Environmental Water Management Plan

Photo: Cardross Lake, Cardross

Cardross and Koorlong Lakes

mallee catchment management authority

Document Control

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Contact

For queries regarding this document, please contact:

Mallee Catchment Management Authority

Email: reception@malleecma.com.au

Phone: 03 5001 8600

Cover image: Cardross Lake, Cardross.

Acknowledgement of Country

Mallee Catchment Management Authority (CMA) acknowledges and respects Traditional Owners, Aboriginal communities and organisations. We recognise the diversity of their cultures and the deep connections they have with Victoria's lands and waters. We value partnerships with them for the health of people and Country.

Mallee CMA Board, management and staff pay their respects to Elders past, present and emerging and recognise the primacy of Traditional Owners' obligations, rights and responsibilities to use and care for their traditional lands and waters.

Abbreviations and acronyms

AVIRA	Aquatic Value Identification and Risk Assessment
CAMBA	China-Australia Migratory Bird Agreement
CMAs	Catchment Management Authorities
DEH	Department of Environment and Heritage
DEECA	Department of Energy, Environment and Climate Action
DSE	Department of Sustainability and Environment
EA	Ecological Associates
EPBC	Environment Protection and Biodiversity Conservation Act
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
EWH	Environmental Water Holder
EWR	Environmental Water Reserve
FFG	Flora Fauna Guarantee Act
FSL	Full Supply Level
G-MW	Goulburn-Murray Water
JAMBA	Japan-Australia Migratory Bird Agreement
MCMA	Mallee Catchment Management Authority
MDBA	Murray-Darling Basin Authority (formally Murray-Darling Basin Commission, MDBC)
Ramsar	Global treaty adopted in the Iranian city of Ramsar in 1971 that focuses on the conservation of internationally important wetlands
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RRG	River Red Gum

SWP	Seasonal Watering Proposals
TLM	The Living Murray Initiative
TSL	Targeted Supply Level
VEWH	Victorian Environmental Water Holder
VWMS	Victorian Waterway Management Strategy
WMU	Waterway Management Unit

Executive summary

Environmental water management plans have been developed for key sites in the Mallee region by the Mallee Catchment Management Authority (CMA) in partnership with the Victorian Department of Energy, Environment, and Climate Action (DEECA). These plans are based on waterway management units (WMUs) of the Murray River floodplain and have been developed to guide future environmental water events at these sites. This EWMP has been developed for Cardross and Koorlong Lakes, which are situated 15 km's south-west of Mildura. This plan focuses on a target area within the Dispersed Wetlands - Saline Irrigation Drainage WMU for environmental watering events with an inundation extent of 108.5 ha.

Cardross and Koorlong Lakes are high-profile sites for environmental watering, with high numbers of visitors due to their environmental values and their proximity to Mildura. Environmental values for the Dispersed Wetlands - Saline Irrigation Drainage WMU include a diverse range of water dependent flora and fauna species including some listed under state, national and international treaties, conventions, Acts, and initiatives such as the Murray hardyhead. The area also contains several depleted and vulnerable water dependent ecological vegetation classes and wetlands. The target area has significant social values for the local community and the local Indigenous community has connections to the area. The values which are central to the management of the site are the Murray hardyhead population and the Ruppia aquatic macrophyte community which provide essential habitat for Murray hardyhead.

This EWMP was developed in collaboration with key stakeholders, including Lower Murray Water, DEECA, and local interest groups. This plan also outlines consultation with Traditional Owners to review and provide input into the plan.

Several risks associated with environmental water delivery have been identified, and management measures have been put in place in an attempt to decrease and/or mitigate these risks.

The long-term management goals of Cardross and Koorlong Lakes are:

- To provide a water regime to maintain and improve threatened fish and waterbird populations.

To achieve these objectives, a long-term watering regime has been developed. To achieve the management goals to maintain and improve Murray hardyhead populations and preserve Ruppia at these sites a rigid water regime is proposed which will potentially require annual watering.

The ecological objectives for Cardross and Koorlong Lakes target area are outlined below:

CK1: By 2030, improve the population of Murray hardyhead (Craterocephalus fluviatilis) at Koorlong Lake.

CK2: By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with Ruppia beds containing both R. polycarpa and R. megacarpa.

CK3: By 2030, maintain representative populations of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at the Koorlong Lake asset, by maintaining a mixture of shallow and deep-water habitats.

The following minimum and optimal regimes for the short-term and long-term have been developed to sustain and improve the ecological components of Cardross and Koorlong Lakes. The short-term regime is shown below.

Table 1. Cardross and Koorlong Lakes short-term regime

Short-term regime
Minimum watering regime Provide environmental water to the target areas each year from August to October to above the minimum recommended level (36.7mAHD). Allow the water level to decrease slowly over summer, ensuring it does not fall below the identified minimum level (36.7mAHD).
Optimal watering regime Provide environmental water to the target area each year from August to October to the recommended optimal level to inundate fringing vegetation (36.7-38.0mAHD). Allow the water level to decrease slowly over summer to (but not below) the recommended minimum water level (36.7mAHD).

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1. Introduction

An EWMP is a management plan for a wetland, wetland complex or river system that sets out the environmental watering goals and objectives, and the water regime required to meet the set objectives. An EWMP describes the:

- consultation undertaken for EWMP preparation and implementation
- asset overview and characteristics
- water-dependent environmental values present
- water-related threats to the environmental values
- management goals for the asset
- environmental objectives, targets and values that environmental watering of the asset will support or improve
- watering requirements needed to meet environmental objectives
- environmental water delivery infrastructure, management and constraints
- risks associated with environmental water delivery
- outcomes intended to be demonstrated through monitoring and assessment, and
- knowledge gaps to address.

This Environmental Water Management Plan (EWMP) has been prepared by the Mallee Catchment Management Authority (CMA) to establish the long-term management goals of the Cardross and Koorlong Lakes. Cardross and Koorlong Lakes are located 15km Southeast of Mildura.

The Cardross and Koorlong Lakes EWMP was developed in 2015 and updated in 2020 to review and update the ecological objectives. The EWMP was updated in 2021 to make it compliant with the draft version 6 of the EMWP guidelines, which were released in early 2021. The latest version of the EWMP (2023 has been updated to incorporate new information and align with the Department of Energy, Environment and Climate Action (DEECA) Draft EWMP Guidelines (Version 6 – April 2022).

Environmental water management in Victoria is entering a new phase as ongoing water recovery sees significant volumes of water being returned to the environment. The increasing environmental water availability is providing new opportunities to protect, restore and reinstate high value ecosystems throughout northern Victoria. The spatial coverage of environmental watering has expanded considerably in recent years and this trend will continue.

Management of environmental water in Victoria is a statewide partnership between the Victorian Environmental Water Holder (VEWH), catchment management authorities (including Melbourne Water), the Department of Energy, Environment and Climate Action (DEECA), land managers including Parks Victoria and local councils, water corporations, Traditional Owner groups, and interstate agencies including the Commonwealth Environmental Water Office (CEWO) and the Murray–Darling Basin Authority (MDBA).

Environmental watering in Victoria has historically been supported by management plans such as EWMPs, that document key information including the watering requirements of an asset, predicted ecological responses and water delivery arrangements. These plans support annual decisions about which sites should receive water and help managers evaluate how well those assets responded to the water they received or what could be done better.

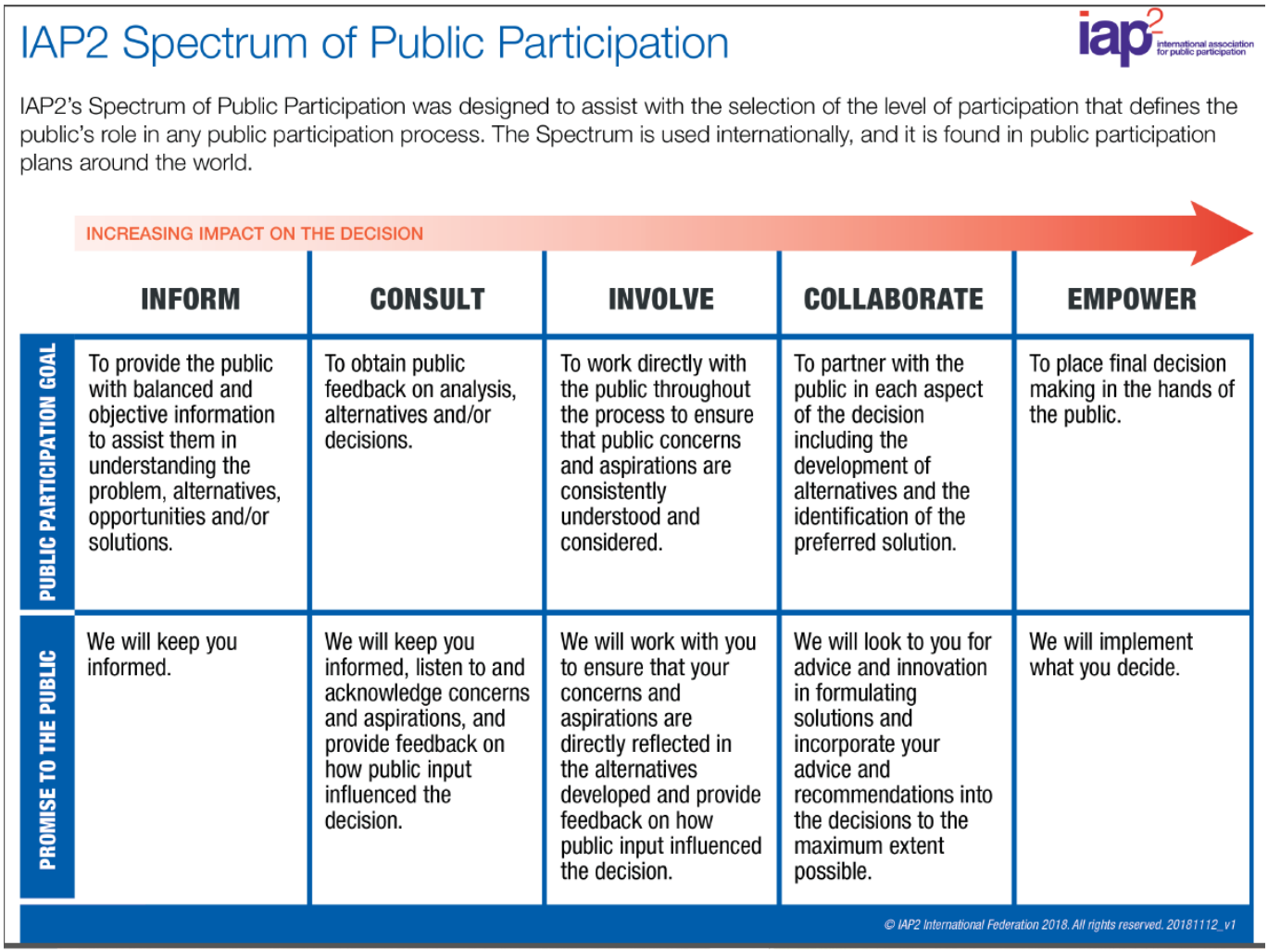
Information on how this EWMP relates to other environmental water documents and policies is included in Appendix 1.

2. Partnership and consultation

2.1 Target Audience

This section identifies the target audience and modes of consultation necessary to manage environmental water delivery, report against stated objectives and targets, and promote adaptive management over the life of the EWMP.

Engagement with different stakeholder groups is based on the International Association of Public Participation (IAP2) spectrum (Figure 1). The spectrum allows for a tailored approach based on stakeholder groups and their needs.



IAP2 Spectrum of Public Participation

IAP2's Spectrum of Public Participation was designed to assist with the selection of the level of participation that defines the public's role in any public participation process. The Spectrum is used internationally, and it is found in public participation plans around the world.

INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 1. IAP2 Spectrum

Source: (c) International Association for Public Participation www.iap2.org

Table 2 lists the main stakeholder groups with an interest in environmental water based on their needs and interests and level of engagement required. To read more about the role of specific stakeholders in overseeing environmental water at Cardross and Koorlong Lakes, refer to Section 3.2.

Mallee CMA develops a communication and engagement plan each year that covers environmental watering events for the entire Mallee CMA region, including Cardross and Koorlong Lakes. This ensures that all stakeholders and community members are aware of the Cardross and Koorlong Lakes environmental watering operations.

Table 2. Stakeholder groups with an interest in environmental water at Cardross and Koorlong Lakes

Stakeholder groups	Stakeholders	Needs and interest	IAP2 level	Consultation modes
Traditional Owners and Interested Parties	See Section 2.4: Traditional Owners	Ongoing connection to Country and protection of cultural heritage and values. Environmental impacts and benefits. environmental watering regimes and how these may be timed to support/promote cultural values.	Collaborate	Via Mallee CMA's Traditional Owner engagement team. Consultation is largely undertaken in-person and, where possible, on Country.
Victorian water holders	VEWH	Make decisions about annual environmental water usage.	Collaborate	Via formal meetings.
River operators	Lower Murray Water	Manage water storage.	Collaborate	Via formal meetings.
Scientists	Arthur Rylah Institute, consultancies	Floodplain health, biodiversity and use of environmental water.	Involve	Workshops, meetings, phone calls.
Public land managers	Parks Victoria, DEECA Forest Fire and Regions Group	Managing impacts from watering such as access.	Collaborate	Via monthly meetings.
Local government	Mildura Rural City Council	Access during watering events.	Involve	Meetings, phone calls, correspondence.
Basin-wide river management	MDBA	River Murray operations.	Involve	Via formal meetings.
Private landowners and managers	Adjacent landholders and managers	Possible access to properties during operation as defined in landholder agreements.	Collaborate	Directly affected landholders will be informed of watering proposals and asked to provide feedback if relevant.
Community (interest groups)	Irrigators Community Advisory Groups Environmental, recreational and social groups	Consumptive water use/access. Watering benefits and impacts on local communities such as access to parks and river during watering events.	Inform	Via existing groups such as the Mallee CMA Land and Water Committee. Via Mallee CMA social media and news.
Media	Local, state and national media outlets	Across issues that interest the local community.	Inform	Media packs and media releases.

2.2 Developing / Updating the EWMP

Mallee CMA carried out community consultation through the following channels:

- Mallee CMA Land and Water Advisory Committee
- surveys at community events such as farmers' markets
- workshops and on-country visits with Traditional Owners (see Section 2.4)
- campaign emails
- meeting with landholders
- social media channels.

Relevant government agencies were invited to participate in the consultation process via a formal letter. They have also been engaged through existing channels, with discussions and presentations.

The key outcomes from this engagement were:

- ensuring that Traditional Owner values were represented in the ecological outcomes.
- building more frequent initial watering into the proposed watering regime to help the landscape recover and monitoring outcomes to determine future water needs, in response to Traditional Owner feedback.

2.2.1 Verifying asset values

Asset values at Cardross and Koorlong Lakes have been established through environmental assessments and the development of previous versions of this EWMP. Consultation has been a key part of these processes with Traditional Owners, community members and technical specialists. Mallee CMA has continued to engage on asset values throughout the development of the EWMP, particularly with Traditional Owners and private and public landholders.

2.2.2 Informing proposed management objectives, targets and approaches

Mallee CMA has long worked with those who have an extensive knowledge of Cardross and Koorlong Lakes and floodplain ecosystems. This work has been central to providing a basis for local knowledge and expertise.

Combined with the Seasonal Watering Proposal, the data and knowledge from the will guide future watering events, as part of the adaptive management approach (see Section 11: Adaptive Management).

2.2.3 Promoting adaptive management

Mallee CMA and other partners will take an adaptive management approach taking into account both varying seasonal conditions and lessons learned from previous events (see Section 11: Adaptive Management).

After the annual adaptive management checkpoint, Mallee CMA will adapt the EWMP if needed, which would then go through consultation, giving stakeholders the opportunity to see any updates.

2.3 Community Engagement

Community stakeholders were engaged via an online survey, which was hosted on the Mallee CMA website in January-February 2023. The survey was designed to enable community, landholders, recreational users, Landcare groups, environmental groups and other interested parties to provide input to the plans. The survey supplements earlier community engagement about the Cardross and Koorlong Lakes EWMPs, and annual community engagement that informs the Seasonal Watering Proposal (SWP). Two survey respondents nominated Cardross and Koorlong Lakes important sites for them, however no further information was provided on the specific values of this site.

2.4 Traditional Owners

Cardross and Koorlong Lakes are located within the formally recognised Country of the First People of the Millewa-Mallee Aboriginal Corporation (FPMMAC), FPMMAC were engaged in March 2023 to collaborate on the EWMP update process. This involved a presentation to a group of TO's from FPMMAC about the sites included in the update. Discussions included ecological, social and cultural outcomes and watering regimes to support these. Engagement and discussions about these topics will be on going and essential to future watering programs.

FPMMAC have indicated in DEECA's EWMP guidelines how they would like to be consulted about environmental watering. Consultation with FPMMAC, in-line with the EWMP guidelines, is ongoing. Engagement with Traditional Owners is conducted

on a one-on-one basis at the COLLABORATE level of the IAP2 framework, with the level of interest and involvement self-determined by FPMMAC.

Annual consultation is also undertaken with Traditional Owner groups during the development of the SWP for Cardross and Koorlong Lakes.

3. Asset overview

The Mallee CMA is situated in the north-west of Victoria. The area of responsibility is close to 39,000km^2 (3.9 million ha), and population centres include Mildura, Birchip, Sea Lake, Ouyen, Robinvale, Red Cliffs and Merbein. The boundaries of the Mallee CMA region cover almost one fifth of Victoria, making it the largest area managed by a Catchment Management Authority in the state.

Approximately 40% of the land area within the Mallee CMA boundary is public land, consisting mainly of National Parks, reserves, wilderness areas and large tracts of riverine and dryland forests. The other 60% is predominantly dryland cropping by area, but there is also a significant investment in irrigation of grapes, citrus, almonds, olives, and vegetables along the Murray River corridor which contributes over 40% of the value of agricultural production for the region.

In 2007 the Mallee CMA engaged consultants, Ecological Associates, to investigate water management options for the Murray River floodplain from Robinvale to Wallpolla Island. One of the major outcomes of these investigations (EA, 2007) was the development of a system of Floodplain Management Units (FMUs). These divide the floodplain into management units which are areas in which water regimes can be managed independently, but which are relatively consistent in their ecological values and land uses. The Mallee CMA has based its environmental water management plans on these FMUs to achieve more effective management of hydrologically connected system. The site for this plan is situated outside the scope of the 2007 investigation however the Mallee CMA has expanded the development of the Waterway Management Unit (WMU)'s to incorporate the waterways and wetlands of the Mallee which are not part of the Murray River floodplain.

The site for this plan is within the Dispersed Wetlands – Saline Irrigation Drainage WMU, hereafter referred to as Cardross and Koorlong Lakes in this document. Cardross and Koorlong Lakes are situated 15km south-west of Mildura in the Murray Mallee bioregion.

3.1 Catchment setting

The Cardross and Koorlong Lakes are situated approximately 15 km south-west of Mildura in the Murray Mallee bioregion. The Murray Mallee bioregion is typified by calcareous material in the form of a broad undulating sandy plains that is often associated with linear, west-east aligned, low sand dunes with intervening heavier textured swales developed from Cainozoic deposits of alluvial, aeolian and swampy deposits. The vegetation is dominated by East/West-Dune Mallee with some Chenopod Mallee and Shallow-Sand Mallee. The plains, drainage lines and groundwater discharge landscapes are dispersed with salt lakes and gypsum flats with lunettes developed on the eastern margins of the lakes. The Cainozoic deposits give rise to calcareous earths (Calcarosols), cracking clays (Vertosols), red sands (Rudosols). The vegetation is dominated by Gypseous Plains Shrubland, Saline Shrubland (Raak), Plains Grassland and Drainage-line Grassy Woodland.

Cardross / Koorlong Wetlands

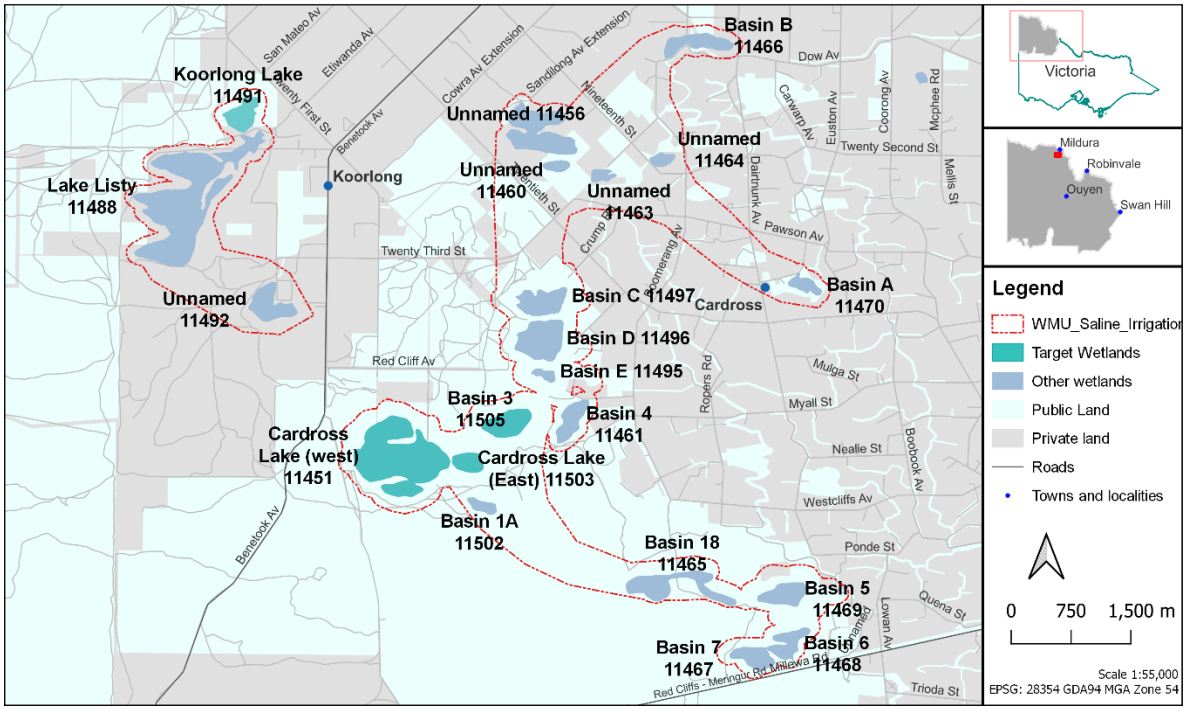


Figure 2. Cardross and Koorlong Lakes

The WMU boundary indicates the area for which water regimes can be managed largely independently of each other. Cardross and Koorlong Lakes have a water requirement as a wetland complex of 554 ha but the focus for this plan is restricted to a target area within Cardross and Koorlong Lakes of 108.5 ha, as shown in Figure 2. The target area at Cardross Lakes is restricted to Cardross Lake (west) (#11451, 73.2ha), Cardross Lake (east) (#11503, 7.99 ha) and Basin 3 (#11505, 15.5ha). The target area at Koorlong Lakes is restricted to Koorlong Lake (11.81ha).

3.2 Land status and management

Parks Victoria is the land manager of Cardross and Koorlong Lakes. Mallee CMA is the Waterway Manager; other agencies have a supporting role in environmental water delivery.

Cardross and Koorlong Lakes are managed as drainage basins by Lower Murray Water under the Land Conservation Council (LCC) recommendations. The Lakes are surrounded by crown and freehold land and state forest which is managed by the Department of Energy, Environment and Climate Action (DEECA).

Table 3. Environmental Water Management at Cardross and Koorlong Lakes

Organisation	Management role
Minister for Water (Vic)	• Oversee Victoria's environmental water management policy framework, and its implementation. • Administer the broader water allocation and entitlements framework and the *Water Act 1989* (Vic).
Mallee CMA	• The waterway manager that plans and identifies environmental water needs across the Mallee region *Water Act 1989 (Vic*). • Approves and manages delivery of environmental water and monitoring and reporting of outcomes, in accordance with ecological objectives.

Organisation	Management role
Parks Victoria	• The land manager for the Crown land under the *National Parks Act 1975* (Vic) and *Crown Land (Reserves) Act 1978* (Vic). • Manages pests and specific environmental impacts. • Supports watering on public land and manages any impacts, for example by engaging with site visitors about environmental water-related matters and managing public access during and after an event.
DEECA	• State level environmental management planning, land management and threatened species manager
Lower Murray Water	• Local Water Authority; manages the Cardross and Koorlong Lakes environmental water infrastructure
Murray-Darling Basin Authority	• Management and operation of the Murray River (Milloo) on behalf of the Basin States in accordance with the *Water Act 2007* (Cth).
VEWH	• Responsible for statewide planning for the use of Victoria's environmental water and allocating its water to seasonal environmental watering actions.
CEWO	• Provides water across the Murray–Darling Basin to meet environmental priorities and targets in accordance with the requirements of the Basin Plan.
First People of the Millewa Mallee Aboriginal Corporation (FPMMAC)	• Local registered aboriginal party (RAP) • Mallee CMA partners with FPMMAC in environmental water management at Cardross and Koorlong Lakes by inviting FPMMAC to be involved in water planning and management, through; 1. collaborating on ways environmental water deliveries can complement/support/promote cultural values and uses 2. working together to determine annual watering actions and priorities • monitoring and assessing water deliveries, where possible.

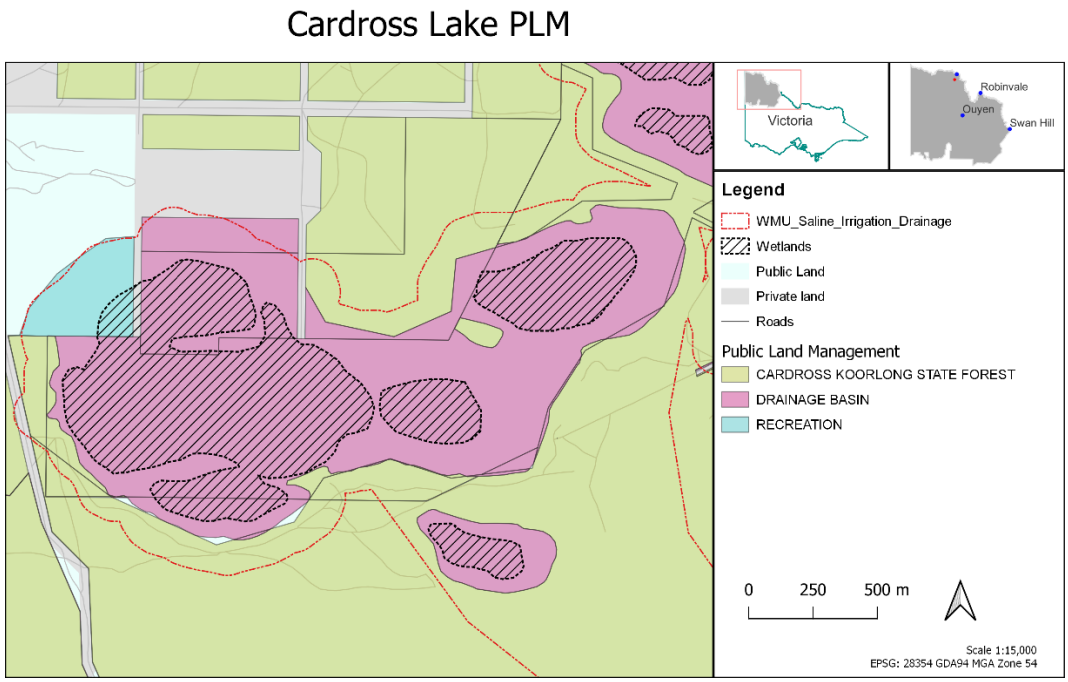


Figure 3. Land management boundaries within Cardross Lakes

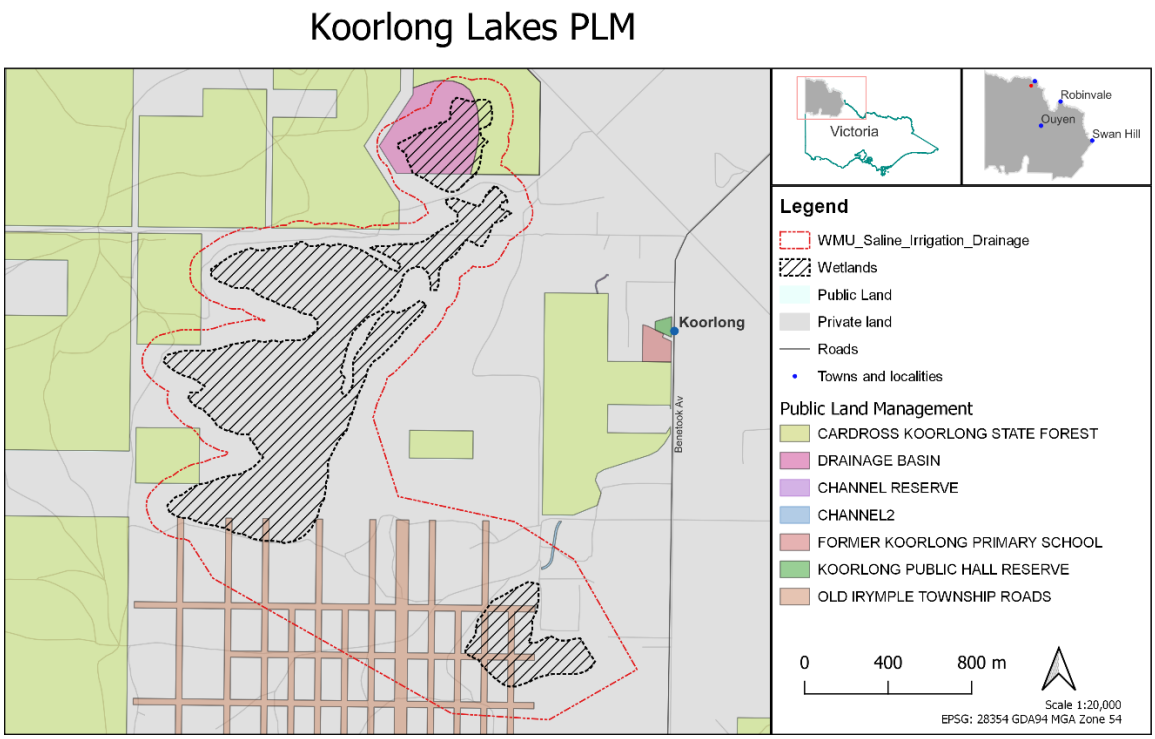


Figure 4. Land management boundaries within Koorlong Lake

3.3 Asset characteristics

Cardross and Koorlong Lakes are located 15 km south-east of Mildura and the target area covers 108.5 ha.

The primary use of Cardross and Koorlong Lakes is for irrigation drainage disposal – it is likely that this use will continue into the future. These artificially constructed wetlands now host a range of important environmental, social and cultural values. The Mallee CMA acknowledges that there are opportunities to protect the values of the sites within Cardross and Koorlong Lakes through environmental watering.

Table 4. Wetland characteristics at Cardross and Koorlong Lakes

Characteristics	Description
Name	Cardross and Koorlong Lakes
Mapping ID (Wetland Current layer)	Cardross sub-unit: Cardross Lake (west) (#11451), Cardross Lake (east) (#11503), Basin 1A (#11502), Basin 3 (#11505), Basin 4 (#11461) Basin 5 (#11505), Basin 6 (#11468), Basin 7 (#11467), Basin A (#11470), Basin B (#11466), Basin C (#11497), Basin D (#11496), Basin E (#11495), and numerous unnamed wetlands (#11456, #11460, #11463, #11464). Koorlong sub-unit: Koorlong Lake (#11491), Lake Listy (#11488), and unnamed wetland (#11492).
Area of wetlands in target area	108.5 ha
Bioregion	Murray Mallee
Conservation status	Listed on the Directory of Important Wetlands in Australia

Characteristics	Description
Land status	LMW Drainage Basins, State Forest, Freehold and Crown Land
Land manager	LMW, DEECA
Surrounding land use	Irrigated horticulture
Water supply	Lower Murray Water supply
Wetland category (Wetland Current layer)	Permanent freshwater lakes, Permanent saline lakes, Permanent saline marshes and meadows, Temporary freshwater lakes, Temporary freshwater marshes and meadows, Temporary freshwater swamps/marshes/meadows, Temporary saline marshes and meadows
Wetland depth at capacity	Unknown

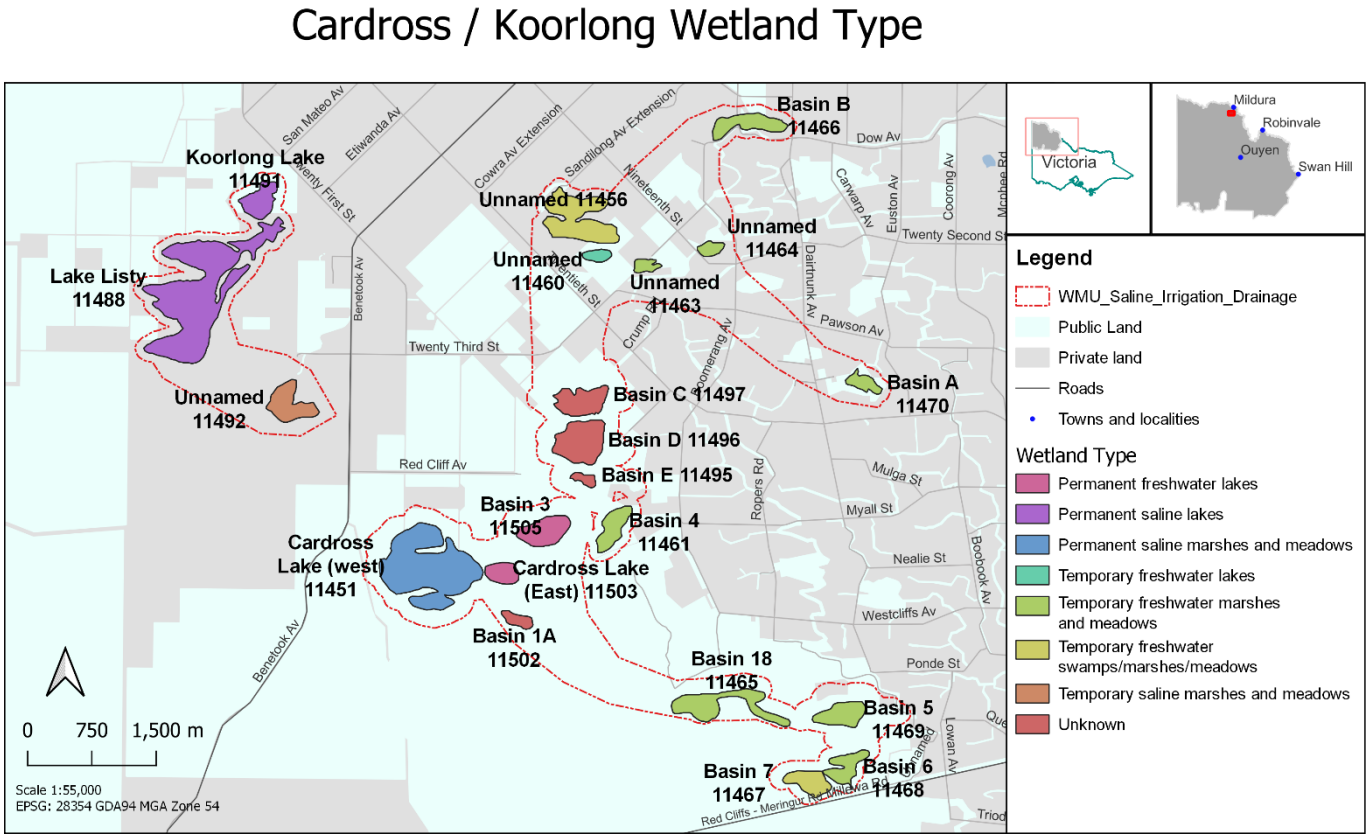


Figure 5. Wetland locations and classification at Cardross & Koorlong Lakes

3.4 Environmental water sources

Water delivered to Cardross and Koorlong Lakes will be made available by the VEWH under the *Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999* held by the VEWH. This may include water held by the CEWO and donated water. Other sources of water may become available through water trading or changes in water entitlements.

Figure 6. Cardross Lake (west)

4. Current/historical hydrological regime and system operations

Wetland hydrology is the most important determinant in the establishment and maintenance of wetland types and processes. It affects the chemical and physical aspects of the wetland which in turn affects the type of flora and fauna that the wetland supports (DSE 2005). A wetland's hydrology is determined by surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration (Mitsch and Gosselink, 2000 in DSE 2005). Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers.

The target area within Cardross and Koorlong Lakes is located 15km southwest of Mildura. These wetlands are relatively unique in that they are not naturally occurring and have no connection to the Murray River. The lakes were established in the 1930's as part of Australia's first irrigation drainage scheme and rely on this drainage inflow to sustain water levels within the lakes.

The Cardross Lakes are a series of connected basins which were historically used to provide irrigation drainage disposal for the Red Cliffs Irrigation District (SKM 2002). A total area of 904 ha of land drained into the Cardross Lakes basins, excluding Basin 5 (Ryan et al. 2003). Prior to the establishment of a pipeline system to the Red Cliffs area, excess irrigation water drained freely to the Lakes via channels. Increased irrigation efficiency in the district has led to decreased inflows to the Lakes and increased salinity levels (SKM 2002). The Lakes are now managed by Lower Murray Water.

Drainage inflows to the Cardross system gravitate from Basins A and B, which are at the highest elevation, then to Basins C, D and E. Flows then pass through an earthen channel to Basin 3, Cardross Lake (east) and Cardross Lake (west) Drainage water from Basin 4 also gravitates via a channel to Cardross Lake (west). Cardross Lake (west) incorporates Cardross Lake (east) and Basin 3 when water levels are high enough but as water levels drop these basins may become isolated from one another. Ryan et al. (2003) predicted the frequency of disconnection between these basins was expected to increase as irrigation drainage

inflows continued to decrease. The previously named Basin 1 is now divided by a levee with the section east of the levee known as Cardross Lake (east) and the section west of the levee known as Cardross Lake (west).

Basin 1A is a terminal basin that is connected to southern end of Cardross Lake (west) via an open channel. Water only reaches Basin 1A when water levels in Cardross Lake (west) reach approximately EL 40.9m. Basin 5 is located 3km south-east of Cardross Lake (west) and receives excess irrigation flows. Basin 5 outflows to Basin 18 when full via an open channel and these basins are not connected to any other basins in the system (SKM 2002). Environmental water is delivered to Cardross Lakes through a channel to Basins E and 3 (Ellis 2013). This water is now all diverted directly to Cardross Lake (west).

The Koorlong Lakes are also a system of irrigation drainage basins close to Cardross Lakes, although the two systems are not connected. Koorlong Basin at the northern end of the system was originally a natural rainwater catchment area that had a tank constructed on site to retain water in the early days of Mildura Sheep Station. This was then called Irymple Tank. The drainage infrastructure that flows into Koorlong Lake (or Irymple Tank) was constructed in the 1930's when the Red Cliffs drainage scheme was established. This lake now receives drainage from surrounding land in the Red Cliffs Irrigation district.

The larger Lake Listy (or Koorlong South Lake) receives water from Koorlong Lake during periods of high drainage via a connecting channel (Ellis 2013). This basin also receives drainage from surrounding land in the Red Cliffs Irrigation district. The Koorlong Lakes also receive some storm water run-off from nearby residential properties (LMW 2013).

Figure 7. Cardross Lakes (Basin C)

4.1 Environmental watering

Environmental water is delivered to the Cardross and Koorlong Lakes through Lower Murray Water infrastructure from the Red Cliffs Irrigation District. As these sites have no connection to the Murray River, environmental water allocations are the only source of water apart from irrigation drainage and stormwater. Water delivery for irrigation uses this same infrastructure, resulting in environmental water delivery being subject to interruption.

Environmental watering at Cardross Lakes was originally provided to support the diverse native fish communities at this site up until 2001/2002. In 2004 Murray hardyhead became the focus of the environmental watering program at this site. In 2007 the Department of Sustainability and Environment (now DEECA) set up an Emergency Action Plan to preserve Murray hardyhead habitat effected by reduced water supply, including Cardross Lakes (Ellis et al. 2011). The Plan was established to try to prevent the extinction of Murray hardyhead which were at this time limited to four populations in Victoria and three in South Australia (Ellis 2008). This Action Plan resulted in delivery of environmental water supply to Cardross Lakes.

As part of the 2007 Action Plan a channel to allow diversion of environmental and drainage water directly to Basin 1 was constructed. A levee was later constructed to reduce environmental water requirements and confine delivery to a small section of Basin 1 (now referred to as Cardross Lake (east)) for the management of Murray hardyhead. Cardross Lake (east) received environmental water from the Victorian River Murray Flora and Fauna Bulk Entitlement since 2007 to sustain the Murray hardyhead population at this site. Cardross Lake (west) was dry for almost two years before being reconnected to Cardross Lake (east) in July 2010. Environmental water has since been used to maintain the connection and water levels in Cardross Lake (east) and Cardross Lake (west) with approximately 1026.7ML delivered to these basins in 2012-2013 (Ellis 2013).

DSE (now DEECA) and the Mallee Catchment Management Authority (MCMA) began delivering environmental water to the Koorlong Lakes in 2009, as the site was deemed suitable for translocation of Murray hardyhead and fish were released to Koorlong Lake later that year (Ellis et al. 2011). Water levels in Koorlong Lake have been sustained through drainage and stormwater inflows since 2010/11.

Table 5. A summary of recent environmental watering events at Cardross and Koorlong

Water year	Inflow source	Total Volume (ML)	
		Cardross	Koorlong
1997/98	Victorian River Murray Flora and Fauna Bulk Entitlement	800	0
1998/99		1000	0
1999/00		1200	0
2001/02		1766.8	0
2002/03		1997.1	0
2003/04		2005.2	0
2004/05		1702	0
2005/06		1060.1	0
2006/07		810.1	0
2007/08		145.7	0
2008/09		138.524	0
2009/10		119.066	93.235
2010/11		1012.726	36.028
2011/12		820.602	6.7
2012/13		1026.662	0
2013/14		1012.174	0
2014/15		576.502	0
2015/16		953.225	0
2017/18		505.818	0
2018/19		0	56.83
2019/20		0	147.85
2020/21		0	62.34
2021/22		0	0
2022/23		0	0

5. Water-dependant values

Wetlands and waterways on the floodplain are a vital component of the landscape and support flora and fauna which vary with the type of wetland/waterway system. The habitat provided by vegetation communities around wetlands is essential for maintaining populations of water dependent fauna species. Other ecological functions provided by floodplain complexes include water filtration, slowing surface water flow to reduce soil erosion, flood mitigation and reducing nutrient input into waterways. Protecting the ecological functioning of wetlands ensures these vital services are maintained.

Cardross and Koorlong Lakes provide a range of shelter and food resources for indigenous fauna, flora and vegetation communities. The types of habitats provided, and consequently the species that utilise the site, change as water fills the wetlands, creek and floodplain and recedes again.

Data from the Victorian Biodiversity Atlas (DEECA, 2016b) and recent monitoring (Ecology Australia, 2022) have been referenced. It is recommended that flora and fauna surveys are repeated at the site to improve knowledge of the site's ecological values.

5.1 Environmental Values

5.1.1. Ecosystem Type and Function

The wetlands in this area are a mix of Permanent-Temporary Freshwater & Saline Lakes, Marshes and Meadows (see Figure 5). Present vegetation communities include Low Chenopod Scrubland, Semi-Arid Woodland, Woorinen Sands Mallee and Chenopod Mallee. The wetland extent of Cardross Lakes has reduced by around 276 hectares between pre-European settlement and now, whereas the wetland extent of Koorlong Lakes has remained about the same.

Wetland ecosystems support distinctive communities of plants and animals and support numerous ecosystem functions. Floodplain wetlands perform important functions necessary to maintain the hydrological, physical and ecological health of river systems.

Three key broad ecosystem functions have been identified for the Cardross and Koorlong Lakes EWMP. Each function is interlinked and must be supported in order for the ecosystem to flourish. The functions are briefly described below.

Creation and maintenance of vital habitat for threatened/endangered species

Wetlands act as refugia for frogs, native fish and waterbirds during periods of extended drought in an arid landscape. Inundation of areas of the wetland woodland mosaic provides a diversity of feeding, breeding and nursery sites for native water-dependent biota including waterbirds.

Maintenance of permanent shallow brackish habitat at Koorlong Lake will allow the key Murray hardyhead population to continue to thrive and expand. Areas of deeper, permanent water with quality in-stream habitat will support a range of fish species, provide a reliable food source for piscivorous waterbirds, and enable suitable depth for diving ducks.

The provision of basking sites within and on wetland edges supports frog habitat at Koorlong Lakes. The abundant hollows and crevices at Cardross Lakes support a high diversity of microbats, including Little Pied Bat (Ecology Australia, 2022).

Diversity of habitat for feeding, breeding and nursery

Seasonal fluctuations in water levels in the wetlands increase the availability of specific habitat niches for feeding, breeding and nursery areas. Permanent and semi-permanent water bodies provide a source of food, refuge from predators and nesting sites and materials (Kingsford and Norman, 2002).

Wetland filling and water recession increases the extent of the band of sedges, rushes and semiaquatic forbs surrounding wetlands. Areas of deeper, permanent water support submerged aquatic macrophytes, and promote high levels of aquatic productivity and high habitat value for frogs, fish, and waterbirds.

The presence of Ruppia sp. at Koorlong Lake supports aquatic habitat, particularly for Murray hardyhead (EA, 2022). Seasonal variation in water levels is recommended by EA (2022), to promote germination of Ruppia.

Transportation and dilution of nutrients and organic matter and increase in macroinvertebrate productivity and biofilm diversity

Drying of wetlands, particularly during summer and autumn, exposes sediments and facilitates decomposition and processing of organic matter. The microbial decay of plant material is an important route for energy and nutrients to enter the riverine food chain (Young, 2001).

Wetland inundation transports nutrients and carbon into the water column, which then becomes available for consumption by bacteria, algae and macroinvertebrates. On re-wetting, decomposition accelerates and becomes more efficient. Carbon and nutrients are released from the soil and enter the water and are available for aquatic plants and animals. The release of energy and nutrients results in increased productivity, with an increase in bacteria and invertebrates (Ecological Associates, 2013). This results in abundant food for fish, birds and other animals.

Fluctuations in water levels allows exposure of substrates such as large wood and plant stems through a drying cycle, which increases the diversity of the biofilms grazed by macroinvertebrates and fish.

Figure 8. Lake Listy

5.1.2 Flora and Fauna

The Cardross Lakes are of national significance and are listed on the Directory of Important Wetlands. There are 4 water-dependant EVCs modelled in the Cardross and Koorlong Lakes target area, described in Table 6. However, surveys conducted by Ecology Australia (2022) noted that the vegetation present at Cardross and Koorlong Lakes was markedly different from the mapped EVC type. The EVCs observed by Ecology Australia are detailed in Table 7.

Table 6. List of EVCs modelled at Cardross and Koorlong Lakes

EVC Number	EVC Name	Bioregional Conservation Status	Observed in 2022 (Ecology Australia, 2022)
EVC 86	Woorinen Sands Mallee	Depleted	No
EVC 97	Semi-Arid Woodland	Vulnerable	No
EVC 102	Low Chenopod Shrubland	Depleted	Yes
EVC 158	Chenopod Mallee	Vulnerable	No

Table 7. List of EVCs observed at Cardross and Koorlong Lakes

EVC Number	EVC Name	Bioregional Conservation Status
EVC 102	Low Chenopod Shrubland	Depleted
EVC 101	Samphire Shrubland	Least Concern
EVC 821	Tall Marsh	Least Concern

Where Semi-Arid Woodland (EVC 97) and Low Chenopod Scrubland (EVC 102) are the modelled EVCs present at Cardross Lakes, only Low chenopod Scrubland (EVC 102) was observed in 2022. Where Semi-Arid Woodland (EVC 97) was the modelled EVC present at Koorlong Lake, Samphire Shrubland (EVC 101) and Tall Marsh (EVC 821) were observed in 2022.

Low Chenopod Shrubland (EVC 102) is present in the bed of Cardross Lake; it is characterised by succulents and a suite of annual herbs and does not rely on inundation events for persistence across the landscape.

Samphire Shrubland (EVC 101) is described as a low open shrub layer to 0.5m of succulent chenopods on saline clay pans. Tall Marsh (EVC 821) is described as a wetland, dominated by tall emergent graminoids (rushes, sedges, reeds), typically in thick, species-poor swards. Tall Marsh (EVC 821) contains almost permanently wet soils and dominant species are tolerant of relatively deep but sustained inundation (but not total immersion for any sustained period).

Figure 9. Lake Listy

Water Dependent Fauna

129 species have been recorded at Cardross and Koorlong Lakes, five of which are introduced. Of special interest and management responsibility are the 14 water dependant fauna species listed in legislation, agreements or conventions.

Cardross and Koorlong Lakes support species listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), and Victoria's Flora and Fauna Guarantee Act 1988 (FFG Act) (Table 8).

These records are drawn from Naturekit (incidental and targeted surveys), and observations undertaken by Ecology Australia in surveys conducted in 2022; however, it is fair to assume that more listed species are likely to occur due to the availability of habitat and nearby sightings.

Table 8. Listed water-dependant fauna at Cardross and Koorlong Lakes

Scientific Name	Common Name	Type	FFG Act	EPBC Act Status
Craterocephalus fluviatilis	Murray hardyhead	F	CE	E
*Emydura macquarii**	Murray River turtle	R	CE	
Mogurnda adspersa	Southern purple-spotted gudgeon	F	CE	
Tandanus tandanus	Freshwater catfish	F	EN	
Chelodina expansa	Broad-shelled turtle	R	EN	
Maccullochella peelii	Murray cod	F	EN	V
Tringa nebularia	Common greenshank	B	EN	
Stictonetta naevosa	Freckled duck	B	EN	
Spatula rhynchotis	Australasian shoveler	B	VU	
Biziura lobata	Musk duck	B	VU	
Aythya australis	Hardhead	B	VU	
Nyctophilus corbeni	South-eastern long-eared bat	M	EN	
Polytelis anthopeplus	Regent parrot	B	VU	
Oxyura australis	Blue-billed duck	B	VU	

Lifeform type: Amphibian (A), Bird (B), Fish (F), Reptile (R), Mammal (M)

EPBC threatened status/Victorian Status - FFG: VU = Vulnerable, EN = Endangered, CE = Critically Endangered, NL = Not Listed

*Note that it is unusual for Murray River turtle to be observed outside of a connected river network.

The above listed species are directly dependent on water due to food, shelter or breeding requirements.

Fish

Koorlong Lake provides habitat for a range of listed threatened species, including Southern purple-spotted gudgeon (*Mogurnda adspersa*), Freshwater catfish (*Tandanus tandanus*), and Murray cod (*Maccullochella peelii*). As well as the listed species, a range of other fish species have been recorded within the target area, including Western carp gudgeon (*Hypseleotris klunzingeri*), Dwarf flatheaded gudgeon (*Philypnodon macrostomus*), Bony herring (*Nematalosa erebi*), Flatheaded gudgeon (*Philypnodon grandiceps*) and Golden perch (*Macquaria ambigua*).

Murray Hardyhead

Murray hardyhead (Craterocephalus fluviatilis) is listed as Endangered under the EPBC Act and Critically Endangered under the FFG Act. Murray hardyhead was once abundant throughout its range but has suffered a dramatic decline due to altered flow regimes and drought. These factors have led to reduced connection between the Murray River and floodplain wetlands and drying of some lake habitats (Lintermans 2007). Altered flow regimes and drought have also impacted on water quality in waterways that historically supported Murray hardyhead (Ellis 2013), increasing salinity and degrading habitat (Lintermans 2007).

Murray hardyhead use the edges of lakes, backwaters and wetlands only in the lowland areas of the southern Murray-Darling basin. They prefer clear, slow-moving or still waters with sand or silt substrate. Juveniles use well vegetated fringes of waterbodies, and the adults are more commonly seen in open deep-water habitat with submerged macrophytes (Ellis, 2005). Plant species associated with the Murray hardyhead include fringing macrophytes such as *Typha* and *Juncus* species and submerged macrophytes such as *Myriophyllum* and *Vallisneria*. The salt-tolerant Ruppia is particularly important in saline lakes (Backhouse, Lyon and Cant, 2008) such as Koorlong Lake. Recently submerged terrestrial vegetation such as areas of chenopod shrubland can provide temporary cover for the species (Ellis et al., 2013).

The Ecology Australia (2022) report noted that the Koorlong Lakes held a significant self-sustaining population of Murray hardyhead. The Koorlong Lake population is a well-known and important stronghold for the species, previously established at this site via translocation in 2009 (Ellis 2013). The Ecology Australia 2022 survey found that the species remains highly abundant at Koorlong Lake, with a healthy population structure including a dominant cohort of juveniles. The hydrological regime and salinity levels at this site are required to be carefully managed to maintain a large and healthy population of Murray hardyhead, particularly in terms of salinity tolerances of eggs/larvae (Ecology Australia 2022). The Ecology Australia report (2022) noted that although adults and juveniles can tolerate higher salinities (e.g. up to 105 ppt, ~190 mS/cm), the tolerances of egg/larvae have been shown to be substantially lower and thus a salinity range of 12–45 ppt (~21–81 mS/cm) is recommended at sites being managed for this species (Stoessel et al. 2020).

Spawning occurs during spring and summer when the water temperature reaches 23-24ºC. The ripening of eggs is a continuous process during the breeding season and females lay a few at a time over a period of about one month (Cadwallader and Backhouse, 1983). A reduction in water depth in shallow wetlands can expose the critical habitat of submerged macrophyte beds and increase inter and intra-specific resource competition (Ellis and Kavanaugh, 2014). Maintaining water levels and the input of fresh water are important for keeping the salinity levels within the tolerable range for eggs and larvae (Ellis, 2005).

Cardross Lake (particularly Cardross Lake (west)) was an important site for Murray hardyhead until at least 2013 (Ellis 2013, Ecology Australia 2022).

Waterbirds

Waterbird diversity and abundance are influenced by wetland habitat diversity, with different species and feeding guilds using different habitats for breeding and foraging (Haig, Mehlman and Oring, 1998). Water depth in particular influences waterbird diversity due to the specific feeding behaviours of different species (Bancroft, Gawlick and Rutchey, 2002). Managing wetlands to provide diverse habitats such as variable water depth, mud flats, inundated vegetation and areas of deep water increases the likelihood of increased waterbird diversity (Taft, Colwell, Isola and Safran, 2002).

Table 9. Waterbird functional feeding groups (Roshier, Robertson and Kingsford, 2002) and their resource use.

Waterbird Group	Food Resource	Habitat Use	Waterbird Group
Dabbling and Diving Ducks (e.g. Chestnut teal, Pink-eared duck, Freckled duck)	Generalists; plankton, small invertebrates, plant material	Shallow Water (Dabblers)	Solitary
Grazing Waterfowl (e.g. Shellduck, Wood Duck)	Plant material, seeds, invertebrates	Shallow Water, littoral zone	Colonial or solitary
Fish Eaters (e.g. Pelican, Cormorants, Grebes, Darter, Egret, Heron, Tern)	Fish	Open and deep water	Colonial
Small Waders (e.g. Stilt, Plovers, Dotterels)	Small invertebrates, seeds	Littoral zone, mudflats	Solitary
Large Waders (e.g. Ibis)	Macroinvertebrates, fish, amphibians	Littoral zone	Colonial or solitary
Shoreline Foragers (e.g. Lapwings, Hens)	Plant material, seeds, invertebrates,	Littoral zone, mudflats	Solitary or small groups

Figure 10. Hardhead duck and Hoary-headed grebes on Lake Koorlong

Reptiles

The Eastern long-necked turtle (*Chelodina longicollis*) is predominantly found in floodplain wetlands such as oxbow lakes, anabranches and swamps. Its ability to persist in these ephemeral habitats is likely due to its capacity to aestivate, resist

desiccation and migrate overland. Females nest in the banks of their residence in early summer laying a clutch of between 2 and 10 eggs with the capacity to lay one to three clutches each year. It feeds on aquatic invertebrates, tadpoles and small fishes.

Broad-shelled turtles are listed as threatened in Victoria. They have less specific habitat requirements occupying both river and wetland habitats, although the wetlands tend to be permanent and located close to the river. Like Eastern long-neck turtles, Broad-shelled turtles, will move over land to find other water sources. They also have the capacity to aestivate in the mud until water levels increase. Broad-shelled turtles usually nest in autumn, early winter or occasionally spring. Nests are often located on sandy ridges and can be located up to 1 km but more commonly within 100 m of the water's edge. The eggs incubate on average for between 324 and 360 days. This means that nests would be vulnerable to inundation which may be why nests are selected on either ridges or distant from the water's edge.

Flora

87 flora species have been recorded at Cardross and Koorlong Lakes, 35 of which are introduced. Three flora species that have been recorded at Cardross and Koorlong Lakes are listed under the FFG Act (Table 10).

Table 10. Listed flora at Cardross and Koorlong Lakes

Scientific Name	Common Name	FFG Act
Sida spodochroma	Limestone sida	EN
Minuria cunninghamii	Bush minuria	VU
Myoporum montanum	Waterbush	EN

Victorian Status - FFG: VU = Vulnerable, EN = Endangered, CE = Critically Endangered, NL = Not Listed

Aquatic macrophytes are vital to the ecosystem at Cardross and Koorlong Lakes. These plants are rooted to the wetland floor with their canopies floating near the water surface. They rise and fall with water levels and provide a physical structure to the aquatic environment as well as providing a food source for waterbirds and habitat for fish (EA 2007). Aquatic macrophytes are highly productive wetland habitats also providing shelter for macro-invertebrates and dabbling ducks such as the Freckled Duck that graze on this vegetation and the macro-invertebrates within it (EA 2007). Aquatic macrophytes are dependent on water for growth and reproduction, and under sudden draw down these plants lose support and collapse and die quickly. The ideal flood requirement is 9-12 months (Rogers & Ralph 2011). They may persist in wetlands that are frequently flooded but if summer drying occurs they will die off and be replaced by lake bed herbs (EA 2007).

Ruppia

Salt tolerant Ruppia species are of particular importance at Cardross and Koorlong Lakes as this macrophyte species provides complex submerged aquatic vegetation for Murray hardyhead. This genus is mostly found in saline wetlands (Sainty & Jacobs 1981). As well as providing protection from predation, Murray hardyhead also use Ruppia for attachment of eggs during breeding. Ruppia also provides habitat for zooplankton fauna which are important dietary items for Murray hardyhead (DSE 2010). Without Ruppia the potential for fauna diversity within these wetlands is reduced (DSE 2004). This makes maintaining and improving Ruppia communities at Cardross and Koorlong Lakes particularly relevant as these saline wetlands are some of the last remaining refuges for Murray hardyhead. Brock (1981) states that the drying of seeds and substrate during a drawdown is likely to break seed coating and make seeds more permeable to water on rewetting of the wetland.

5.1.3. Current Condition

The Cardross and Koorlong Lakes are natural depressions in the terrestrial landscape. In the 1930's these depressions were altered, and infrastructure was constructed to facilitate the use of the basins for drainage as part of Australia's first community irrigation drainage scheme. This has resulted in a network of more than 30 interconnected artificial wetlands some of which are of significant biodiversity value. Cardross Lakes and Koorlong Lake are man-made evaporation basins, and as such would not have naturally supported wetland EVCs (Ecology Australia 2022). Their creation via irrigation drainage is a significant disturbance within the landscape – disconnection to pre-existing natural rivers or wetlands has limited the establishment of indigenous wetland species (Ecology Australia, 2022). Surveys conducted in 2022 found that these inundated sites now support significant infestations of opportunistic exotic wetland species such as Spiny rush (*Juncus acutus* subsp. *Acutus*) (Ecology Australia, 2022).

Figure 11. Cardross Lake (east)

Recent improvements in irrigation techniques have seen less drainage flowing into the lakes causing water levels to drop and salinity levels to increase. In most wetland systems a reduction in irrigation drainage would be considered a significant environmental improvement. In the case of Cardross and Koorlong Lakes however, the reduced water supply poses a major threat to the resident aquatic fauna (Ryan et al. 2003). As a result, this system which Raadik & Harrington (1996, cited in Ryan et al. 2003) considered the most diverse native fish wetland system in Victoria, has already experienced significant decline in fish diversity. The wetlands, in their current state, still provide essential habitat for some of the state's most endangered species

however, particularly Murray hardyhead which can tolerate these saline conditions. The Cardross Lakes are of national significance and are listed on the Directory of Important Wetlands (Ryan et al. 2003).

Koorlong Lake remains important habitat for Murray hardyhead and supports a 'well-known and important stronghold for the species' (Ecology Australia, 2022). Murray hardyhead are highly abundant at Koorlong Lake, with a healthy population structure, including a dominant cohort of juveniles (Ecology Australia 2022). Koorlong Lake is a species-rich site, with a high diversity of fringing and emergent vegetation (Ecology Australia, 2022). A survey undertaken by Ecology Australia in 2022 identified that Koorlong Lake contained by submergent and emergency aquatic vegetation and had an average depth of greater than 1.5m (Ecology Australia, 2022).

Cardross Lake by comparison has a low diversity of species and is heavily modified by weed invasion from the surrounding land (Ecology Australia, 2022). During a survey in 2022, Ecology Australia found no Murray hardyhead or aquatic vegetation present at Cardross Lake, as it was completely dry at the time of surveying. Cardross Lake has previously been an important site for Murray hardyhead until at least 2013, so has the potential to support Murray hardyhead if there is reliable environmental water (Ecology Australia, 2022).

Currently, due to a persistent La Nina and the associated high rainfall across the Murray-Darling Basin, Cardross and Koorlong Lakes are experiencing very wet conditions.

It is likely that Cardross and Koorlong Lakes will be subject to more extreme wetting and drying cycles under a changing climate. It is important to ensure that climate change adaptation is considered in environmental watering management decisions for Cardross and Koorlong Lakes, in order to preserve and enhance their significant environmental values.

Figure 12. Koorlong Lake in April 2023

Index of Wetland Condition

One method for assessing the current condition of a wetland is the Index of Wetland Condition (IWC) developed by DEECA. The IWC defines wetland condition as the state of the biological, physical, and chemical components of the wetland ecosystem and their interactions. The condition of three of the wetlands within the target area of the Cardross and Koorlong Lakes was assessed in December 2009.

The IWC has five sub-indices based on the catchment of the wetland and its fundamental characteristics: physical form, hydrology, water properties, soils and biota. The overall IWC rating for three wetlands assessed in December 2009 was poor (Table 11).

Table 11. IWC sub index and overall scores for Cardross and Koorlong Lakes

Wetland Name	Wetland Catchment	Physical Form	Hydrology	Water Properties	Soils	Biota (Vegetation)	Overall IWC Category
Wetland #7329010030 Cardross Lakes (east & west) *Summary of sites 1, 2 & 3*	Poor	Excellent	Very Poor	Moderate	Excellent	Poor	Poor
Wetland #7329025045 Cardross Lakes Basins C, D & E *Summary of sites 1 & 2*	Poor	Excellent	Very Poor	Poor	Excellent	Very Poor	Poor
Wetland #732902805 Cardross Lakes Basin 4 *Summary of site 1*	Moderate	Excellent	Very Poor	Moderate	Excellent	Very Poor	Poor

The overall hydrology scores were very poor for each wetland and the biota ratings were poor to very poor at each site. Hydrology was considered to be very poor due to a reduction in water reaching the wetlands as a result of improved irrigation practices and dry conditions. These altered conditions are also reflected in the poor biota score which indicates a lack of diversity and abundance of the species expected to be present in these wetlands.

The altered water regime is considered the major threat for the target area of Cardross and Koorlong Lakes and is the primary factor behind the development of this environmental water management plan.

5.2 Shared benefits

While the primary requirement of environmental watering is to achieve environmental objectives and outcomes, environmental water can provide benefits beyond environmental objectives. Shared benefits will arise from improving the condition of an asset by using environmental watering, which in turn may contribute to benefits or outcomes for other water users and values, including for cultural outcomes and increased recreation and amenity value (DEECA EWMP Guidelines 2022, pg. 16).

In addition to its significant environmental values, Cardross and Koorlong Lakes have significant social and economic values. Water-dependant values that were identified for Cardross and Koorlong Lakes are detailed in Table 12.

Table 12. Water-dependant values at Cardross and Koorlong Lakes

Type of value	Water-dependant value
Environmental	Ecosystem function (supporting the health of the river and wetlands)
Environmental	Vegetation
Environmental	Fauna
Cultural	Traditional owner values
Social (Recreational)	Bushwalking
Social (Recreational)	Bird watching
Social (Recreational)	Duck hunting
Social (Recreational)	Fishing
Cultural	Indigenous and European cultural heritage

The above water-dependant values are reflected in or are closely tied to the ecological values of the site. Environmental watering decisions at Cardross and Koorlong Lakes will have direct impacts on the social, cultural and environmental values identified. Improved environmental watering will therefore have broader positive impacts for a wider range of community values at Cardross and Koorlong Lakes.

5.2.1 Aboriginal cultural values

The Mallee region has been occupied by hundreds of generations of Indigenous people with human activity dated as far back as 23,400 years ago. The region's rich and diverse Indigenous heritage has been formed through the historical and spiritual significance of sites associated with this habitation; together with the strong and enduring connection Traditional Owners have with the Mallee's natural landscapes.

In Indigenous culture, water is inseparable from the land, air, plants and animals. Caring for, and healing, Country is an inherited cultural obligation that is reliant upon having water in the landscape in the right place, at the right time of year. Water creates and sustains life and is a living and cultural entity that connects Traditional Owners to Ancestors, Country, cultural practice and identity.

Within the Mallee CMA region, the Murray River and its associated waterways continue to be culturally significant habitation areas for many Aboriginal groups. The high number of Indigenous cultural heritage sites throughout the Murray floodplain is unique in Victoria because of their concentration and diversity. It is typical to find high densities of identified Indigenous cultural heritage sites located around, or close to, freshwater sources. The Aboriginal Heritage Regulations 2018 define "areas of cultural heritage sensitivity" which include land within 200 m of named waterways and land within 50 m of registered Aboriginal cultural heritage places. A review of the Aboriginal Cultural Heritage Register and Information System (ACHRIS) confirms that all of the target area at Cardross and Koorlong Lake is defined as an area of cultural heritage sensitivity.

The current Registered Aboriginal Party (RAP) for the area is the First People of the Millewa-Mallee Aboriginal Corporation (FPMMAC). Their Action Plan and Country and Water Plan "seek to repair the natural environment and our people's place in the environment" (Mallee CMA, 2022). The Mallee CMA have engaged with the FPMMAC about this EWMP, and are committed

to working with Traditional Owners to ensure that tangible and intangible Aboriginal culture and heritage is protected, and that Traditional Owner led practices are imbedded in the management and healing of Country (Mallee RCS, 2022).

Cultural heritage

Even though the Cardross and Koorlong Lakes are not naturally occurring wetlands they still have some cultural importance for the local Indigenous people. The area is traditionally owned by those nations belonging to the FPMMAC and there are a number of hearths and artefact scatters throughout the area. Earthen ovens (hearths) are listed and some cultural sites have been documented and records are held by Aboriginal Affairs Victoria.

5.2.2. Recreational values

Cardross Lakes are no longer used as a community swimming pool. However, the lakes are still used for recreational fishing, duck hunting and bird watching. Dirt bike riding is common at these sites and is a concern for natural values management.

Cardross and Koorlong Lakes contain significant European footprints, with defined evidence such as the establishment of these artificial wetlands as the first irrigation drainage scheme in Australia and as the site of the country's first inland life-saving club. These social and cultural values are important to local communities of the area. The values contained within Cardross and Koorlong Lakes and specifically the target area for this plan makes this area a priority for protection and enhancement through environmental water management. Of particular significance are the native fish communities which inhabit the artificial wetlands throughout the target area. The presence of Murray hardyhead and the Ruppia communities which support them are the primary focus of this plan. While the Cardross Lakes were originally established as part of Australia's first irrigation drainage scheme, the Lakes were also an important recreational area for local people. The lakes were used as a community swimming pool in the early 1900's. Australia's first registered inland life-saving club was at Cardross and this group, along with Cardross Rowing Club were situated at Cardross Lake (MRCC 2011). Chandler (1979, cited in ARI 2002) states that a kiosk, diving platform and lawns were constructed to facilitate the use of the lake as a swimming pool, along with caretaker's quarters.

Waterways also play a large role in the region's more recent non-Indigenous heritage due to the historical infrastructure (e.g. buildings, irrigation and river navigation structures) they often contain. These places provide links to early industries and settlements and play a key part in the region's identity.

5.2.3. Trajectory of change

The environmental water management regime within Cardross and Koorlong Lakes has led to improvement of environmental conditions at Koorlong Lake, and environmental conditions at Cardross Lake have deteriorated over the same time period. Management intervention via environmental watering began at Cardross Lakes in 1997, initially to maintain native fish diversity and later for Murray hardyhead specifically, and at Koorlong Lakes in September 2009 to support Murray hardyhead populations.

If these interventions are not continued the benefits from these watering events to aquatic macrophyte and zooplankton communities may not be sustained. Salinity levels within the lakes may increase, possibly beyond the tolerance of Murray hardyhead and Ruppia species. Water levels will decrease and eventually the lakes may dry out.

Ryan et al. (2004) suggests that the likelihood of regeneration of aquatic macrophyte communities through seed bank would decrease with each year the wetlands remained dry. This would result in loss of Ruppia communities and Murray hardyhead populations at these sites could be lost entirely under these conditions.

It is likely that Cardross and Koorlong Lakes will be subject to more extreme wetting and drying cycles under a changing climate, and without proper consideration of climate change adaptation, it is likely that the environmental values at Cardross and Koorlong Lakes will deteriorate.

6. Managing water-related threats

The values for the target area of Cardross and Koorlong Lakes are described in section 5. Some of the threats which may have an impact on Cardross and Koorlong Lakes include:

- Changed water regime
- Loss or reduction of wetland connectivity
- Water quality
- Introduction/increase of exotic flora and fauna

Changed water regime

The main threat to the Cardross and Koorlong wetlands is the changed water regime due to improvements to water delivery infrastructure and more efficient water-use on surrounding irrigated properties. As artificial basins constructed for irrigation drainage, Cardross Lakes rely on this inflow as their only source of water other than environmental allocations. With a reduction in drainage and recent dry conditions the lakes have been under significant stress affecting productivity and wetland function. Cardross Lakes have now been reduced to a shallow pool of highly saline water that no longer supports Ruppia or Murray hardyhead.

Figure 13. Cardross Lakes in April 2023.

The Koorlong Lakes receive some storm water inflow as well as irrigation drainage and Koorlong Lake has remained self-sufficient since it last received environmental water in 2011/12. Deliveries then were recommenced from 2018/19 and have continued into 2021 (see Table 5). However, without the saline water inflows to Lake Koorlong from the local irrigation drainage network this wetland would require further environmental water delivery. Annual freshwater top- ups of this kind may lead to freshening of the system. For this reason, it is essential that the connection of Koorlong Lakes to the drainage network is maintained.

Poor water quality

The historical use of Cardross and Koorlong Lakes as irrigation drainage basins was associated with increased salinity. Although increased salinity can be detrimental to some types of vegetation, levels in Cardross and Koorlong Lakes suited Ruppia and Murray hardyhead and habitat now needs to be maintained appropriately at these sites. For a period, declines in saline inflows and increases in delivery of environmental flows meant the Cardross Lakes became fresher (Ellis 2013). Although this freshwater was important, managers lacked the capacity to sustain an appropriate salinity regime for Murray hardyhead. Given this, the focus has shifted to maintaining Murray hardyhead populations in Koorlong Lake and environmental flows are no longer delivered to Cardross Lakes. Murray hardyhead tolerate moderately saline conditions, although lower levels may be required to facilitate breeding and recruitment (Backhouse et al. 2008). Ellis (2013) suggests Murray hardyhead can tolerate a range of approximately 1,000 to 110,000 µS.cm-1 although low EC may actually benefit competitive species. The ability of Murray hardyhead to tolerate elevated salinity levels gives them an advantage over competitive introduced species such as Common carp and Eastern gambusia. Elevated salinity levels are also required to support the Ruppia habitat which Murray hardyhead rely on. If the saline nature of Koorlong Lake cannot be maintained into the future, it's viability as a Murray hardyhead refuge may be lost. Various translocation sites in the Mallee region are being assessed to address this, however, no Murray hardyhead have been recorded in Cardross Lake (east) since June 2012 (Ellis 2013).

Other Threats: Invasive species

Introduced fauna such as Common carp pose a serious threat to the ecology of Koorlong Lakes. Carp have been found to contribute to the loss of aquatic vegetation and increased turbidity, resulting in loss of habitat for waterfowl (Purdy & Lyon 2008). Carp also competes with the native fish for habitat and food as well as having a detrimental effect on water quality (MCMA 2003). This is of particular concern given that these wetlands are one of the last remaining sites containing Murray hardyhead. However, managing salinity levels for Murray hardyhead can also help control carp which are less salt tolerant. An Ecology Australia survey undertaken in 2022 found that no invasive carp were present at Koorlong Lakes during the time of survey (May and June 2022). No fish were detected at Cardross Lakes as Cardross Lake was dry at the time of survey.

Introduced *Easter gambusia* are considered to have imposed significant competitive pressure on Murray hardyhead populations at Koorlong Lake. This aggressive introduced species has been observed to chase adult and juvenile Murray hardyhead from their preferred habitat and also prey on Murray hardyhead larvae (Ellis et al. 2011). A large population of *Eastern gambusia* was detected at Koorlong Lake in a survey undertaken by Ecology Australia in May-June 2022.

Cumbungi has encroached on fringing wetland vegetation and Ruppia habitat at Cardross Lakes (Ellis 2012). This plant uses large amounts of water and can alter the wetland character, reduce plant diversity and obstruct water flow (Roberts & Marston 2011). Indeed, the growth of Cumbungi in a delivery channel in the past created a blockage to environmental water delivery at this site (Ellis 2008). Environmental water may be useful in managing this species by maintaining ponding at high enough levels to submerge the dense Cumbungi stands for prolonged periods. Managing water levels to allow a drop over summer can also disconnect Cumbungi from the wetlands and allow for treatment. A list of exotic flora and fauna species identified in Cardross and Koorlong Lakes are listed in Appendix 3.

Assessing risks.

Consideration of risk provides a link between recognition of system threats and key management processes, including decade and seasonal planning. Risk assessments are composed of both likelihood and consequence components. In this instance likelihood is influenced by the probability that there will be sufficient environmental water to maintain lake water and salinity levels.

From a seasonal watering perspective, prioritisation of watering actions will be based on consequence. While consequence for an individual wetland can be determined, environmental water allocations require consideration of the consequences at larger scales. For the Mallee CMA it is their region, for the VEWH it is Victoria and the CEWH it is the Murray Darling Basin. Koorlong Lake represents the last viable habitat for Murray hardyhead in the Mallee region and a significant remnant population in Victoria. The consequence of a change in flow regime or water quality is therefore loss of a listed species from the region.

Not all consequences can be identified as readily and so we have provided a process that can be followed in Appendix 5.

7. Management goals, objectives and targets

7.1 Management goal

The overall goal proposed for Cardross and Koorlong target area has been developed through consultation with various experts and stakeholders including DEECA Parks Victoria, and local residents. The goal considers the values the wetland supports and the potential threats that need to be managed. This includes consideration of the values the wetland has historically supported and the likely values it could support into the future.

To provide a water regime to maintain and improve threatened native fish and waterbird populations.

It is strongly linked to the goals of the Mallee Waterway Strategy 2014-22 (Mallee CMA 2014):

- To maintain or improve habitat within waterways and on surrounding riparian land;
- To manage all land tenures for water quality benefits and respond appropriately to threatening events (both natural and pollution based);
- To restore appropriate water regimes and improve connectivity;
- To protect the extent and condition of Cultural Heritage (Indigenous and non-Indigenous) sites associated with waterways; and
- To increase community capacity for, awareness of and participation in waterway management.

7.2 Environmental objectives and targets

Environmental objectives represent the desired environmental outcomes of the site based on the management goal, as well as the key values outlined in the Water Dependent Values section. It is intended that EWMP objectives will be described in terms of the primary environmental outcomes.

During 2020, the environmental objectives (formally ecological objectives) were refined with the intent of improving the specificity and measurability of the objectives through the development of targets, and to improve line of sight to the Basin Plan. While the process attempted to maintain the intent and integrity of the original objectives, it provided an opportunity to reassess the suitability of these objectives for the asset. The rationalisation, assessment of SMARTness, mapping to Basin Plan and update of each objective for Cardross and Koorlong Lakes can be found in Section 5.7.1 of Butcher et al. (2020). The numbering of the environmental objectives in this EWMP have been adopted directly from the Butcher et al (2020) assessment.

The outcome of the refinement process in 2020 resulted in the consolidation of the original four objectives into two concise objectives.

Table 13. Change in Environmental Objectives in the Cardross and Koorlong Lakes EWMP

Old Environmental Objective	New environmental objective
CK1: Maintain Murray hardyhead populations	CK1: By 2030, improve the population of Murray hardyhead (Craterocephalus fluviatilis) at Koorlong.
CK2: Improve Murray hardyhead populations	
CK3: Maintain Ruppia community	CK2: By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with Ruppia beds containing both R. polycarpa and R. megacarpa.
CK4: Improve Ruppia community	

The above changes were made to align the language used with the Basin Plan and to consolidate the number of environmental objectives. Following community consultation in 2023, and recommendations from a report by Ecology Australia in 2022, Mallee CMA added an additional environmental objective (CK3) to support management action around maintaining waterbird habitat.

Table 14. Updated Environmental Objectives for Cardross and Koorlong Lakes

Environmental objective	Target
CK1: By 2030, improve the population of Murray hardyhead (*Craterocephalus fulivatilis*) at Koorlong.	By 2030, maintain a self-sustaining population of Murray hardyhead (Craterocephalus fulivatilis) at Koorlong Lake: • YoY recorded annually • Abundance of adult fish increased by 20% from 2019 baseline of 12.9 CPUE (based on Whiterod & Wood 2019) • Maintain salinity levels during summer within thresholds to support Ruppia growth and condition, and tolerances of Murray hardyhead (<60,000 EC µs/cm) • Maintain water level of at least 36.7m AHD from summer to winter. At the start of spring increase water level to above 38.0m AHD and maintain above this level into early summer.
CK2: By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with Ruppia beds containing both R. polycarpa and R. megacarpa.	By 2030, vigorous populations of saline aquatic vegetation at Cardross and Koorlong Lakes: At Koorlong Lake • Maintain ≥30% cover of Ruppia and at least 10 live (green) shoots per core at 80% of sites assessed • Measured by taking sediment 5 core samples (75mmx4cm deep) at transects of dry zone above waterline, waterline, 30cm and 60cm depths • Up to five random transects per site minimum of 200m apart At Cardross Lake (west) • Improve cover of Ruppia to ≥30% and at least 10 live (green) shoots per core at 40% of sites assessed • Measured by taking sediment 5 core samples (75mmx4cm deep) at transects of dry zone above waterline, waterline, 30cm and 60cm depths • Up to five random transects per site minimum of 200m apart To achieve this, specific water regime and salinity levels will need to be established – i.e. once a baseline is established these targets may be modified. Sampling method modified from Paton et al. (2018). Suggested salinity threshold of 30ppt should support growth/germination and condition of both species (see Sim et al. 2006). Flowering is likely to require 3 months at <15ppt salinity (Sim et al. 2006). These thresholds need to be confirmed for this wetland system and others where Ruppia outcomes are the objective.
CK3: By 2030, maintain representative populations of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at the Koorlong Lake asset, by maintaining a mixture of shallow- and deep-water habitats.	By 2030, 80% of representative F2 and F3 species recorded at Koorlong Lake in 8 years out of any 10-year period in which conditions are suitable. • Representative F2 species include: Australasian Grebe (Tachybaptus novaehollandiae), Australasian Shoveler (Spatula rhynchotis), Australian Shelduck (Tadorna tadornoides), Australian Wood Duck (Chenonetta jubata), Black Swan (Cygnus atratus), Black-fronted Dotterel (Elseyornis melanops), Common Greenshank (Tringa nebularia), Dusky Moorhen (Gallinula tenebrosa), Eurasian Coot (Fulica atra), Great Egret (Ardea modesta), Grey Teal (Anas gracilis), Masked Lapwing (Vanellus miles), Pacific Black Duck (Anas superciliosa), Red-capped Plover (Charadrius ruficapillus), Red-kneed Dotterel (Erythrogonys cinctus), White-faced Heron (Egretta novaehollandiae), Yellow-billed Spoonbill (Platalea flavipes) • Representative F3 species include: Australasian Darter (Anhinga novaehollandiae), Australasian Shoveler (Spatula rhynchotis), Australian Pelican (Pelecanus conspicillatus), Blue-billed Duck (Oxyura australis), Freckled Duck (Stictonetta naevosa), Great Cormorant (Phalacrocorax carbo), Hardhead (Aythya australis), Little Pied Cormorant (Microcarbo melanoleucos), Musk Duck (Biziura lobata), Pied Cormorant (Phalacrocorax varius). • Feeding habitat defined as a mixture of deep feeding areas (water >1 m) and shallow feeding areas (<0.5 m depth and or drying mud) with intermittent inundation of densely vegetated shrublands.

7.3 Regional significance

Cardross and Koorlong Lakes support a range of environmental values of local, regional and Basin significance as described in section 5. The Cardross Lakes are of national significance and are listed on the Directory of Important Wetlands (Ryan et al. 2003). Cardross and Koorlong Lakes support habitat for many species listed under the Environment Protection and Biodiversity Conservation Act (EPBC Act). Koorlong Lakes support more significant environmental values compared to Cardross Lakes – this has informed decisions on environmental water allocations undertaken for Cardross and Koorlong Lakes.

The environmental values listed in Section 5 are linked to the management goals and environmental objectives and targets described in Section 7. Details of the links between the environmental objectives and environmental outcomes at a regional/Basin scale are provided in Appendix 4.

The management goals and environmental objectives and targets are aligned with the goals of the Mallee Waterway Strategy as described in Section 7.1.

7.4 Alignment to the Basin Plan

Key elements of the Basin Plan have been integrated into the Cardross and Koorlong Lakes EWMP objectives, including adopting the same conceptual framework. The EWMP objectives were also developed based on the same ecological knowledge about how Murray River floodplains work.

Under the Basin Plan, the overall environmental objectives for the water-dependent ecosystems of the Murray–Darling Basin are:

- to protect and restore water-dependent ecosystems of the Murray–Darling Basin (8.05)
- to protect and restore the ecosystem functions of water-dependent ecosystems (8.06)
- to ensure that water-dependent ecosystems are resilient to climate change and other risks and threats (8.07).

The Cardross and Koorlong Lakes EWMP objectives were developed to align with these overall objectives and to integrate and encode the intent of Basin Plan. Table 15 shows the alignment between the EWMP objectives and the Basin Plan's overall environmental objectives and subobjectives under 8.05, 8.06 and 8.07.

Table 15. Alignment between Cardross and Koorlong Lakes EWMP ecological objectives and overall objectives (8.05 to 8.07) and subobjectives in the Murray–Darling Basin Environmental Watering Plan

EWMP objective	Alignment with Basin Plan		
	8.05 Ecosystem and biodiversity	**8.06** Ecosystem function	**8.07** Ecosystem resilience
CK1: By 2030, improve the population of Murray hardyhead (*Craterocephalus fulivatilis*) at Koorlong.	3a		
CK2: By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with Ruppia beds containing both R. polycarpa and R. megacarpa.	3b	2, 6b	
CK3: By 2030, maintain representative populations of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at the Koorlong Lake asset, by maintaining a mixture of shallow- and deep-water habitats.	2b, 3b		

8. Environmental water requirements and intended water regime

8.1 Watering requirements and intended watering regimes

The wetland watering regime has been derived from the ecological and hydrological objectives and is limited by these specific objectives. To allow for adaptive and integrated management, the watering regime is framed using the seasonally adaptive approach. This means that a watering regime is identified for optimal conditions, as well as the minimum tolerable watering scenario. The minimum watering regime is likely to be provided in drought or dry years and the optimum watering regime in average or wet conditions. There is no maximum water regime in this case as management for Murray hardyhead and Ruppia communities would be jeopardised by watering above the optimal regime.

However, due to the inter-annual variability of these estimates (particularly the climatic conditions), determination of the predicted volume requirements in any given year will need to be undertaken by the environmental water manager when watering is planned.

Table 16. Short-term water regime for Cardross and Koorlong Lakes

Short-term regime
Minimum watering regime Provide environmental water to the target areas each year from August to October to above the minimum recommended level (36.7mAHD). Allow the water level to decrease slowly over summer, ensuring it does not fall below the identified minimum level (36.7mAHD).
Optimal watering regime Provide environmental water to the target area each year from August to October to the recommended optimal level to inundate fringing vegetation (36.7-38.0mAHD). Allow the water level to decrease slowly over summer to (but not below) the recommended minimum water level (36.7mAHD).

8.2 Expected watering effects

This section aims to explicitly outline the potential watering actions and expected watering effects needed to achieve the stated environmental objective.

Table 17. Environmental objectives for Cardross and Koorlong Lakes and the watering actions required to achieve them

Objective Code	Environmental objective	Potential watering actions	Expected watering effects
CK1	By 2030, improve the population of Murray hardyhead (Craterocephalus fulivatilis) at Koorlong.	Environmental watering should commence from August to October to coincide with Murray hardyhead breeding season. Water levels should be high enough to inundate exposed sediments to promote a rise in zooplankton as a food source for breeding Murray hardyhead. Water levels should be allowed to decrease through summer to expose wetland sediments and fringing vegetation whilst also maintaining Ruppia beds within the wetlands. Maintain water level of at least 36.7m AHD from Summer to Winter. At the start of spring increase water level to above 38.0m AHD and maintain above this level into early summer.	Maintain adequate habitat at Koorlong to support Murray hardyhead populations.
CK2	By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with Ruppia beds containing both R. polycarpa and R. megacarpa.	Facilitate seasonally variable watering to support natural wetting and drying cycles of the wetlands. Facilitate variable and brief inundation (for <1 month) to support EVC 101 Samphire Shrubland, and permanent inundation (>6 months) to support EVC 821 Tall Marsh present at Koorlong Lake. Maintain a salinity threshold of 30ppt to support growth/germination and condition of both Ruppia species. Maintain water level of at least 36.7m AHD from Summer to Winter. At the start of spring increase water level to above 38.0m AHD and maintain above this level into early summer.	Maintain and improve environmental conditions to support saline aquatic vegetation (including Ruppia species) at Koorlong.
CK3	By 2030, maintain representative populations of shallow-water and deep-water feeding guilds of waterbird (F2 and F3, respectively, after Jaensch 2002) at the Koorlong Lake asset, by maintaining a mixture of shallow- and deep-water habitats.	Facilitate seasonally variable watering to support natural wetting and drying cycles of the wetlands. Maintain permanent ponding with variations in water levels. Time inflows preferably in late Winter/early Spring, allow water levels to recede over summer/autumn.	Maintain adequate sallow- and deep-water habitats at Koorlong Lake to support waterbird populations.

8.3 Seasonally adaptive approach

Victoria has adopted an adaptive and integrated management approach to environmental management. A key component of this approach for environmental watering is the 'seasonally adaptive' approach, developed through the Northern Region Sustainable Water Strategy and incorporated into the Victorian Waterway Management Strategy.

The seasonally adaptive approach identifies the priorities for environmental watering, works and complementary measures, depending on the amount of water available in a given year. It is a flexible way to deal with short-term climatic variability and helps to guide annual priorities and manage droughts. The approach is outlined in Figure 15.

The seasonally adaptive approach has been used to guide the watering regime under various climatic scenarios. In drier periods, restricted water resource availability will potentially limit the number of ecological objectives which can realistically be provided through environmental water management. However, these ecological objectives can be achieved in wetter periods as water resource availability increases.

During droughts and dry periods, it will be important to maintain a refuge pool to protect Murray hardyhead populations and the Ruppia on which they depend. Being an annual species, this will be an enduring commitment. In dry years the focus will shift to ensuring there are appropriate rises and falls in water level and associated changes in salinity that will promote aquatic vegetation.

As the volumes of environmental water increase, there are increasing opportunities to initiate cycles of inundation and draw-down to promote productive aquatic vegetation that provides habitat and food resources for a range of animals including waterbirds. As the volumes of available water increase the focus should be on the capacity to engage higher regions of the riparian zone and to promote habitat heterogeneity which would be expected to be associated with increases in vegetation species richness.

Management of salinity will remain an ongoing management issue which will need to be managed through dilution flows in some years to ensure salt loads within the lake do not affect aquatic vegetation or fish.

Figure 14. Lake Koorlong looking north.

Figure 15. Seasonally adaptive approach for Cardross and Koorlong Lakes

9. Environmental water delivery infrastructure

9.1 Water delivery infrastructure

Environmental water is delivered via existing irrigation supply infrastructure operated by Lower Murray Water.

9.2 Constraints and complementary works recommendations

The existing arrangements (Section 4.1) allow 554 ha of land to be inundated by environmental watering at Cardross and Koorlong Lakes. However, inundation of this extent is considered to be unsustainable, inefficient use of environmental water and would be severely limited by allocation amounts, security of supply and delivery capacity. Instead, inundation at these sites will be limited to priority basins that currently support Murray hardyhead populations. This will include Cardross Lakes (east and west) and Koorlong Lake with a total area of 93 ha.

10. Demonstrating outcomes – monitoring and assessment

10.1 Environmental monitoring

The watering program at Cardross and Koorlong Lakes has been designed to optimise ecological outcomes based on environmental water requirements.

Table 18. Links between environmental objectives, monitoring questions and survey methods

Objective	Monitoring focus	Monitoring question	Method	When
CK1	Improving Murray hardyhead populations	Is the Murray hardyhead population self-sustaining? What is the abundance of adult fish compared to the 2019 baseline?	Electrofishing	Annual
CK2	Maintaining aquatic vegetation (including Ruppia) population and extent	Has environmental water increased aquatic vegetation population and extent?	Core samples, transects	Annual
CK3	Maintaining shallow - and deep-water feeding guilds of waterbird by maintaining a mixture of shallow- and deep-water habitats.	Has environmental water increased the extent of shallow- and deep-water habitat? What is the abundance of representative populations of shallow- and deep-feeding guilds of waterbirds that utilise the target area?	Surveying	Annual

10.2 Monitoring priorities at the asset

Ecological monitoring is required to demonstrate the effectiveness of environmental watering in achieving ecological objectives, to help manage environmental risks and to identify opportunities to improve the efficiency and effectiveness of the program. The broad program logic for the lakes is:

- Objectives (Section 7.2)
- Environmental flows to achieve appropriate:
    - Water quality
    - Wetland habitat
- Outcomes
    - Ruppia
    - Murray hardyhead
    - Shallow-water and deep-water feeding waterbirds

The highest priorities for monitoring at Cardross and Koorlong Lakes are the monitoring questions that most strongly influence watering decisions and the evaluation of watering effectiveness.

All these priorities align with the following long-term outcomes of the Mallee Regional Catchment Strategy Waterway theme:

- 3.2.1 The condition of high value aquatic and riparian habitat is improved
- 3.2.2 Appropriate water regimes are restored to priority waterways and connectivity is improved.

Table 19. Monitoring priorities at Cardross and Koorlong Lakes

Monitoring priority	Reason for priority
Water Quality	Driver of wetland condition
Environmental Water delivery	Major management lever to protect wetland
Murray hardyhead population	Listed species, vulnerable to loss of habitat
Wetland vegetation (Ruppia) population and extent	Important habitat and food resource
Shallow- and deep-water habitat for waterbirds	Some listed species utilise Lakes

Figure 16. Ducks and grebes on Koorlong Lake

11. Adaptive Management

Mallee CMA uses an adaptive management approach in planning, delivering and managing environmental watering actions.

Adaptive management is the process of incorporating new scientific and operational information into the implementation of a project or plan to ensure that the goals of the activity are being reached efficiently. It is a standard and well-established practice for environmental water management, recognising the inherent uncertainties and risks associated with the complex relationships between changes to hydrology and ecological responses, and the potential for a watering event to provide both positive and adverse outcomes. Figure 17 shows an illustration of the adaptive management cycle for environmental water delivery.

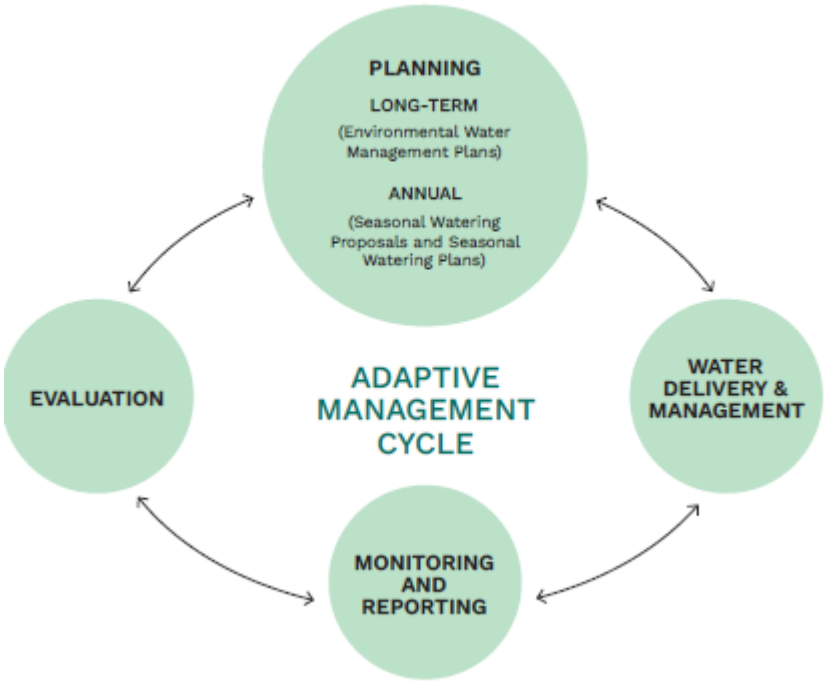


Figure 17. The adaptive management cycle for environmental water delivery and management.

Mallee CMA uses three main pathways to identify inputs to the adaptive management process (also referred to as lessons):

- monitoring to detect differences between what was planned and the outcomes at the environmental watering site
- incidental observations by managers, operators or other observers that identify opportunities to reduce risk or improve outcomes
- research or investigations into hydraulic or ecological management practices that could improve the conceptual models on which operations are based.

In 2022, Mallee CMA further refined its adaptive management approach, implementing the Environmental Watering Adaptive Management Framework (MCMA, 2022).

Mallee CMA formally documents lessons to strengthen organisational memory and provide transparency in continual improvement measures. Recording of lessons is crucial for both annual environmental watering actions and long-term planning. Demonstrating continual improvement provides the justification for monitoring programs and confirms that assets are being managed responsibly.

Mallee CMA's adaptive management framework has several components that work together to build lessons learned from environmental watering actions and program partners into the environmental water program. In this way, we iteratively improve the way environmental watering is undertaken using the best available evidence.

The EWMP will be constantly refined to incorporate learnings from ecological monitoring as well as feedback from community consultation.

Land managers and river operators are included in the operational planning cycle which include adaptive management processes to incorporate learnings and risk management.

12. Knowledge gaps and recommendations

This plan is based on best information at the time of writing. The information sources used in the development of this report have a number of limitations. These limitations include that the data contained in the Flora Information System and the Atlas of Victorian Wildlife comes from a combination of incidental records and systematic surveys. The data varies in accuracy and reliability due to the distribution and intensity of survey efforts. In addition, the lack of knowledge about the distribution and characteristics of invertebrates and non-vascular plant species means the data is weighted towards the less cryptic elements of flora and fauna, i.e. vascular flora and vertebrates. This report also draws on material collated from management plans, research documents and published literature. These sources vary in their age and hence the degree to which they reflect the current situation. However, the Plan is intended to be a live document and will be amended as new information becomes available.

Regarding the potential for Cardross Lakes to support Murray hardyhead habitat, Ecology Australia proposes that if reliable environmental water is available to maintain an appropriate area of permanent refuge habitat in refuge in Cardross Lake (east) or Cardross Lake (west) during future drought conditions, and to provide a suitable annual hydrological regime for re-establishment of Ruppia sp., and an appropriate salinity range of ~21– 81 mS/cm, then reinstatement of these conditions and reintroduction Murray hardyhead from the Koorlong Lakes population should be considered.

Some areas where further knowledge would be beneficial are outlined in Table 20. A cultural heritage management plan and salinity impact assessment would be essential before any on ground works could be undertaken.

Table 20. Knowledge gaps and recommendations for the target area

Knowledge gaps and data	Action recommended	Responsibility
Suitability of Cardross Lakes as Murray hardyhead habitat	Survey, data collection and monitoring	Implementation of any of these recommendations would be dependent on investment from Victorian and Australian Government funding sources such as projects managed through the Mallee CMA.
Conceptual and detailed designs for the management works	Engage consultants to carry out investigations and designs	
Condition of Koorlong wetlands	Assess using Index of Wetland Condition method	
Role of wetland on fish breeding	Monitoring of fish population	
Accurate depth and volumes for the wetland	Install depth gauges and bathymetric survey	
Nesting habitats of birds at the site	Data collection and monitoring	
Impacts of climate variability	Data collection and modelling	
Fauna presence for each wetland – especially fish	Survey, data collection and monitoring	
Flora condition for each wetland – especially aquatic flora	Survey, data collection and monitoring	
Monitoring of water quality condition on a regular basis including monitoring of salinity levels through the water column to identify seasonal stratification.	Survey, data collection and modelling	
Monitoring of groundwater bores to identify salinity and water table levels, and to confirm that watering will abate the leaching of highly saline groundwater through the Parilla Sands aquifer into the wetlands.	Survey, data collection and modelling	

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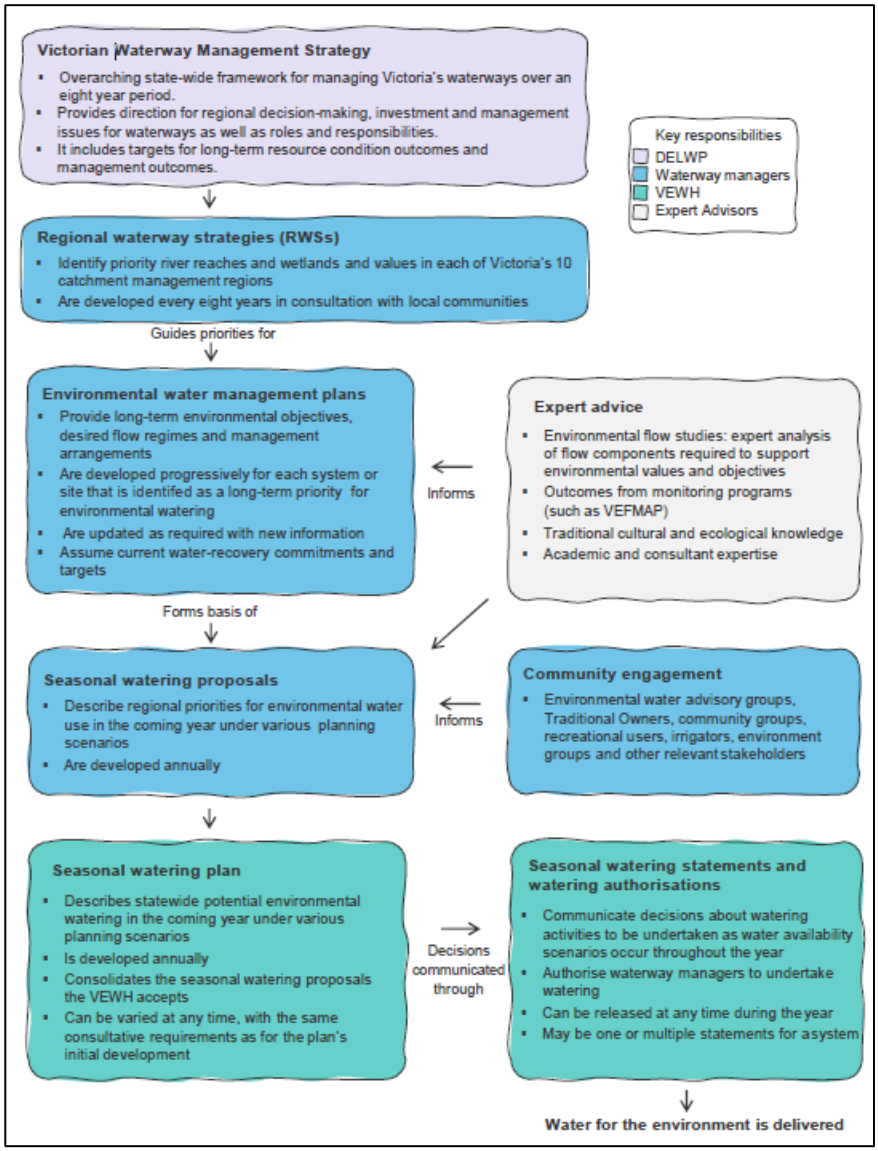
Appendix 1 Framework for Environmental Water Management

Environmental water in Victoria is managed as an integral part of the Victorian Waterway Management Program. The state-level Victorian Waterway Management Strategy (VWMS) provides the overarching framework for environmental water management (see accompanying figure below). The Mallee Waterway Strategy (2014-22) drives implementation of the VWMS at the regional level. Information from the Mallee Waterway Strategy is a key input to environmental water planning arrangements, including the selection of eligible assets to receive environmental water. Environmental water management plans are site-specific plans developed for a wetland or wetland complex deemed a priority to receive environmental water through the Mallee Waterway Strategy development process. This document is the Environmental Water Management Plan (EWMP) for Cardross and Koorlong Lakes in the Mallee Catchment Management region.

Environmental watering in the Mallee Region has historically been supported by management plans such as this one, that document key information including the watering requirements of an asset, predicted ecological responses and water delivery arrangements. These plans support annual decisions about which sites should receive water and assist managers to evaluate how well those assets respond to the water they receive or what could be done better. Environmental water management at Cardross and Koorlong Lakes is further underpinned by the Murray-Darling Basin Plan 2012 (Commonwealth) and the associated Basin-wide environmental watering strategy. In accordance with Basin Plan requirements, Victoria has also developed the Victorian Murray Water Resource Plan and Victorian Murray Long-Term Watering Plan, which apply at Cardross and Koorlong Lakes.



Mallee Catchment Management Authority (MCMA), the Department of Energy, Environment and Climate Action, the Victorian Environmental Water Holder (VEWH) and Traditional Owner groups have worked together to develop several EWMPs for watered assets throughout the Mallee region. These plans are continually updated through an adaptive management process. A primary purpose of EWMPs is to provide a consistent set of documents that support seasonal watering proposals to be submitted by asset managers to the VEWH annually.

Appendix 2 – Flora and fauna species list

Flora and fauna species lists were sourced from Naturekit records, extracted May 2023. Observations within the Ecology Australia 2022 report were added.

Flora

Scientific Name	Common Name	Record Number	Source
Crassula sieberiana s.l.	Sieber Crassula	1	
Asteraceae spp.	Composite	1	Ecology Australia 2022
Atriplex lindleyi subsp. inflata	Corky saltbush	1	Ecology Australia 2022
Atriplex semibaccata	Berry saltbush	1	Ecology Australia 2022
Atriplex spp.	Saltbush	1	Ecology Australia 2022
Atriplex stipitata subsp. stipitata	Kidney saltbush	1	Ecology Australia 2022
Austrostipa elegantissima	Feather spear-grass	1	Ecology Australia 2022
Brachyscome ciliaris var. ciliaris	Variable daisy	1	Ecology Australia 2022
Brachyscome lineariloba	Hard-head daisy	1	Ecology Australia 2022
Bromus spp.	Brome	1	Ecology Australia 2022
Calandrinia eremaea	Small purslane	1	Ecology Australia 2022
Calotis hispidula	Hairy burr-daisy	1	Ecology Australia 2022
Calotis hispidula	Hairy burr-daisy	1	Ecology Australia 2022
Chara spp.	Algae	1	Ecology Australia 2022
Chenopodium spp.	Goosefoot	1	Ecology Australia 2022
Convolvulaceae spp.		1	Ecology Australia 2022
Crassula colorata	Dense crassula	1	Ecology Australia 2022
Crassula sieberiana s.l.	Sieber Crassula	1	Naturekit Export May 2023
Cressa australis	Rosinweed	1	Ecology Australia 2022
Disphyma crassifolium subsp. clavellatum	Rounded Noon-flower	1	Naturekit Export May 2023
Dissocarpus paradoxus	Hard-head saltbush	1	Ecology Australia 2022
Enchylaena tomentosa var. tomentosa	Ruby Saltbush	1	Naturekit Export May 2023
Eragrostis dielsii	Mallee love-grass	1	Ecology Australia 2022
Erodium crinitum	Blue heron's-bill	1	Ecology Australia 2022
Hyalosperma demissum	Moss sunray	1	Ecology Australia 2022
Laphangium luteoalbum	Jersey cudweed	1	Ecology Australia 2022
Liliaceae spp.	Lily	1	Ecology Australia 2022
Lotus australis	Austral trefoil	1	Ecology Australia 2022
Lycium australe	Australian box-thorn	1	Ecology Australia 2022
Maireana appressa	Grey bluebush	1	Ecology Australia 2022
Maireana brevifolia	Short-leaf bluebush	1	Ecology Australia 2022
Maireana decalvans s.s.	Black cotton-bush	1	Ecology Australia 2022
Maireana pyramidata	Sago bush	1	Ecology Australia 2022
Maireana spp.	Bluebush	1	Ecology Australia 2022
Maireana turbinata	Satiny bluebush	1	Ecology Australia 2022
Menkea australis	Fairy spectacles	1	Ecology Australia 2022
Minuria cunninghamii	Bush minuria	1	Ecology Australia 2022
Myoporum montanum	Waterbush	1	Naturekit Export May 2023

Rhagodia spinescens	Hedge Saltbush	1	Naturekit Export May 2023
Ruppia megacarpa	Large-fruit tassel	1	Ecology Australia 2022
Salsola tragus subsp. tragus	Prickly saltwort	1	Ecology Australia 2022
Sclerochlamys brachyptera	Short-wing saltbush	1	Ecology Australia 2022
Sclerolaena obliquicuspis	Limestone copperburr	1	Ecology Australia 2022
Senecio glossanthus s.s.	Slender groundsel	1	Ecology Australia 2022
Senecio spanomerus	Mallee Groundsel	1	Naturekit Export May 2023
Sida spodochroma	Limestone Sida	1	Naturekit Export May 2023
Sigesbeckia spp.	Sigesbeckia	1	Ecology Australia 2022
Spergularia marina s.l.	Salt sand-spurrey	1	Ecology Australia 2022
Tecticornia halocnemoides subsp. halocnemoides		1	Ecology Australia 2022
Tecticornia halocnemoides subsp. halocnemoides	Grey glasswort	1	Ecology Australia 2022
Tecticornia tenuis	Slender glasswort	1	Ecology Australia 2022
Tetragonia moorei	Annual spinach	1	Ecology Australia 2022
Typha domingensis		1	Ecology Australia 2022

Fauna

Scientific Name	Common Name	Record Number	Source
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	2	Naturekit Export May 2023
Acanthiza uropygialis	Chestnut-rumped Thornbill	1	Naturekit Export May 2023
Acrocephalus australis	Reed-Warbler	2	Naturekit Export May 2023
Aegotheles cristatus	Australian Owlet-nightjar	1	Naturekit Export May 2023
Anas castanea	Chestnut Teal	1	Naturekit Export May 2023
Anas gracilis	Grey Teal	32	Naturekit Export May 2023
Anas superciliosa	Pacific Black Duck	32	Naturekit Export May 2023
Anhinga novaehollandiae	Australasian Darter	5	Naturekit Export May 2023
Ardea alba	Great Egret	1	Naturekit Export May 2023
Austronomous australis	White-striped free-tailed bat	1	Ecology Australia 2022
Aythya australis	Hardhead	5	Naturekit Export May 2023
Barnardius zonarius	Mallee ringneck	1	Ecology Australia 2022
Biziura lobata	Musk Duck	19	Naturekit Export May 2023
Chalinolobus morio	Chocolate wattled bat	1	Ecology Australia 2022
Chalinolobus picatus	Little pied bat	1	Ecology Australia 2022
Charadrius ruficapillus	Red-capped Plover	2	Naturekit Export May 2023
Chelodina expansa	Broad-shelled Turtle	12	Naturekit Export May 2023
Chelodina longicollis	Eastern Snake-necked Turtle	43	Naturekit Export May 2023
Chenonetta jubata	Australian Wood Duck	5	Naturekit Export May 2023
Cherax destructor destructor	Common Yabby	82	Naturekit Export May 2023
Chlidonias hybrida	Whiskered Tern	2	Naturekit Export May 2023
Chroicocephalus novaehollandiae	Silver Gull	8	Naturekit Export May 2023
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo	1	Naturekit Export May 2023
Chrysococcyx osculans	Black-eared cuckoo	1	Ecology Australia 2022
Cincloramphus cruralis	Brown songlark	1	Ecology Australia 2022

Scientific Name	Common Name	Record Number	Source
Circus approximans	Swamp Harrier	1	Naturekit Export May 2023
Cladorhynchus leucocephalus	Banded Stilt	3	Naturekit Export May 2023
Colluricincla harmonica	Grey strike-thrush	1	Ecology Australia 2022
Coracina novaehollandiae	Black-faced Cuckoo-shrike	2	Naturekit Export May 2023
Corvus coronoides	Australian Raven	3	Naturekit Export May 2023
Corvus mellori	Little Raven	1	Naturekit Export May 2023
Cracticus nigrogularis	Pied Butcherbird	2	Naturekit Export May 2023
Cracticus torquatus	Grey Butcherbird	1	Naturekit Export May 2023
Craterocephalus fluviatilis	Murray Hardyhead	39	Naturekit Export May 2023
Crinia parinsignifera	Eastern-sign bearing froglet	1	Ecology Australia 2022
Cygnus atratus	Black Swan	34	Naturekit Export May 2023
Egretta novaehollandiae	White-faced Heron	5	Naturekit Export May 2023
Elanus axillaris	Black-shouldered kite	1	Ecology Australia 2022
Elseyornis melanops	Black-fronted Dotterel	9	Naturekit Export May 2023
Emydura macquarii	Murray River Turtle	12	Naturekit Export May 2023
Eolophus roseicapilla	Galah	1	Ecology Australia 2022
Epthianura albifrons	White-fronted Chat	3	Naturekit Export May 2023
Erythrogonys cinctus	Red-kneed Dotterel	2	Naturekit Export May 2023
Falco berigora	Brown falcon	1	Ecology Australia 2022
Falco cenchroides	Nankeen kestrel	1	Ecology Australia 2022
fam. Atherinidae gen. Craterocephalus	Freshwater Hardyheads	17	Naturekit Export May 2023
Fulica atra	Eurasian Coot	17	Naturekit Export May 2023
Gallinula tenebrosa	Dusky Moorhen	1	Naturekit Export May 2023
Gavicalis virescens	Singing Honeyeater	3	Naturekit Export May 2023
Grallina cyanoleuca	Magpie-lark	3	Naturekit Export May 2023
Gymnorhina tibicen	Australian Magpie	3	Naturekit Export May 2023
Haliastur sphenurus	Whistling Kite	1	Naturekit Export May 2023
halinolobus gouldi	Gould’s wattled bat	1	Ecology Australia 2022
Himantopus leucocephalus	Pied Stilt	4	Naturekit Export May 2023
Hirundo neoxena	Welcome Swallow	4	Naturekit Export May 2023
Hypseleotris klunzingeri	Western Carp Gudgeon (Species Complex)	142	Naturekit Export May 2023
Limnodynastes dumerilii	Southern Bullfrog (ssp. unknown)	1	Naturekit Export May 2023
Limnodynastes tasmaniensis	Spotted Marsh Frog (race unknown)	1	Naturekit Export May 2023
Litoria peronii	Peron's tree frog	1	Ecology Australia 2022
Maccullochella peelii	Murray Cod	7	Naturekit Export May 2023
Macquaria ambigua	Golden Perch	20	Naturekit Export May 2023
Macrobrachium australiense	Inland River Prawn	11	Naturekit Export May 2023
Macropus fuliginosus	Western grey kangaroo	1	Ecology Australia 2022
Macropus giganteus	Eastern grey kangaroo	1	Ecology Australia 2022
Malacorhynchus membranaceus	Pink-eared Duck	3	Naturekit Export May 2023
Malurus assimilis	Purple-backed Fairywren	1	Naturekit Export May 2023
Malurus cyaneus	Superb Fairy-wren	1	Naturekit Export May 2023
Malurus leucopterus	White-winged Fairy-wren	3	Naturekit Export May 2023

Scientific Name	Common Name	Record Number	Source
Malurus splendens	Splendid fairy-wren	1	Ecology Australia 2022
Manorina flavigula	Yellow-throated Miner	2	Naturekit Export May 2023
Merops ornatus	Rainbow Bee-eater	1	Naturekit Export May 2023
Microcarbo melanoleucos	Little Pied Cormorant	7	Naturekit Export May 2023
Mogurnda adspersa	Southern Purple-spotted Gudgeon	7	Naturekit Export May 2023
Nematalosa erebi	Bony Herring	54	Naturekit Export May 2023
Northiella sp.	Blue bonnet	1	Ecology Australia 2022
Nyctophilus corbeni	South-eastern long-eared bat	1	Ecology Australia 2022
Nyctophilus geoffroyi	Lesser long-eared bat	1	Ecology Australia 2022
Nyctophilus gouldi	Gould's long-eared bat	1	Ecology Australia 2022
Ocyphaps lophotes	Crested Pigeon	3	Naturekit Export May 2023
Oxyura australis	Blue-billed Duck	15	Naturekit Export May 2023
Ozimops petersi	Inland free-tailed bat	1	Ecology Australia 2022
Ozimops planiceps	Southern free-tailed bat	1	Ecology Australia 2022
Ozimops ridei	Ride's free-tailed bat	1	Ecology Australia 2022
Paratya australiensis	Common Freshwater Shrimp	1	Naturekit Export May 2023
Pardalotus striatus	Striated Pardalote	1	Naturekit Export May 2023
Pelecanus conspicillatus	Australian Pelican	5	Naturekit Export May 2023
Phalacrocoracidae spp.		1	Naturekit Export May 2023
Phalacrocorax carbo	Great Cormorant	4	Naturekit Export May 2023
Phalacrocorax sulcirostris	Little Black Cormorant	6	Naturekit Export May 2023
Phalacrocorax varius	Pied Cormorant	1	Naturekit Export May 2023
Phaps chalcoptera	Common Bronzewing	1	Naturekit Export May 2023
Philypnodon grandiceps	Flatheaded Gudgeon	53	Naturekit Export May 2023
Philypnodon macrostomus	Dwarf Flatheaded Gudgeon	16	Naturekit Export May 2023
Platalea flavipes	Yellow-billed Spoonbill	1	Naturekit Export May 2023
Podiceps cristatus	Great Crested Grebe	7	Naturekit Export May 2023
Podicipedidae spp.	Grebes	2	Naturekit Export May 2023
Poliocephalus poliocephalus	Hoary-headed Grebe	18	Naturekit Export May 2023
Polytelis anthopeplus	Regent Parrot	1	Ecology Australia 2022
Pomatostomus ruficeps	Chestnut-crowned Babbler	1	Naturekit Export May 2023
Poodytes gramineus	Little Grassbird	3	Naturekit Export May 2023
Porphyrio melanotus	Australasian Swamphen	1	Naturekit Export May 2023
Psephotus haematonotus	Red-rumped Parrot	3	Naturekit Export May 2023
Psephotus varius	Mulga parrot	1	Ecology Australia 2022
Ptilotula penicillata	White-plumed Honeyeater	2	Naturekit Export May 2023
Retropinna semoni	Australian Smelt	42	Naturekit Export May 2023
Rhipidura leucophrys	Willie Wagtail	3	Naturekit Export May 2023
Scotorepens balstoni	Inland broad-nosed bat	1	Ecology Australia 2022
Scotorepens greyii	Little broad-nosed bat	1	Ecology Australia 2022
Smicrornis brevirostris	Weebill	2	Naturekit Export May 2023
Spatula rhynchotis	Australasian Shoveler	3	Naturekit Export May 2023
Stictonetta naevosa	Freckled Duck	1	Naturekit Export May 2023
Strepera versicolor	Grey Currawong	1	Naturekit Export May 2023

Scientific Name	Common Name	Record Number	Source
supf. Atyoidea fam. Atyidae	Freshwater Shrimps	9	Naturekit Export May 2023
Synoicus ypsilophorus	Brown Quail	1	Naturekit Export May 2023
Tachybaptus novaehollandiae	Australasian Grebe	18	Naturekit Export May 2023
Tachyglossus aculeatus	Short-beaked Echidna	1	Naturekit Export May 2023
Tadorna tadornoides	Australian Shelduck	20	Naturekit Export May 2023

Appendix 3 - Exotic flora and fauna species list

Flora

Scientific Name	Common Name	Record Number	Source
Asphodelus fistulosus	Onion Weed	1	Naturekit Export May 2023
Atriplex prostrata	Hastate orache	1	Ecology Australia Report 2022
Brassica tournefortii	Mediterranean turnip	1	Ecology Australia Report 2022
Bromus rubens	Red Brome	1	Naturekit Export May 2023
Carrichtera annua	Ward's weed	1	Ecology Australia Report 2022
Centaurea melitensis	Malta thistle	1	Ecology Australia Report 2022
Erigeron bonariensis	Flaxleaf fleabane	1	Ecology Australia Report 2022
Hordeum glaucum	Northern barley-grass	1	Ecology Australia Report 2022
Hordeum murinum s.l.	Barley-grass	1	Naturekit Export May 2023
Hypochaeris radicata	Flatweed	1	Ecology Australia Report 2022
Juncus acutus subsp. acutus	Spiny Rush	4	Naturekit Export May 2023
Lactuca serriola	Prickly lettuce	1	Ecology Australia Report 2022
Limonium lobatum	Winged sea-lavender	1	Ecology Australia Report 2022
Lycium ferocissimum	African Box-thorn	3	Naturekit Export May 2023
Medicago polymorpha	Burr medic	1	Ecology Australia Report 2022
Mesembryanthemum crystallinum s.s.	Common ice-plant	1	Ecology Australia Report 2022
Mesembryanthemum granulicaule		1	Ecology Australia Report 2022
Mesembryanthemum nodiflorum	Small Ice-plant	1	Naturekit Export May 2023
Onopordum acaulon		1	Ecology Australia Report 2022
Poa annua s.l	Annual meadow-grass	1	Ecology Australia Report 2022
Polypogon monspeliensis		1	Ecology Australia Report 2022
Reichardia tingitana	False sow-thistle	1	Ecology Australia Report 2022
Rhagodia spinescens	Hedge Saltbush	1	Naturekit Export May 2023
Rostraria pumila	Tiny bristle-grass	1	Ecology Australia Report 2022
Schismus barbatus	Arabian Grass	1	Naturekit Export May 2023
Silene apetala var. apetala	Mallee catchfly	1	Ecology Australia Report 2022
Sisymbrium erysimoides	Smooth mustard	1	Ecology Australia Report 2022
Sisymbrium irio	London Rocket	1	Naturekit Export May 2023
Sisymbrium irio	London rocket	1	Ecology Australia Report 2022
Sonchus oleraceus	Common Sow-thistle	1	Naturekit Export May 2023
Spergularia diandra	Lesser sand-spurrey	1	Ecology Australia Report 2022
Spergularia rubra s.s.	Red Sand-spurrey	1	Naturekit Export May 2023
Suaeda baccifera	Berry Seablite	1	Naturekit Export May 2023
Suaeda maritima subsp. maritima		1	Ecology Australia Report 2022
Typha orientalis	Broad-leaf cumbungi	1	Ecology Australia Report 2022

Fauna

Scientific Name	Common Name	Record Number	Source
Gambusia holbrooki	Eastern Gambusia	101	Naturekit Export May 2023
Cyprinus carpio	European Carp	98	Naturekit Export May 2023

Carassius auratus	Goldfish	23	Naturekit Export May 2023
Perca fluviatilis	Redfin	8	Naturekit Export May 2023
Sturnus vulgaris	Common Starling	3	Naturekit Export May 2023

Appendix 4: Cardross and Koorlong Lakes EWMP Updated Environmental Objectives, Further Information (From Butcher et al 2020).

5.7.1 SMARTness and rationalisation

Site-specific environmental objectives for the Cardross and Koorlong Lakes EWMP (DEPI 2016).

EWMP objectives
CK1: Maintain Murray hardyhead populations
CK2: Improve Murray hardyhead populations
CK3: Maintain Ruppia community
CK4: Improve Ruppia community

Assessment of SMARTness of current Cardross and Koorlong Lakes EWMP objectives. Scoring: 1 is criterion met, 0 is criterion not met, and 0.5 is partially met

	Specific		Measurable			Achievable		Relevant		Timely	
Objective	Magnitude clearly specified	Location and scale detailed	Indicators available or easily developed	Can be analysed using accepted statistical practices	Capacity to collect data exists	Under river operating constraints and current climate variability	Considered feasible by knowledgeable stakeholders	Matters driven by environmental watering and/or works and measures	Linked to BP objectives	Absolute date or time period specified	Considers likely lags in response
CK1	0	0	1	1	1	0.5	1	1	1	0	0
CK2	0	0	1	1	1	0.5	0.5	1	1	0	0
CK3	0	0	0.5	1	0.5	0.5	1	0.5	0.5	0	0
Ck4	0	0	0.5	1	0.5	0.5	1	0.5	0.5	0	0

Rationalised environmental objectives for the Cardross and Koorlong Lakes EWMP (DEPI 2016)

Objective	Issue	Outcome
CK1	No problem with objective.	Align language to Basin Plan.
CK2	See CK1	Combine with CK1
CK3	There are two species listed as present at the site *polycarpa* and *megacarpa*. *Ruppia megacarpa* is more sensitive to salinity levels however, it is less abundant according to the EWMP. Baseline surveys of the benthic aquatics is required to support fin tuning of the target, in the meantime change in polycarpa as surrogate.	Objective for Ruppia will be based on persistence and improvement in *R. polycarpa*. Methods for the target are base on a modified approach taken in the Coorong which focuses on cover, extent, recruitment. The proposed target may be able to be simplified once a baseline extent is established.
Ck4	See CK3.	This objective can be combined with CK3

5.7.2 Mapping to Basin Plan

Basin Plan Schedule 8 and 9 criteria.

Schedule 8 criteria met	Schedule 9 criteria met
From DELWP (2015a)	
1: JAMBA, CAMBA **3:** Significant water depth, good water quality and diversity of aquatic habitat at Cardross Lakes made it the most significant wetland in the region, particularly for native fish. Provides connectivity **4:** EPBC Act, FFG Act, DSE Listed **5:** High fauna diversity. Good water quality and diversity of aquatic habitat	**1:** Supports the creation and maintenance of vital habitats and populations **2:** water quality - ecosystem processes supports the transportation and dilution of nutrients, organic matter and sediment; supports the dilution of carbon and nutrients from the floodplain to the river system **4:** lateral connectivity - (between floodplains, anabranches and wetlands)
Updated assessment	
4(a): EPBC listed spp and communities – Murray Hardyhead	**1(e):** Vital habitat - preventing decline of native biota
3(b): Prevents declines in native biota	

5.7.3 Updated objectives for Cardross and Koorlong Lakes

Current objective	CK1: Maintain Murray hardyhead populations
Comments	No major issues with the objective.
EWP objective(s)	8.05,3(a) 8.05,3(b)
Schedule 7 targets	Condition of priority asset - supports listed species and communities Condition of priority asset - prevention of decline in native biota
PEA/PEF criteria met	PEA criteria: 4(a) EPBC listed spp and communities PEA criteria: 3(b) Prevents declines in native biota
BEWS QEEO	B4.1 No loss of native fish spp currently present within the basin
LTWP objective	LTWPVM16 Maintain distribution of threatened small-bodied native fish in wetlands
LTWP target	Maintain current distribution of threatened small-bodied native fish in 2025.
2020 Objective:	By 2030, improve the population of Murray hardyhead (*Craterocephalus fluviatilis*) at Koorlong.
2020 Targets:	By 2030, maintain a self-sustaining population of Murray hardyhead (*Craterocephalus fulivatilis*) at Koorlong Lake: - YoY recorded annually - Abundance of adult fish increased by 20% from 2019 baseline of 12.9 CPUE (based on Whiterod & Wood 2019)
	- Maintain salinity levels during summer within thresholds to support *Ruppia* growth and condition, and tolerances of Murray hardyhead (<60,000 EC µs/cm). - maintain water level of at least 36.7m AHD from Summer to Winter. At the start of spring increase water level to above 38.0m AHD and maintain above this level into early summer.

Current objective	CK2: Improve Murray hardyhead populations
Comments	Combined with CK1

Current objective	CK3: Maintain Ruppia community
Comments	Consider focus on *R. polycarpa* until baseline levels of extent of species is established, but salinity levels should be at lower levels. *R. megacarpa* is a perennial species whereas *R. polycarpa* is an annual – both occur in fresh to hypersaline environments. Germination is likely to decrease in both species. Optimal conditions for germination may be below 30 ppt (roughly 60,000 EC µs/cm) with an upper threshold of 40 ppt (Sim et al. 2006). *Ruppia polycarpa* may be able to germinate at higher salinities than *megacarpa* given longer times to germinate (Sim et al. 2006). Plant condition in polycarpa declines after 45 ppt and rate of salinity rises also leads to more rapid decline in condition of the plants (Sim et al. 2006).
EWP objective(s)	8.05,3(b) 8.06,2 8.06,6(b)
Schedule 7 targets	Condition of priority asset - prevention of decline in native biota Extent and contiguousness of native water dependent vegetation
PEA/PEF criteria met	PEA 3(b) Prevents declines in native biota PEF 1(e) Vital habitat - preventing decline of native biota
BEWS QEEO	B2.11
LTWP objective	LTWPVM2 Improve the species richness of aquatic vegetation in wetlands LTWPVM4 Improve the extent of aquatic vegetation
LTWP target	None specified
2020 Objective:	By 2030, maintain populations and extent of saline aquatic vegetation at Koorlong including benthic herblands with *Ruppia* beds containing both *R. polycarpa* and *R. megacarpa*.
2020 Targets:	By 2030, vigorous populations of saline aquatic vegetation at Cardross and Koorlong lakes: At Koorlong Lake

	- maintain ≥30% cover of *Ruppia* and at least 10 live (green) shoots per core at 80% of sites assessed - measured by taking sediment 5 core samples (75mmx4cm deep) at transects of dry zone above waterline, waterline, 30cm and 60cm depths - up to five random transects per site minimum of 200m apart At Cardross Basin 1 West - improve cover of *Ruppia* to ≥30% and at least 10 live (green) shoots per core at 40% of sites assessed - measured by taking sediment 5 core samples (75mmx4cm deep) at transects of dry zone above waterline, waterline, 30cm and 60cm depths - up to five random transects per site minimum of 200m apart To achieve this specific water regime and salinity levels will need to be established – i.e. once a baseline is established these targets may be modified. Sampling method modified from Paton et al. (2018). Suggested salinity threshold of 30ppt should support growth/germination and condition of both species (see Sim et al. 2006). Flowering is likely to require 3 months at <15ppt salinity (Sim et al. 2006). These thresholds need to be confirmed for this wetland system and others where Ruppia outcomes are the objective.

Current objective	CK4: Maintain Ruppia community
Comments	Combined with CK3

Appendix 5. Assessing Risks

When prioritizing wetland watering, it is often difficult because there is no framework by which you can compare the fate of different species. To support prioritization, this guide seeks to put each wetland and its associated species within a regional context. For example, the last remaining population of Hardyhead is a high priority because loss from Koorlong Lake would represent loss from the region. The process can also be used when communicating the rationale behind decisions or support engagement by providing a framework for discussion.
The process is presented in Figure 1, with a more detailed explanation provided in Tables 1 and 2.

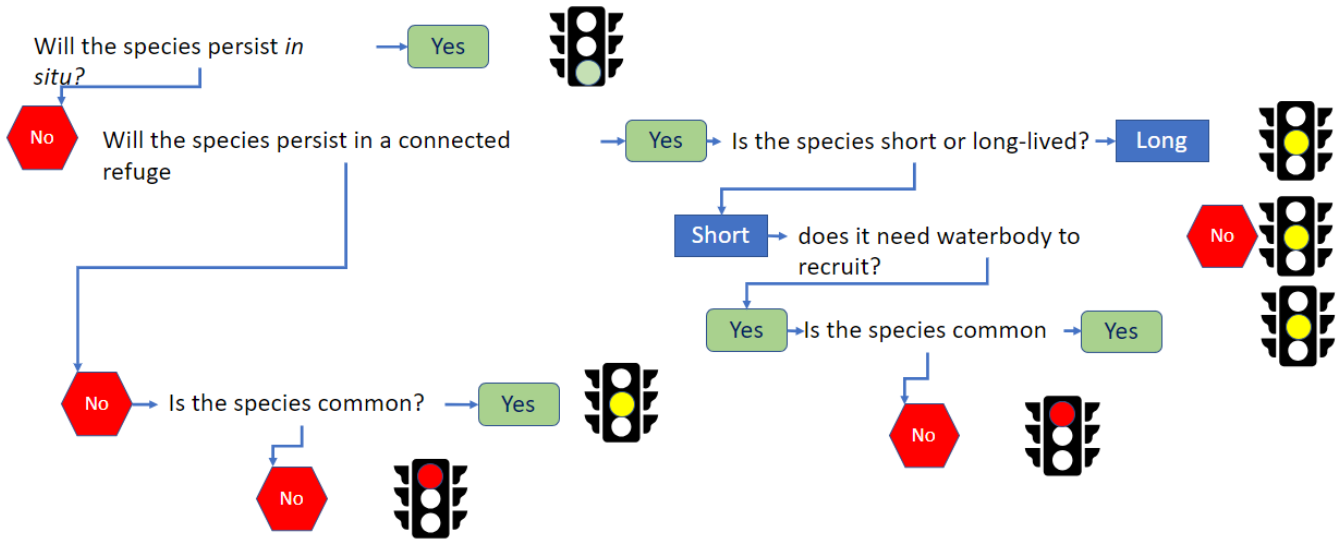


Figure 18. Risk decision tree

Table 21. Risk decision tree

Row	Question	Rationale	Response	Risk	Go To
1	Will the species persist *in situ*?	If the species will survive without intervention, It becomes a lower priority	Yes	Low	
			No		Row 2
2	Will the species persist in a connected refuge?	If the species has the capacity (its own capability and appropriate connectivity) to survive, it becomes a lower priority	Yes		Table 2
			No		Row 3
3	Is the species common?	If a species is common then there may be other populations that are more likely or easier to protect than the ones in the wetland.	Yes	Med	
			No	High	

Table 22. Risk decision tree

Row	Question	Rationale	Response	Risk	Go To
1	Is the species short or long lived?	Long-lived species often have greater capacity to endure periods of hardship, whereas short lived species are programmed to die.	Long	Med	
			Short		Row 2
2	Does the species need the wetland to recruit?	If the species requires the wetland to recruit then sustaining will require protection of wetland condition.	No	Med	
			Yes		Row 3
3	Is the species common?	If a species is common then there may be other populations that are more likely or easier to protect than the ones in the wetland.	Yes	Mod	
			No	High	

mallee
catchment management authority

Cnr Koorlong Ave & Eleventh St, Irymple
03 5051 4377 | reception@malleecma.com.au
www.malleecma.com.au