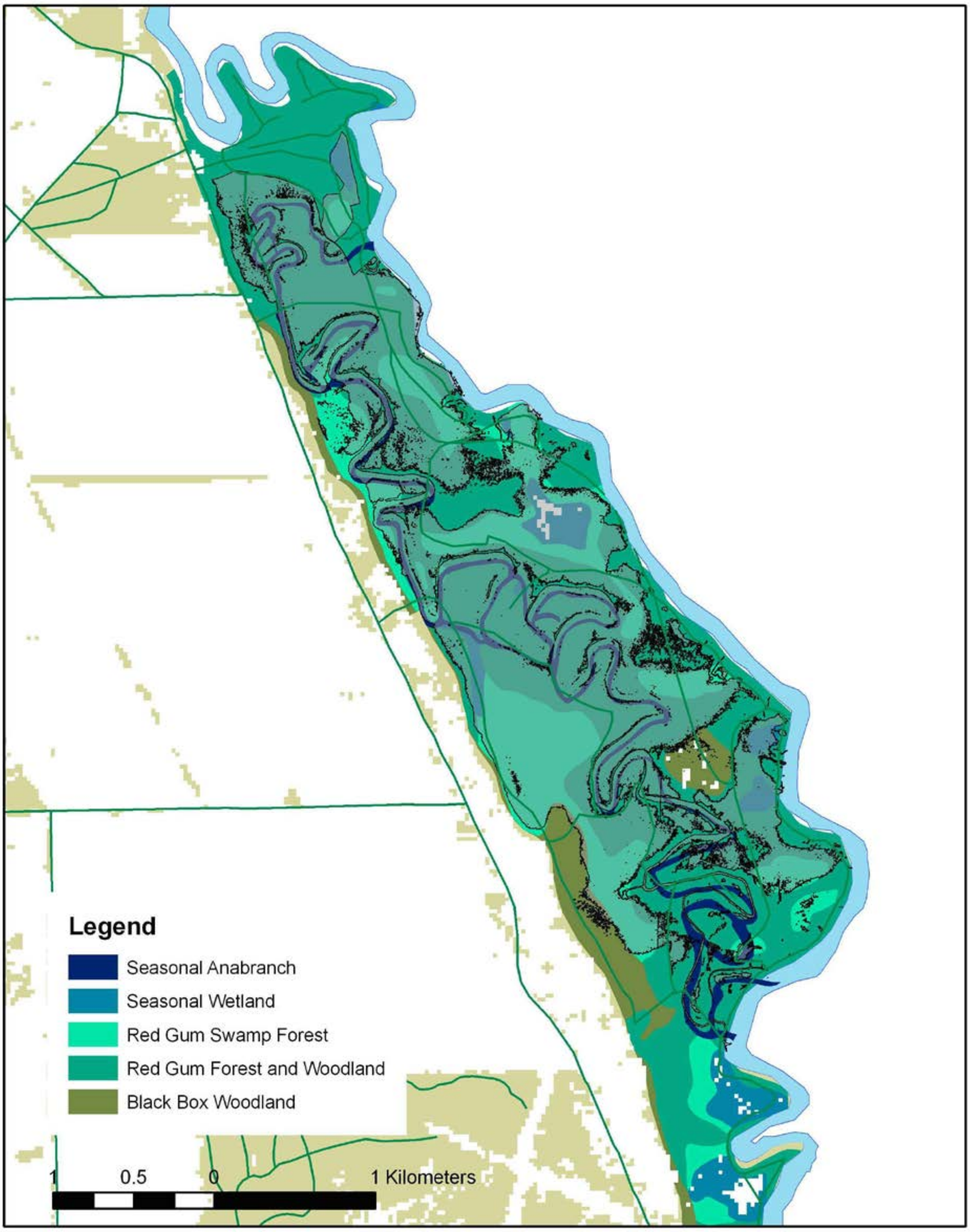


Figure 32. Inundation of Water Regime Classes by proposed works at Nyah Park

DESIGN

It is proposed to meet targets for flood duration and frequency using flow detention and regulating structures. Water will be detained in the floodplain basin by regulating outflows to the north.

The primary component of the works is a regulator and stop bank near the downstream river connection of Parnee Malloo Creek. The bank will be created by raising an existing track to retain water at a level of up to 63.2 m AHD. The regulator will be installed in the bank to allow through-flow in the creek and to manage water levels. A second regulator is required at the upstream entrance of Parnee Malloo Creek to maintain the ponded area. Minor works are also required at effluents along the river levee to prevent the escape of water. The works will inundate up to 476 ha.

The works include removal of former irrigation infrastructure including two blockages and an overflow bypass on Parnee Mallee Creek.

OPERATION

The Nyah Floodplain Management Project will be operated to augment the frequency and duration of floodplain inundation to meet environmental targets.

The structures will be operated to achieve environmental watering targets under three scenarios.

- Under normal flow conditions (when no environmental watering is occurring) the upstream and downstream regulators on Parnee Malloo Creek will be open.
- When a flow peak is anticipated, the regulators will remain open to promote flowing habitat in Parnee Malloo Creek. As river levels fall, the regulators will be closed to store flood water. The level at which water is stored will depend on the ecological objectives of the event. When the hydrological targets of the watering event are met, water will be released at the downstream regulator.
- If peaks in river flow are too infrequent to meet environmental watering targets, part or all of the system may be flooded by temporary pumps installed on the river bank.

To restore seasonal flow to Parnee Malloo Creek, the river will need to be operated at flows exceeding 15,000 ML/d. Environmental water reserves are potentially available for this purpose and will best meet the requirements of Nyah Park if they are provided annually over 2 to 4 months, centred on the months of October to December.

Table 99. Hydrological Change

Water Regime Class	Hydrological Targets	Ecological Objectives
Seasonal Anabranch	Seasonal flow in Parnee Malloo Creek for 4 to 6 months annually	Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities
Seasonal Wetland	Wetlands completely dry 1 year in 10 Wetland depth to exceed retention level of wetland 9 years in 10 - 6 of these events to last more than 9 months - 3 of these events to last more than 12 months Wetland depth to be less than 50% of retention level in May 5 years in 10	Restore resident populations of frogs and small fish Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species
Red Gum Swamp Forest	For areas above an inundation threshold equivalent to 17,500 ML/d - provide flooding 9 times in 10 years - five of these events to be 5 months long - four of these events to be 7 months long	Provide reliable breeding habitat for waterbirds, including colonial nesting species Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler Contribute to the carbon requirements of the River Murray channel ecosystem
Red Gum Forest and Woodland	For areas above an inundation threshold equivalent to 25,000 ML/d - provide flooding 8 times in 10 years - four of these events to be 6 weeks long - four of these events to be 12 weeks long	Provide reliable breeding habitat for waterbirds, including colonial nesting species Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler Contribute to the carbon requirements of the River Murray channel ecosystem

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

Table 100. Nyah Park specific ecological targets

Objective	Target
Restore the vegetation structure of wetland plant communities	The projected red gum canopy cover in seasonal wetlands decreases by 50% from 2015 levels by 2030. The projected aquatic macrophyte plant cover in December in seasonal wetlands exceeds 50% by 2030.
Re-establish resident populations of frogs and small fish	At least four native fish species are present in seasonal wetlands every spring between 2025 and 2035. At least three frog species are present in seasonal wetlands every spring between 2025 and 2035.
Provide seasonal feeding and reproductive opportunities for riverine fish species	Juveniles of murray cod are present in Parnee Malloo Creek every spring between 2025 and 2035. Adults of murray cod are present in Parnee Malloo Creek in spring in six years between 2025 and 2035.
Provide reliable breeding habitat for waterbirds, incldiung colonial nesting species	Any species of waterfowl, crake, rail, waterhen or coot breeds every year between 2025 and 2035 at Nyah Park. Cormorants and / or nankeen night heron breed at Nyah Park on at least six occasions between 2025 and 2035.
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	All red gum and black box stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035. Total bat abundance increases by 25% from 2015 levels by 2030.
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Nyah Park for the period 2025 to 2035 is double 2015 to 2020 levels.

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray (Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

8 VINIFERA FLOODPLAIN MANAGEMENT PROJECT

8.1 PROJECT DETAILS

The Vinifera Floodplain Management Project is a Supply Measure project located in Vinifera Park on the River Murray floodplain, 20 km northwest of Swan Hill in northwest Victoria. The project is located entirely within Crown Land.

The Vinifera floodplain is located on the left (south) bank of the River Murray between 1356 and 1367 river km. The floodplain includes wetland, forest and woodland areas.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over the floodplain. The project inundates up to 340 ha of intact floodplain habitat.

The Mallee Catchment Management Authority is the project proponent and will have responsibility for implementation.

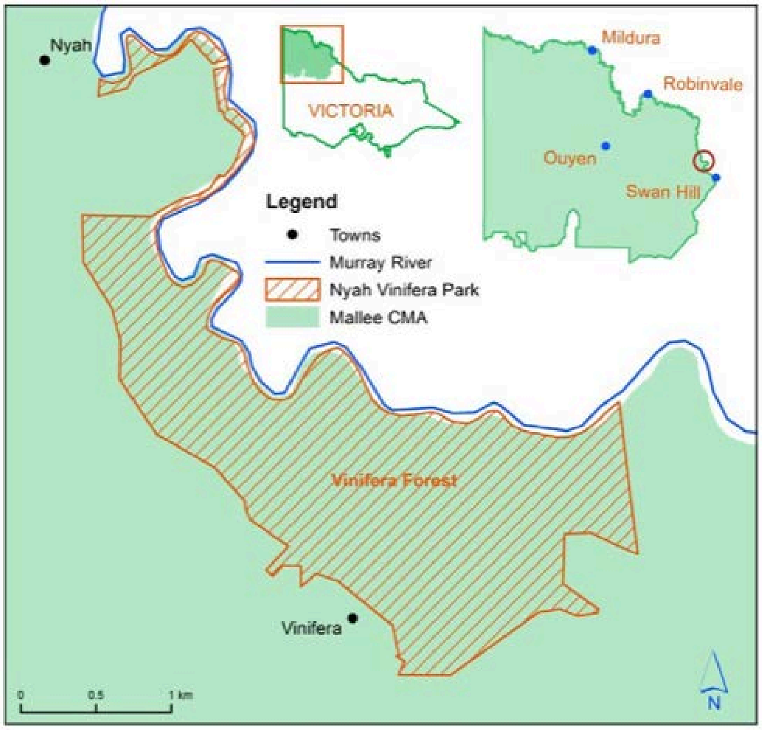


Figure 33. Location of the Vinifera Floodplain Management Project

8.2 ECOLOGICAL VALUES OF THE SITE

OVERVIEW

The Vinifera floodplain lies within the proposed Vinifera Park, which was formerly a state forest. Reclassification of the site was recommended by the Victorian Environmental Assessment Council in recognition of its conservation values and its outstanding range and concentration of Aboriginal cultural heritage sites (VEAC 2008).

The Vinifera floodplain forms an elongate basin aligned parallel to the River Murray. The basin is bounded by the terrestrial landscape to the south and the natural levee of the River Murray to the north. The basin is drained by a central watercourse, Vinifera Creek. River Murray water backs into the downstream connection of the creek at moderate river flows. At higher river flows effluents along the river bank introduce water to creek and forest areas. Overbank flows occur at river discharges exceeding about 25,000 ML/d. The floodplain has an area of 453 ha.

Lying near the western limit of the Murray Fans bioregion, the floodplain is one of the most downstream areas of the central river red gum forests which include Barmah-Millewa, Gunbower-Koondrook-Perricoota, Werai, Campbell Island and Guttrum and Benwell. These communities provide complex physical habitat and are highly productive. Several fauna species common in this bioregion are near the downstream limit of their range at Vinifera, including sugar glider and black wallaby. The forests support breeding by colonial nesting waterbirds and provide habitat for woodland fauna that require dense and productive understorey (Ecological Associates 2006).

Vinifera Park supports an important population of grey-crowned babbler. These birds depend on large, rough-barked trees in a forest community with a complex understorey of shrubs and timber. Flooding maintains the productivity of the ecosystem, including the insect fauna on which grey-crowned babbler depend.

The floodplain includes wetlands along Vinifera Creek. Under a natural flow regime, these wetlands would have been flooded almost annually and frequently remained flooded throughout the year. Persistent annual flooding would have excluded trees and supported a community of marshland plants including spiny mudgrass. Frogs, small fish and other aquatic species that depend on permanent aquatic habitat would have expanded from these refuges into the forest understorey during floods.

WATER DEPENDENT FLORA AND FAUNA

FLORA

Vinifera Park is located in a floodplain area of high plant diversity. The Victorian Flora Information System indicates 394 vascular flora species have been recorded in the vicinity of Vinifera Park, of which 277 are indigenous (Cook 2012). The database together with recent field surveys (Cook 2012)(GHD 2013) report 15 rare or threatened floodplain plants in or close to Vinifera Park (Table 1).

The vegetation of Vinifera Park is dominated by river red gum forest. The central basin of the floodplain has a dense overstorey and very sparse ground layer. Near Vinifera Creek, where the canopy is more open, aquatic macrophytes are present, including *Ludwigia peploides, Eleocharis acuta and Marsilea drummondii.* Higher ground along the river levee has a shrubby understorey that includes pale-fruit ballart. On the southern side of forest, near the boundary of the floodplain, the understorey becomes more terrestrial and includes a greater proportion of grasses and chenopods.

Table 101. Plant species of conservation significance reported from Nyah and Vinifera forest systems (Cook 2012),(GHD 2013)

Scientific Name	Common Name	Conservation Status			2012 and 2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Asperula gemella	twin-leaf bedstraw			R	x	x
Cardamine moirensis	riverina bitter-cress			R	x	x
Cuscuta australis	australian dodder			K	x	x
Cynodon dactylon var. pulchellus	native couch			V	x	x
Cyperus pygmaeus	dwarf flat-sedge			V	x	x
Glossostigma drummondii	desert mud-mat			K	x	
Dianella porracea	riverine flax-lily			V		
Nymphoides crenata	wavy marshwort		L	V	x	x
Ranunculus pumilio var. politus	ferny small-flower buttercup			K	x	x
Ranunculus undosus	swamp buttercup			V	x	x
Rorippa eustylis	dwart bittercress			V	x	
Rutidosis helichrysoides	grey wrinklewort			E	x	
Senecio cunninghamii var. cunninghamii	branching groundsel			R	x	x
Senecio campylocarpus	floodplain fireweed			R		
Templetonia rossii	flat templetonia			V		

In Victoria, vegetation mapping units, known as Ecological Vegetation Classes, are assigned conservation ratings within each bioregion (Table 2). Of the nine EVCs present at Vinifera Park one is considered endangered and two are considered vulnerable.

Table 102. Bioregional conservation status of Vinifera Ecological Vegetation Classes

Ecological Vegetation Class	Bioregional Conservation Status
103 Riverine Chenopod Woodland	Endangered
106 Grassy Riverine Forest	Depleted
295 Riverine Grassy Woodland	Vulnerable
810 Floodway Pond Herbland	Depleted
811 Grassy Riverine Forest / Floodway Pond Herbland Complex	Depleted
814 Riverine Swamp Forest	Depleted
816 Sedgy Riverine Forest	Depleted
819 Spike-sedge Wetlands	Vulnerable
821 Tall Marsh	Least Concern

FAUNA

Ten native fish species are encountered regularly in the River Murray near Vinifera Park. Wetlands and flooded forest provide habitat for a range of small fish that benefit from submerged aquatic vegetation, woody debris and plant, biofilm and invertebrate food sources (Table 3). The restoration of wetland habitat would potentially support resident populations include murray-darling rainbowfish, carp gudgeon, flathead gudgeon and australian smelt. Freshwater catfish may use both wetland and creek habitat. The large channel-specialist fish species of murray cod, silver perch and golden perch are unlikely to use the floodplain to a significant degree.

Carbon generated on the floodplain is conveyed to the river channel by floodwater. This material contributes to the productivity of the riverine ecosystem on which channel-specialist fish depend, including murray cod, silver perch and golden perch.

Table 103. Native fish species expected to occur at Vinifera Park (Davies, et al. 2008)

Scientific name	Common Name	Conservation Status		
		EPBC	FFG	VROTS
Bidyanus bidyanus	silver perch		L	V
Craterocephalus stercusmuscarum fulvus	fly-specked hardyhead			
Hypseleotris klunzingeri	carp gudgeon			
Maccullochella peelii peelii	murray cod	V	L	V
Macquaria ambigua	golden perch		I	NT
Melanotaenia fluviatilis	murray-darling rainbowfish		L	V
Nematalosa erebi	bony herring			
Phylipnodon grandiceps	flathead gudgeon			
Retropinna semoni	australian smelt			
Tandanus tandanus	freshwater catfish		L	E

Vinifera Park has a diverse bird fauna with over 140 bird species reported from the site and the local vicinity. Of these, 20 have conservation significance in Victoria or under the EPBC Act (Table 4). One species, the eastern great egret, is listed under international migratory bird agreements.

An important population of grey-crowned babbler is present at Vinifera. These birds are insectivores that build stick nests in saplings, shrubs and the lower canopy of trees. Their favoured habitat is black box and red gum woodland where they forage partly on the ground and partly on the trunks and branches of trees and shrubs.

Wetlands provide habitat for dabbling, diving and filter feeding ducks while fish provide prey for waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Table 104. Birds of conservation significance expected to occur at Vinifera Park (Brown, Bryant and Horrocks 2013)

Species	Common Name	Conservation Status			Migratory Bird Agreements		2013 Survey	Data-bases
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA		
Biziura lobata	musk duck			V				x
Anas rhynchotis	australasian shoveler			V				x
Aythya australis	hardhead			V				x
Ardea modesta	eastern great egret			V		C J		x
Cacatua leadbeateri	major mitchell's cockatoo		L	V			x	x
Circus assimilis	spotted harrier			NT				x
Climatcteris picumnus	brown treecreeper			NT				x
Egretta garzetta	little egret		L	E				x
Geopelia cuneata	diamond dove		L	NT				x
Haliaeetus (Pontoaetus) leucogaster	white-bellied sea-eagle		L	V				x
Melanodryas cucullata	hooded robin		L	NT				x
Nycticorax caledonicus	nankeen night heron			NT			x	x
Phalacrocorax varius	pied cormorant			NT				x
Platalea regia	royal spoonbill			NT				x
Polytelis anthopeplus	regent parrot	V	L	V				x
Pomatostomus temporalis	grey-crowned babbler		L	E				x
Sterna nilotica	gull-billed tern		L	E				x
Turnix velox	little button quail			NT				x

Seasonally flooded wetlands, that are surrounded by frequently flooded red gum forest provide breeding habitat for colonial nesting waterbirds. Vinifera is known as a breeding area the colonial nesting waterbirds cormorant and australasian darter (Ecological Associates 2006) and may also support breeding by royal spoonbill and nankeen heron.

While not reported from Vinifera Park, the floodplain potentially provides habitat for regent parrot (EPBC vulnerable, DEPI vulnerable, FFG) which feeds in the mallee and depends on tree hollows provided on the floodplain. Other parrot species with similar requirements include major mitchell cockatoo, scarlet-chested parrot and elegant parrot.

Vinifera Forest has a diverse bat fauna with eleven species reported from the site (Table 5). The bats are largely insectivorous and depend on high levels of forest productivity to provide prey. They roost in the crevices and hollows of *Eucalyptus camaldulensis* and *E. largiflorens* trees.

Black wallaby is present. This species prefers thick the forest undergrowth that is often found near wetlands and forest watercourses. It feeds on native shrubs, sedges, rushes, grasses and ferns. Typically patches of dense vegetation provide refuges during the day from which swamp wallabies emerge at dusk to feed on more open vegetation and grassland.

Table 105. Native mammal species reported from Vinifera Park (Brown, Bryant and Horrocks 2013)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROT		
Chalinolobus gouldii	gould's wattled bat				x	
Chalinolobus morio	chocolate wattled bat				x	
Macropus giganteus	eastern grey kangaroo				x	
Mormopterus sp.	freetail bat (female)				x	
Mormopterus sp. (sp. 2)	eastern freetail bat				x	
Mormopterus sp. (sp. 4)	southern freetail bat				x	
Scotorepens balstoni	inland broad-nosed bat				x	
Scotorepens greyii	little broad-nosed bat			NT	x	
Tadarida australis	white-striped freetail bat				x	
Trichosurus vulpecula	common brushtail possum				x	
Vespadelus darlingtoni	large forest bat				x	
Vespadelus regulus	southern forest bat				x	
Vespadelus vultumus	little forest bat				x	
Wallabia bicolor	black wallaby				x	x

The forest provides a variety of complex habitats in understorey vegetation, litter, woody debris, shrubby vegetation tree bark, crevices and hollows. Flooding maintains the structure of these habitat components and high levels of productivity which provide food for reptiles and amphibians in the form of vegetation, invertebrates and small birds and mammals (Table 6).

Table 106. Reptiles and amphibians reported from Vinifera Park (Brown, Bryant and Horrocks 2013)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROT		
Reptiles						
Delma inomata	olive legless lizard				x	
Christinus marmoratus	marbled gecko					x
Cryptoblepharus carnabyi	carnaby's wall skink				x	x
Lampropholis guichenoti	garden skink				x	
Lerista punctatovittata	spotted burrowing skink					x
Morethia boulengeri	boulenger's skink				x	x
Pseudonoja testilis	eastern brown snake				x	
Amphibians						
Litoria peronii	peron's tree frog				x	x
Limnodynastes dumerilii	southern bullfrog				x	x
Limnodynastes tasmaniensis	spotted marsh frog				x	x

FORMAL CONSERVATION AGREEMENTS

The Vinifera project area lies entirely on public land within the Vinifera Park. It is a former forestry reserve that is now managed to protect conservation and aboriginal heritage values .

Vinifera Park is an important cultural site for the Wadi Wadi Aboriginal people and there are numerous burial sites, earth ovens middens and scarred trees. The earthen ovens and middens are listed under the National Estate (VEAC 2008).

VITAL HABITAT AT THE SITE

Vinifera Forest supports an important population of grey-crowned babbler. It supports a diverse bat fauna of eleven species.

Vinifera is a low-lying floodplain area that is reliably inundated in spring by elevated river flows. Under a restored water regime, the wetland and flooded forest areas would provide reliable refuge and breeding habitat for aquatic fauna and waterbirds.

8.3 ECOLOGICAL OBJECTIVES

OVERALL OBJECTIVE

The overall objective of water management at Vinifera Park is:

"to restore the key species, habitat components and functions of the Vinifera Park ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- restoring the vegetation structure of wetland plant communities
- re-establishing resident populations of frogs and small fish
- providing reliable breeding habitat for waterbirds, including colonial nesting species
- restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler
- contributing to the carbon requirements of the River Murray channel ecosystem

Ecological objectives will be achieved by providing ecosystem water requirements of the Vinifera Park floodplain. Five water regime classes have been identified at Vinifera Park (Table 7).

Table 107. Vinifera Park Water Regime Classes

Water Regime Class	Area (ha)	Ecological Vegetation Class
Seasonal Wetland	98	819 Spike-sedge Wetlands 821 Tall Marsh 810 Floodway Pond Herbland
Red Gum Swamp Forest	277	814 Riverine Swamp Forest
Red Gum Forest and Woodland	161	106 Grassy Riverine Forest 811 Grassy Riverine Forest / Floodway Pond Herbland Complex 816 Sedgy Riverine Forest
Black Box Woodland	94	295 Riverine Grassy Woodland 103 Riverine Chenopod Woodland

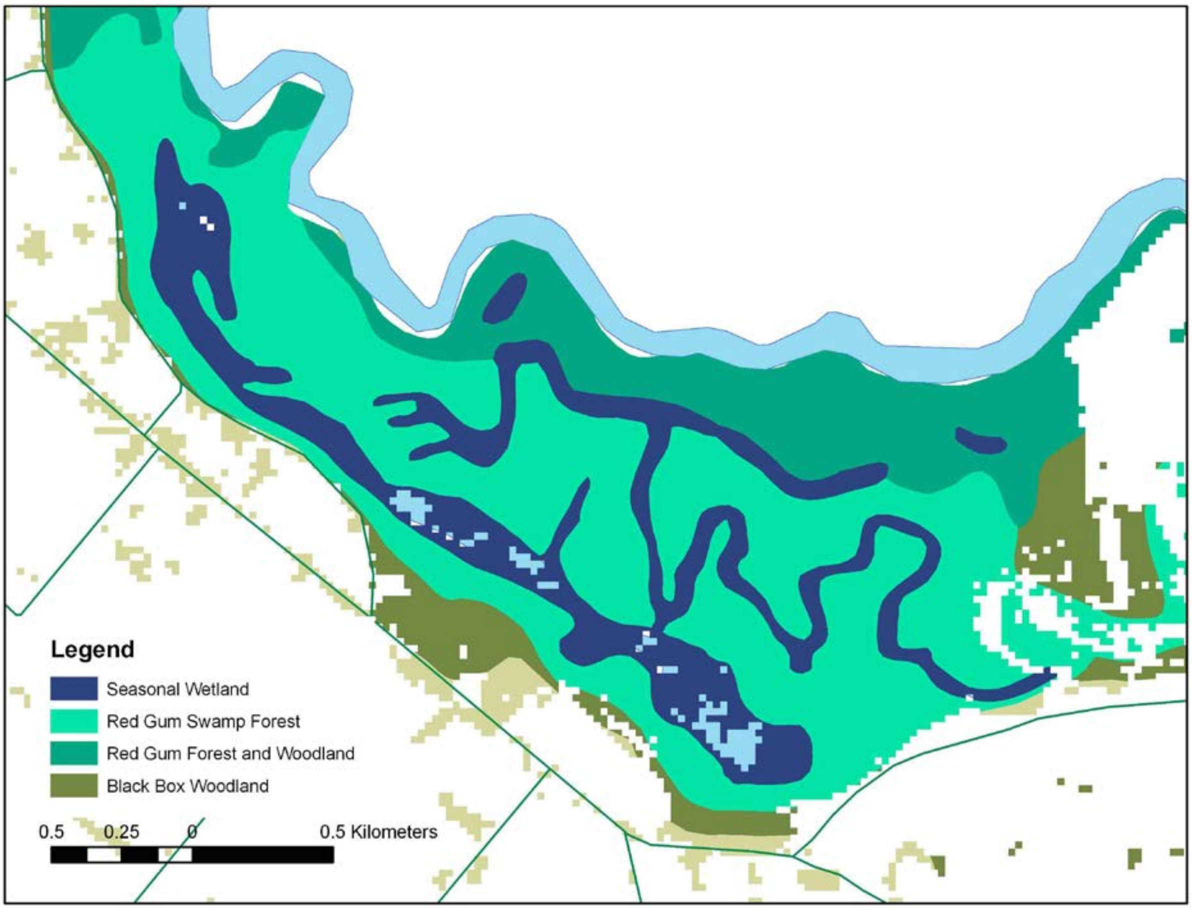


Figure 34. Vinifera Park Water Regime Classes

SEASONAL WETLANDS

Ecology

The Vinifera floodplain features broad watercourses and wetlands that retain water on the flood recession(Ecological Associates 2006). While shallow, the wetlands experienced persistent and frequent flooding under natural flow conditions would have frequently remained flooded throughout the year.

Frequent and persistent flooding promotes an emergent sedgeland dominated by *Eleocharis acuta* and excludes *Eucalyptus camaldulensis* trees. The wetlands would support a range of species adapted to variable water levels including *Myriophyllum crispatum, Ottelia ovalifolia* ssp. *ovalifolia, Azolla filiculoides, Ludwigia peploides* and *Callitriche* spp. As the wetlands dry out, the herbs *Marsilea drummondii, Pratia concolor* and *Persicaria prostrata* will become more abundant (White, et al. 2003). Taller reedy vegetation, such as *Phragmites australis,* may be present at the wetland fringes.

Dense aquatic vegetation, algae and biofilms are a productive food source and provide physical habitat for zooplankton, macroinvertebrates and small fish such as gudgeon, smelt and hardyhead. Tree-less, open water habitat is an important habitat component for waterfowl, fish-eating birds and bats. Soft leaved vegetation and aquatic macro-invertebrates will provide food for dabbling and grazing ducks such as grey teal, pacific black duck and australian shelduck. The wetlands will provide reliable breeding habitat for waterfowl which build nests using reeds on scrapes in and around reedy vegetation. Reeds will provide terrestrial frogs with abundant aquatic invertebrates and flying insects, a substrate for eggs and shelter from predators. Wading birds such as royal spoonbill and intermediate egret will prey on invertebrates and small fish

Seasonal inundation is important to wetland productivity. The plant matter that is exposed on the drying wetland bed in summer and autumn is readily mineralised when reflooded in winter. This supports a productive food web of algae and zooplankton and bacterial biofilms (Young 2001) which in turn provides prey for larger fauna including fish and waterbirds.

The wetlands are a refuge habitat for frogs such as southern bullfrog and spotted marsh frog. Reliable flooding in the wetlands maintains the population, which expands to flooded red gum understorey during floods.

Dense reedy vegetation near the wetlands provides shelter for black wallaby.

Water Requirements

Under natural conditions, high river levels provided sustained, almost annual, inflows to the shallow wetlands on the Vinifera floodplain from winter to summer. Flooding persisted for four to eight months in most years and frequently lasted throughout the year.

Seasonal wetland habitat has been lost from Vinifera Park through a reduction in the duration of spring flow peaks. High river levels now inundate wetlands only briefly, and have promoted the establishment of river red gum on former wetland beds. Flood duration is too short to support aquatic marshland vegetation and the understorey is now dominated by grasses and seasonal floodplain herbs (Cook 2012). The decline in wetland habitat means the floodplain now only provides opportunistic habitat for aquatic fauna that recolonise the system when water is available. The encroachment by trees now excludes many waterbirds that rely on open water.

Seasonal wetland habitat may be restored to Vinifera Park by providing flooding of 6 to 9 months duration 9 years in 10, between winter and summer. This will provide regular breeding habitat for waterbirds and will support the seasonal requirements of aquatic wetland fauna including native fish. Water levels should fall over summer and autumn to promote macrophyte growth over broad areas of the wetland bed and to promote mineralisation of organic matter.

Table 108. Water management objectives to restore seasonal wetlands

Objectives Addressed	Restore resident populations of frogs and small fish Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into wetlands if peaks in river flow are too infrequent
Hydrological Targets	Wetlands completely dry 1 year in 10 Wetland depth to exceed retention level of wetland 9 years in 10 - 5 of these events to last more than 6 months - 4 of these events to last more than 9 months Wetland depth to be less than 50% of retention level in May 5 years in 10

RED GUM SWAMP FOREST

Ecology

In low-lying areas, frequent and sustained inundation limits tree density to an open forest structure. The understorey comprises obligate wetland plant species which require regular spring and summer flooding. This stratum is dominated by *Eleocharis acuta* and *Triglochin multifructum* and includes also *Myriophyllum* spp. *Pseudoraphis spinescens, Ranunculus* spp. Prolonged seasonal flooding provides little opportunity for understorey plants to establish between flood events and the ground layer in late summer and autumn will be largely bare.

The swamp forest represents an extension of the seasonal wetland habitat with a similar understorey and similar habitat values for aquatic fauna.

Inundation of red gum forest and woodland provides temporary habitat for aquatic fauna, particularly vegetation-dependent fish such as gudgeon complex, rainbow fish and hardyhead. The habitat for terrestrial frogs, which is normally limited to the reeds fringing wetlands, will expand to the red gum understorey. Burrowing frogs, which aestivate in the floodplain soil, will become active. Other wetland species that will extend into the flooded woodland will include yabby, tortoises and water rat.

Flooding events will support waterbird breeding. The trees provide nesting sites for waterbirds that breed over water such as little egret, white-necked heron, white-faced heron, great cormorant and little black cormorant. A range of other waterbird guilds will breed including waterfowl, large waders and small waders.

Water Requirements

Flows of 17,500 to 20,000 ML/d inundate the low-lying river red gum forest. Under natural conditions these flows occurred approximately 130 times every 100 years and lasted over 4 months. Frequent and sustained flooding limited the density of red gum trees, creating and open canopy with a diverse and productive ground layer of amphibious plants.

Red gum forest has been severely degraded at Vinifera Park. Median flood duration has declined to less than 6 weeks. However flood frequency has remained high, which has led to higher tree density and increased shading of the understorey. Flood durations are too low to sustain perennial aquatic macrophytes and more drought-tolerant species are now more abundant. Flooding is generally too brief to contribute significantly to the breeding requirements of native fish or waterbirds.

The habitat values of red gum forest can be restored by increasing the duration of flooding events while maintaining a high flooding frequency. Flooding should commence in late winter or early spring and be sustained until summer. Longer events will contribute to the breeding requirements of waterbirds while shorter events will provide foraging habitat and breeding opportunities for resident aquatic fauna. A higher density of vegetation on the forest floor will contribute to the habitat requirements of terrestrial fauna. It will provide forage and shelter for swamp wallaby and a source of prey and physical habitat for carpet python. High levels of insect productivity will sustain local bat populations.

Table 109. Water management objectives for red gum swamp forest

Objectives Addressed	Restore resident populations of frogs and small fish Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	For areas above an inundation threshold equivalent to 17,500 ML/d - provide flooding 9 times in 10 years - five of these events to be 5 months long - four of these events to be 7 months long

RED GUM FOREST AND WOODLAND

Ecology

The density of red gum trees increases outside of the swampy forest areas. The understorey is more sparse and has a broader mix of sedges and rushes that benefit from drier conditions over summer including *Carex tereticaulis, Bolboschoenus medianus, Phragmites australis* and *Eleocharis acuta*. During floods *Triglochin multifructum* is present. Following the flood recession a number of ground-layer species grow including the grasses *Paspalidium jubiflorum* and *Lachnagrostis filiformis* and a range of herbs including *Pratia concolor, Brachyscome basaltica, Brachyscome basaltica, Calotis* spp., *Wahlenbergia luminaries, Senecio quadridentatus* and *Euphorbia drummondii* (White, et al. 2003).

Red gum trees and their understorey have an important role in providing structural habitat for floodplain fauna, particularly hollows for nesting wood duck, carpet python, bats and brush-tailed possum. Red gum growing close to water provide nesting habitat for some birds which feed in adjacent mallee including regent parrot and major mitchell cockatoo. Dense understorey vegetation provides habitat for grey-crowned babbler, swamp wallaby and carpet python.

Water Requirements

Flows of 15,000 to 25,000 ML/d inundate the low-lying river red gum forest. Under natural conditions these flows occurred almost annually and lasted for 3 to 5 months. Frequent and sustained flooding limited the density of red gum trees, creating and open canopy with a diverse and productive ground layer of amphibious plants. Forest flooding provides an extension of aquatic habitat from the seasonal wetlands and Vinifera Creek.

Red gum forest has been severely degraded at Vinifera Park. Median flood duration has declined to less than 6 weeks. Flood frequency, however, has remained high and has led to higher tree density and increased shading of the understorey. Flood durations are too low to sustain perennial aquatic macrophytes and more drought-tolerant species are now more abundant. Flooding is generally too brief to contribute significantly to the breeding requirements of native fish or waterbirds.

The habitat values of red gum forest can be restored by increasing the duration of flooding events while maintaining a high flooding frequency. Flooding should commence in late winter or early spring and be sustained until summer. Longer events will contribute to the breeding requirements of waterbirds while shorter events will provide foraging habitat and breeding opportunities for resident aquatic fauna. A higher density of vegetation on the forest floor will contribute to the habitat requirements of terrestrial fauna. It will provide forage and shelter for swamp wallaby and a source of prey and physical habitat for carpet python. High levels of insect productivity will sustain local bat populations.

Table 110. Water management objectives for red gum forest and Woodland

Objectives Addressed	Restore resident populations of frogs and small fish Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	For areas above an inundation threshold equivalent to 20,000 ML/d - provide flooding 9 times in 10 years - five of these events to be 2 months long - four of these events to be 6 months long

BLACK BOX WOODLAND

Ecology

Black box woodland is present on higher ground near the terrestrial boundary of the floodplain. Black box trees form an open woodland canopy while the understorey is dominated by tussock grasses that respond to winter and spring rain but do not depend on flooding. The ground layer is grassy and dominated by *Austrodanthonia* spp. and *Austrostipa* spp. There is generally a sparse scattering of low shrubs frequently including *Einadia nutans, Atriplex semibaccata, Atriplex eardleyae, Sclerolaena muricate* var. *villosa, Enchylaena tomentosa, Maireana decalvans, Chenopodium curvispicatum* and *Salsola kali* (White, et al. 2003).

The grassy understorey provides seeds and forage for granivores such as finches, cockatoos, galah, lorikeet and budgerigar, the frugivorous emu and large herbivores including western grey kangaroo and swamp wallaby. The trees directly support insectivorous and omnivorous birds such as honeyeaters and wattlebird. Both overstorey and understorey vegetation support insect production on which a wide range of insectivorous birds and bats depend.

High levels of productivity will follow floods as elevated soil moisture promotes the growth and flowering of understorey grasses, shrubs and trees. The abundant food, including forage, insects, nectar and seeds will provide support breeding by many floodplain fauna. Flooding also maintains the propagules of flood-dependent plant such as *Eleocharis acuta* which grows from drought-tolerant rhizomes when flooded and *Marselia drummondii* which grows from drought-tolerant spores. These propagule banks will gradually become depleted between flood events.

Water Requirements

Flows 25,000 to 30,000 ML/d inundate black box woodland at the edges of the floodplain. Under natural conditions these flows occurred approximately 50 years in 100 and lasted approximately six weeks. While the duration of flood events has been maintained under the current flow regime, the frequency of spells has been halved to 25 years in 100.

While the overall health and integrity of black box woodland at Vinifera has been maintained, productivity has declined. The understorey vegetation growth has reduced, providing less physical habitat and contributing less to ecosystem carbon requirements. The food resources and structural habitat carpet python, swamp wallaby, grey-crowned babbler and other woodland species have reduced.

Woodland productivity can be restored by increasing the frequency of floods exceeding 25,000 ML/d to 50% of years with a median event duration of six weeks. Flooding should take place in winter and spring to support tree and the growth of trees and understorey grasses and shrubs over late spring and summer.

Table 111. Water management objectives for black box woodland

Ecological Objective	Provide reliable breeding habitat for waterbirds, including colonial nesting species Restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler Contribute to the carbon requirements of the River Murray channel ecosystem
Strategy	Capture peaks in river flow by closing regulators on the flood recession Pump water into forest if peaks in river flow are too infrequent
Hydrological Targets	For areas above an inundation threshold equivalent to 25,000 ML/d - provide flooding 8 times in 10 years - median event duration to be 6 weeks

8.4 ANTICIPATED ECOLOGICAL BENEFITS AND IMPACTS

BENEFITS

The Vinifera Floodplain Management Project will

- protect an important community of woodland bat species
- restore colonial nesting waterbird breeding habitat
- restore wetland and forest structural diversity and productivity
- maintain the western-most extent of the central Murray floodplain river red gum forest
- provide habitat for mallee vertebrate fauna that depend on floodplain habitat for prey, shelter and breeding including carpet python, regent parrot and major mitchell parrot
- supply organic matter to the River Murray channel ecosystem

ECOLOGICAL ELEMENTS METHODOLOGY

The Ecological Elements method will be used by the Murray-Darling Basin Authority to evaluate the scope to adjust the Sustainable Diversion Limiit on the basis of the ecological outcomes of projects such as Vinifera Park (Overton, et al. 2014).

The method will compare the ecological outcomes of SDL scenarios by evaluating the performance of 12 ecological elements (Table 15).

Table 112. Ecological elements used in the CSIRO SDL adjustment evaluation method (Overton, et al. 2014) in relation to the ecological outcomes of the Vinifera Park project.

Ecological Class	Ecological Element	Vinifera Park
Waterbirds	Bitterns, crakes and rails	❶❶
	General abundance and health - all waterbirds	❶❶
	Breeding - Colonial-nesting waterbirds	❶❶
	Breeding - other waterbirds	❶❶
Vegetation	Woodlands: river red gum (*Eucalyptus camaldulensis*)	❶
	Forests: river red gum (*Eucalyptus camaldulensis*)	❶❶
	Forests and woodland: black box (*Eucalyptus largiflorens*)	
	Shrublands	
	Tall grasslands, sedgelands and rushlands	❶❶
	Benthic herblands	❶
Fish	Short-lived / small-bodied fish	❶❶
	Long-lived / large-bodied fish	

Key

Score	Benefit to the Ecological Element in relation to other sites in the Southern Connected Murray-Darling Basin
	Not significant in relation to other sites
❶	The contribution is infrequent or small in relation to other sites
❶❶	The contribution is frequent but small or substantial but rare in relation to other sites
❶❶❶	The site provides one of the most important contributions to this Ecological Element in the region in terms of frequency, extent and the conservation significance of species that benefit

The wetlands set within red gum forest at Vinifera Park provide important habitat for aquatic fauna. The recommended flooding regime aims to restore open wetland habitat with emergent and submerged aquatic beds. These will provide habitat for small fish species and potentially significant colonial nesting waterbird breeding habitat. Other waterbird species are likely to use the site for feeding and breeding.

Inundation of the red gum forest will improve floodplain productivity and provide seasonal aquatic habitat for fish and waterbirds.

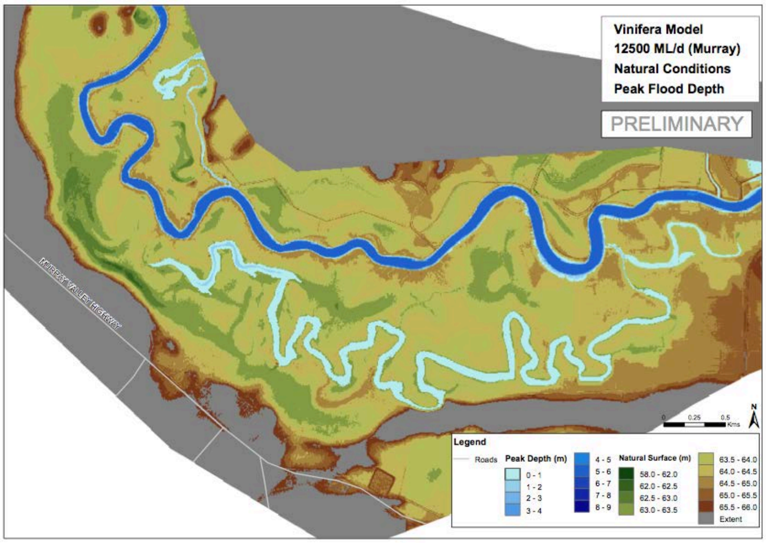
8.5 HYDROLOGY OF THE AREA AND ENVIRONMENTAL WATER REQUIREMENTS

CURRENT HYDROLOGY OF THE AREA

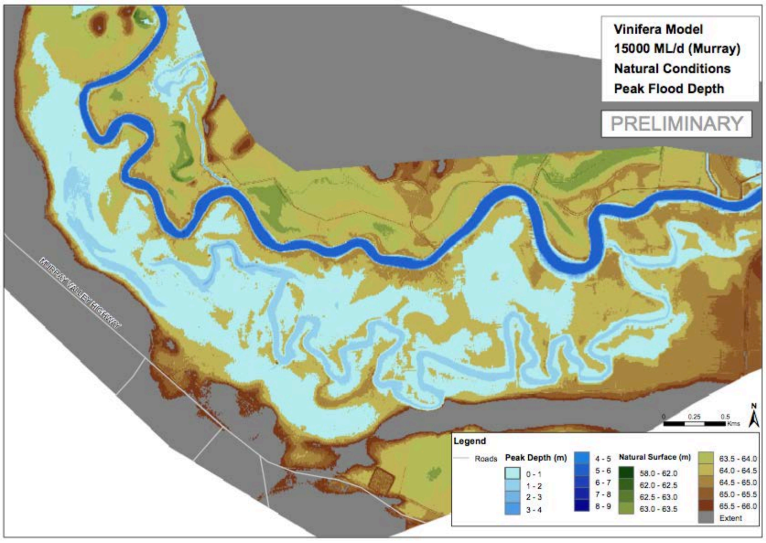
FLOODPLAIN HYDRAULICS

Vinifera Park is an elongate floodplain basin aligned parallel to the River Murray. The basin is formed between the terrestrial landscape to the south and the natural levee of the river bank to the north (Figure 35). An artificial levee has been constructed at the eastern boundary of the park across the floodplain. The levee reduces flooding in private land upstream by isolating it from flooding in the Vinifera system.

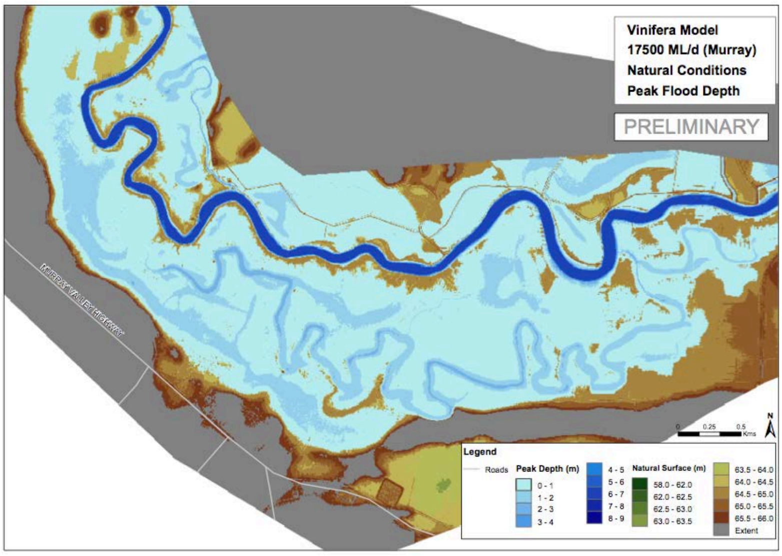
Low-lying meandering watercourses and wetlands in the floodplain are referred to collectively as Vinifera Creek. River flows of 12,500 ML/d introduce water to the creek system from a connection in the east of Vinifera Park. At higher flows minor effluents along the river bank also introduce water to the creek. Under natural conditions, Vinifera Creek would have received inflows from its upstream effluent near this flow threshold and the channel would act as an anabranch. However modifications to the floodplain upstream of the park have blocked the channel and the creek now functions as a separate wetland. A minor effluent, just downstream of the constructed levee may promote through-flow in a narrow flow band, just before overbank flows commence.



12,500 ML/d



15,000 ML/d



17,500 ML/d

Figure 35. Vinifera floodplain inundation at flows of 12,500, 15,000 and 17,500 ML/d (Jacobs 2014).

Water spills from Vinifera Creek to the general forest floor as river flows exceed 15,000 ML/d. Most of the forest inundated at 17,500 ML/d. Red gum and black box woodland on the terrestrial fringe of the floodplain is inundated when river levels exceed 25,000 ML/d.

Most of the forest drains freely as river levels fall. However, wetlands can retain water and would can remain flooded between annual inflow events (Ecological Associates 2006).

HYDROLOGY

The hydrology of the River Murray at Swan Hill was analysed under natural and current conditions by Ecological Associates (2006).

Median monthly and 90th percentile flows have declined substantially under current conditions with the greatest impacts in the high flow months from June to January (Figure 24). The impacts on median flows in autumn are relatively minor. However a reduction on high flow events in summer and autumn is illustrated by the 90th percentile flows.

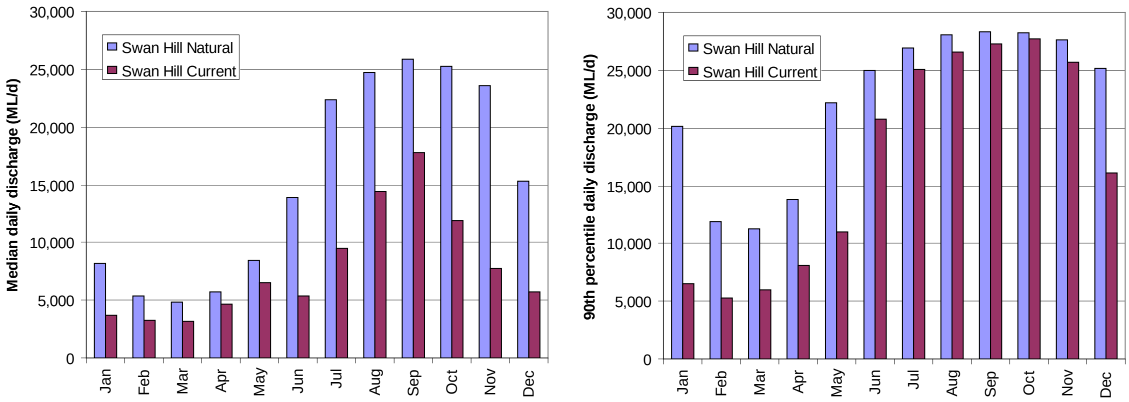


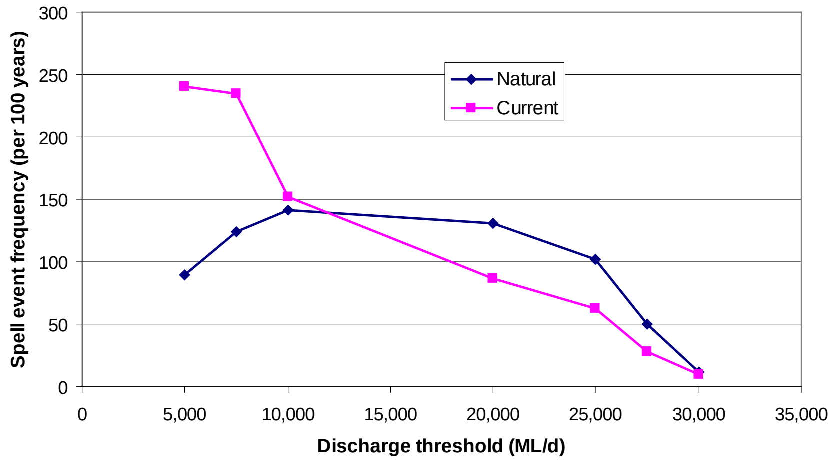
Figure 36. Distribution of median flows (left) and 90th percentile flows (right) for each month in the River Murray for natural and current (benchmark) conditions. Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006).

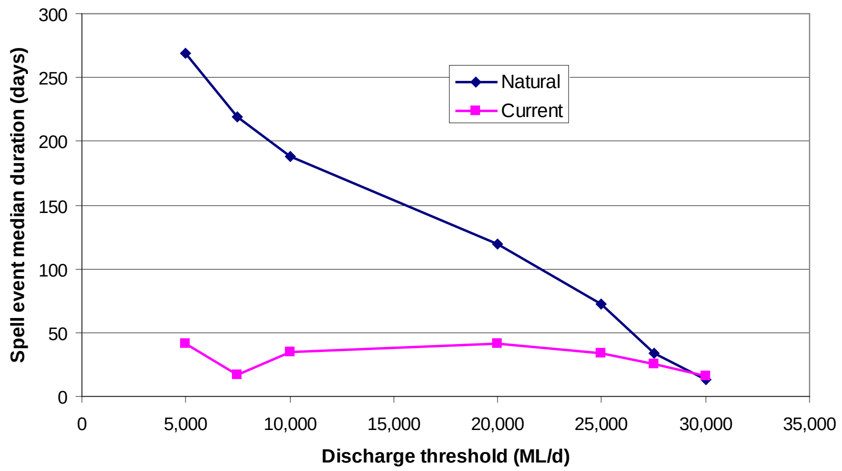
The natural hydrology of the river at Vinifera Park is characterised by frequent and sustained floodplain inundation events. Events between 10,000 ML/d and 25,000 ML/d, which inundate wetland and forest areas, occurred with a frequency of more than 10 events every 10 years. The duration of these events was substantial. Events exceeding 15,000 ML/d, which would introduce water to red gum forest, had a median duration of more than 5 months. Events that would completely flood the forest and reach the edge of the woodland (25,000 ML/d) had a median duration of 2 months. Under this flow regime floodplain wetlands would have frequently remained flooded throughout the year.

Under current conditions, the frequency of flow peaks greater than 10,000 ML/d has declined somewhat but the median duration of these events has declined substantially. Flows of 10,000 to 15,000 ML/d, which would have occurred almost 15 times every 10 years under natural conditions, last only 5 weeks rather than the 5 month median duration under natural conditions. The duration of events which reach the upper extent of red gum forest communities (25,000 ML/d) has almost halved from 75 days to 30. The frequency of these events has also declined significantly from 10 events every 10 years to only 6.

Very high flows of 30,000 ML/d rarely occur in this reach and remain relatively unimpacted by regulation.

The river is managed in a low-flow state for a greater proportion of time in order to deliver water efficiently to downstream consumers. The low-flow component of the hydrology is characterised by a high frequency of brief flow peaks less than 10,000 ML/d.





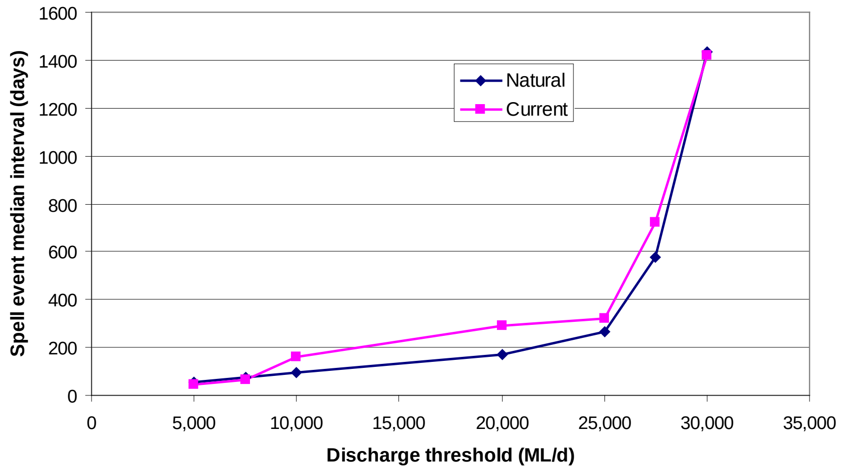


Figure 37. Spell event frequency, median duration and median interval for natural and current conditions (Swan Hill gauge). Derived from MDBC MSM-Bigmod 109 year data (Ecological Associates 2006)

PROPOSED CHANGES TO HYDROLOGY OF THE AREA

The proposed works affect the majority of the Vinifera floodplain including watercourse, wetland and forest habitats (Table 113, Figure 38).

Table 113. Inundation of Water Regime Classes by proposed works at Vinifera Park

Water Regime Class	Area (ha)
Seasonal Wetland	92
Red Gum Swamp Forest	182
Red Gum Forest and Woodland	56
Black Box Woodland	2.4

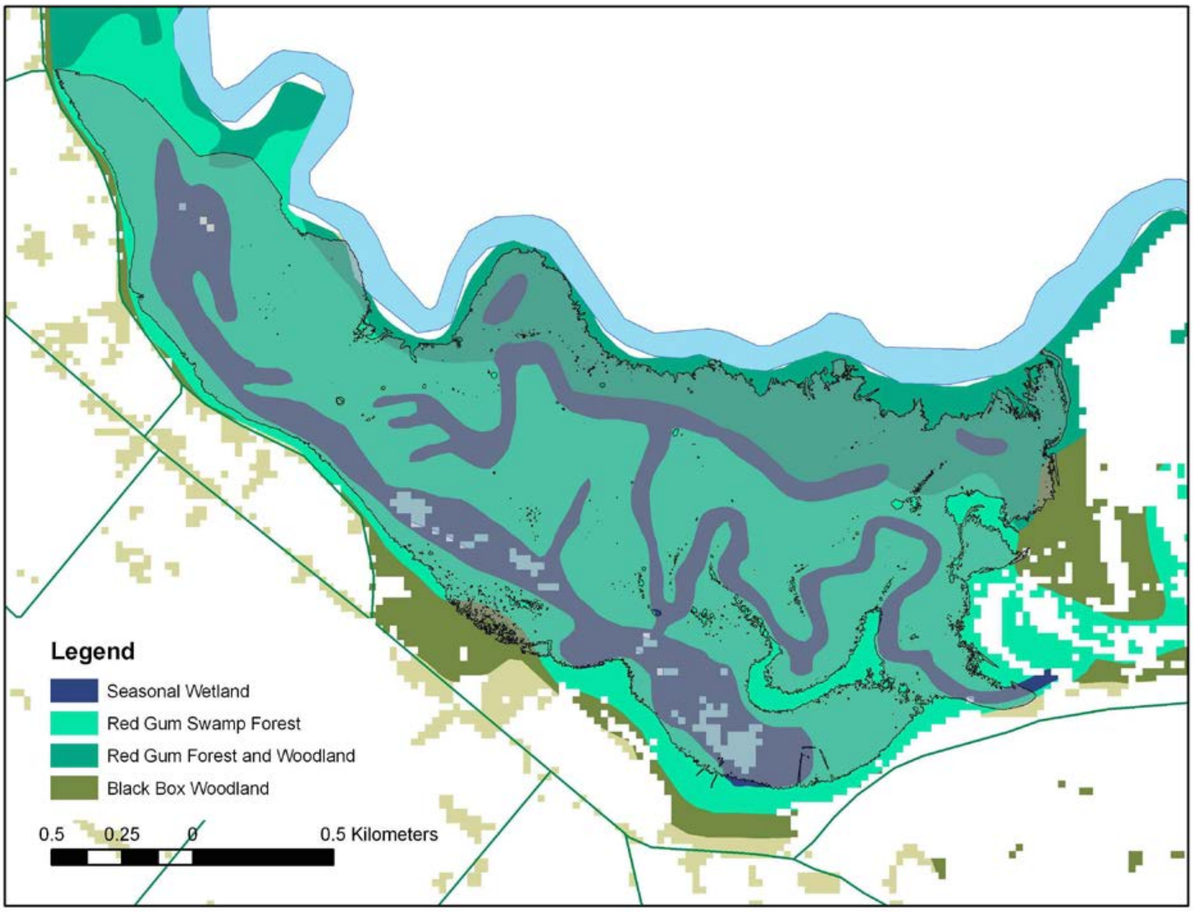


Figure 38. Inundation of Water Regime Classes by proposed works at Vinifera Park

DESIGN

It is proposed to meet ecological targets for flood duration and frequency using flow detention and regulating structures. Water will be detained in the floodplain basin by regulating outflows to the north.

The primary component of the works is a regulator and stop bank near the downstream river connection of Vinifera Creek. The bank will be created by raising an existing track to retain water at a level of up to 64.2 m AHD. The regulator will be installed in the bank to allow through-flow in the creek and to manage water levels. A second regulator is required at the upstream entrance of Vinifera Creek to maintain the ponded area. Minor works are also required at effluents along the river levee to prevent the escape of water. The works will inundate up to 340 ha.

OPERATION

The Vinifera Floodplain Management Project will be operated to augment the frequency and duration of floodplain inundation to meet environmental targets.

Table 114. Environmental water requirements

Water Regime Class	Hydrological Targets	Ecological Objectives
Seasonal Wetland	Wetlands completely dry 1 year in 10 Wetland depth to exceed retention level of wetland 9 years in 10 - 5 of these events to last more than 6 months - 4 of these events to last more than 9 months	Restore resident populations of frogs and small fish Provide seasonal feeding and reproductive opportunities for riverine fish species Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species
Red Gum Swamp Forest	For areas above an inundation threshold equivalent to 17,500 ML/d - provide flooding 9 times in 10 years - five of these events to be 5 months long - four of these events to be 7 months long	Restore resident populations of frogs and small fish Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species Contribute to the carbon requirements of the River Murray channel ecosystem
Red Gum Forest and Woodland	For areas above an inundation threshold equivalent to 20,000 ML/d - provide flooding 9 times in 10 years - five of these events to be 2 months long - four of these events to be 6 months long	Restore resident populations of frogs and small fish Restore the structure of wetland plant communities Provide reliable breeding habitat for waterbirds, including colonial nesting species Contribute to the carbon requirements of the River Murray channel ecosystem

The structures will be operated to achieve environmental watering targets under three scenarios.

- Under normal flow conditions (when no environmental watering is occurring) the upstream and downstream regulators on Vinifera Creek will be open.
- When a flow peak is anticipated, the regulators will remain open to allow floodwater to enter and to allow movement of aquatic fauna. As river levels fall, the regulators will be closed to store flood water. The level at which water is stored will depend on the ecological objectives of the event. When the hydrological targets of the watering event are met, water will be released at the downstream regulator.
- If peaks in river flow are too infrequent to meet environmental watering targets, part or all of the system may be flooded by temporary pumps installed on the river bank.

SPECIFIC ECOLOGICAL TARGETS

Specific ecological targets have been developed to measure progress towards the ecological objectives. The targets:

- describe an ecological outcome or process;
- are quantitative and measurable;
- are time-bound; and
- are justified by existing site data or scientific knowledge.

Most of the ecological targets compare the current state of the ecosystem with a future state after the recommended water regimes have been applied. The time frames in the targets are based on the works being commissioned in 2020. It is expected that the ecological outcomes will only be achieved after the water regimes have applied for several years. The lag will be due to the time required for vegetation to adapt to the new flooding conditions, for floodplain productivity to increase, for additional energy and nutrients to be distributed through the food web and for fauna populations to respond. Targets based on relatively stable variables are evaluated in 2030. Targets based on the frequency of an event occurring are evaluated over the period from 2025 to 2035.

The ecological targets require a baseline to be established any time before the works are commissioned; the targets specify 2015 for current purposes.

The target are based on the extent of habitat that will be affected by the works, the degree of hydrological stress the works will relieve and expert opinion. Where data is poor, targets are conservative.

In most cases existing monitoring programs can be applied or adapted to evaluate the targets including TLM monitoring (Henderson, et al. 2013) and MDBA tree health monitoring (Cunningham, et al. 2011).

However, new methods will be required to evaluate the export of carbon to the floodplain. While the potential significance of the floodplain as a source of carbon in the riverine food web is appreciated (Robertson, et al. 1999); (Oliver and Lorenz 2010), there have been no direct measurements of the carbon conveyed to the river by flood events in the River Murray(Oliver and Lorenz 2010); (Gawne, et al. 2007) In the absence of data, the target for carbon contribution to the river is conservatively set at a 100% increase from current levels. However, given the extent and increased floodplain inundation frequency under the works, much higher contributions are possible.

Table 115. Vinifera Park specific ecological targets

Objective	Target
Restore the vegetation structure of wetland plant communities	The projected red gum canopy cover in seasonal wetlands decreases by 50% from 2015 levels by 2030 The projected aquatic macrophyte plant cover in December in seasonal wetlands exceeds 50% by 2030.
Re-establish resident populations of frogs and small fish	At least four native fish species are present in seasonal wetlands every spring between 2025 and 2035. At least three frog species are present in seasonal wetlands every spring between 2025 and 2035.
Provide reliable breeding habitat for waterbirds, inclduing colonial nesting species	Any species of waterfowl, crake, rail, waterhen or coot breeds every year between 2025 and 2035 at Vinifera Park. Cormorants and / or nankeen night heron breed at Nyah Park on at least six occasions between 2025 and 2035
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	All red gum and black box stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035. Total bat abundance increases by 25% from 2015 levels by 2030
Contribute to the carbon requirements of the River Murray channel ecosystem	The average annual carbon load (dissolved and particulate) to the River Murray from Vinifera Park for the period 2025 to 2035 is double 2015 to 2020 levels.

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