Heywood's Lake Environmental Water Management Plan

mallee
catchment management authority

Document Control

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Contact

For queries regarding this document, please contact:

Louise Chapman

Louise.Chapman@malleecma.com.au

Waterways Coordinator

Mallee Catchment Management Authority

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Executive summary

Environmental Water Management Plans (EWMPs) have been developed for key sites in the Mallee region. The Mallee Waterway Strategy 2014-22 (Mallee CMA, 2014) identified 23 Waterway Management Units (WMU) from 216 targeted waterways in the Mallee. The interconnectedness and commonality of threats impacting on the waterways values were used to group them into planning units. This EWMP has been developed for the Heywood's Lake WMU sub-unit, hereafter referred to as Heywood's Lake. The EWMP will help to guide future environmental watering activities for this area.

Heywood's Lake is situated on the River Murray floodplain between Swan Hill and Robinvale, southeast of Boundary Bend and is approximately 1600 Ha in area. Heywood's Lake includes a Wildlife Reserve (State Game Reserve), areas of private land, River Murray Park and River Murray Reserve.

Heywood's Lake and Little Heywood's Lakes are ephemeral deflation basin lakes (EDBLs). EDBLs are naturally dynamic lowland river floodplain environments which fluctuate between terrestrial and aquatic states (Scholz et. al., 2002).

Heywood's Lake is a nationally important wetland listed in the Directory of Important Wetlands for its cultural significance. Thirty-two species of waterbirds have been recorded at Heywood's Lake between 2012 and 2015 in response to environmental watering. Over 6,000 individual birds were recorded at the Lake in 2013/2014 while the Lake was full, while nearly 2,500 individual birds were counted as the environmental water receded and exposed the littoral fringe of the Lake in early 2015.

Nineteen listed species (birds and fish) including sixteen which are water dependent and three which are indirectly water dependent have previously been found. Heywood's Lake and Little Heywood's Lake are both listed as high priority wetlands in the Mallee Waterway Strategy (Mallee CMA, 2014).

The combination of Black Box woodlands, mudflats, semi-emergent macrophyte beds and open water habitat found within the target area provide a great diversity of feeding, breeding and nursery sites for native water-dependent biota.

Index of Wetland Condition assessments of Heywood's Lake and Little Heywood's Lake indicate that all sub-indices are in moderate to excellent condition, with the exception of hydrology. An appropriate water regime consisting of natural flooding events and supplementary environmental watering will therefore improve the site's condition and support its significant ecological values.

The management goal for the Heywood's Lake EWMP is to *Restore Heywood's Lake to an intermittently flooded deep water wetland that sustains resident aquatic fauna while flooded and supports breeding waterbirds*. The target area for this EWMP is Heywood's Lake and Little Heywood's Lake and the channel linking the Heywood's Lake to the River Murray.

To achieve this, ecological and hydrological objectives have been defined to provide an appropriate environmental watering regime. The ecological objectives are based on the values that the Heywood Lake EWMP target area is likely to support. They are:

- Maintain Black Box Woodland diversity and productivity (Ecological Vegetation Classes (EVCs) 103 and 813).
- Promote diverse aquatic macrophyte zones.
- Provide open water habitat to encourage diversity and abundance of deep water foraging and piscivorous waterbirds

- Provide shallow water habitat that supports foraging, nesting and recruitment of dabbling ducks and large and small waders.
- Encourage a productive aquatic ecosystem through the release of nutrients and organic matter from the sediments and decomposition of inundated terrestrial vegetation through inundation of the wetlands following a dry phase.

The optimal water regimes for Heywood's Lake and Little Heywood's Lake are provided below.

Heywood's Lake

Fill Heywood's Lake to 56.8 mAHD to inundate the fringing Intermittent Swampy Woodland community every eight years during winter/spring. Allow the water level to decrease slowly over summer to expose fringing vegetation and mud flats. Provide a top up in the second year to 54 mAHD to ensure that enough depth is retained for two years to support the formation of open water habitat. Following the two years of available open water habitat, allow Heywood's Lake to enter a drying phase.

Little Heywood's Lake

Inundate Little Heywood's Lake every eight years to 56.8 mAHD for up to four months during winter/spring.

Minor infrastructure upgrades and a temporary pump are required to enable the efficient and effective delivery of environmental water to Heywood's Lake. Further investigation is required to confirm the most efficient means of delivering water to Little Heywood's Lake.

1 Introduction

This Environmental Water Management Plan (EWMP) has been prepared by the Mallee Catchment Management Authority (CMA) to establish the long-term management goals of Heywood's Lake.

The key purposes of the EWMP are to:

- Identify the long-term objectives and water requirements for the wetland, identified as a high priority by the Mallee CMA;
- Provide a vehicle for community consultation, including for the long-term objectives and water requirements of the wetlands;
- Inform the development of seasonal watering proposals and seasonal watering plans; and
- Inform the long-term watering plans that will be developed under the Basin Plan requirements.

2 Site overview

2.1 Site location

The Mallee CMA region is situated in the north-west of Victoria. The area of responsibility is close to 39,000 km^2 (3.9 million ha), with a regional population estimated to be 65,000. 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 CMA in the state.

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

In 2006, the Mallee CMA engaged consultants (Ecological Associates, 2006) to investigate water management options for the River Murray floodplain from Robinvale to Wallpolla Island. One of the major outcomes of these investigations was the development of a system of Floodplain Management Units (FMUs). These divide the floodplain into management units within which water regimes can be managed independently of another FMU, 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 support effective management of hydrologically connected systems. In addition to this, the Mallee CMA has also used individual FMUs or groupings of FMUs to form Waterway Management Units (WMUs) (comprised of Waterway Management Sub-units) for planning within its Mallee Waterway Strategy (Mallee CMA, 2014).

The site for this plan is the Heywood's Lake Waterway Management Sub-unit, hereafter referred to as Heywood's Lake in this document. Heywood's Lake is located within the Heywood WMU, south east of Boundary Bend on the River Murray floodplain (Figure 1).

A regional context document (North, 2014) has been prepared to compliment the Mallee CMA EWMPs and should be read in conjunction with this document.

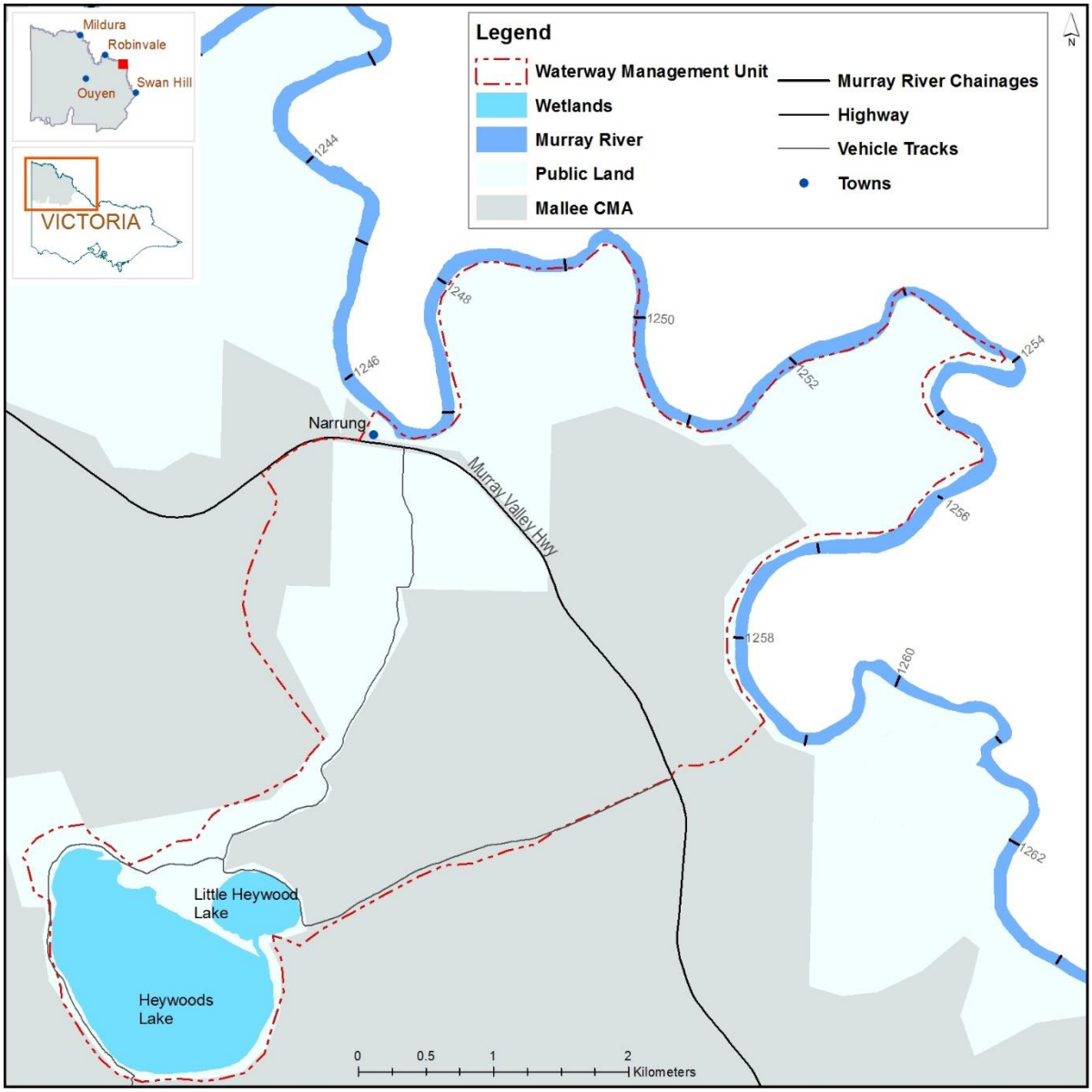


Figure 1 - Heywood's Lake within the Heywood WMU sub-unit

2.2 Catchment setting

Heywood's Lake is located within the Murray Fans bioregion within the Mallee CMA region. The Murray Fans bioregion is characterised by a flat to gently undulating landscape on recent unconsolidated sediments with evidence of former stream channels, braided old river meanders and paleochannels and broad floodplain areas associated with major river systems and prior streams (DSE, 2015). The vegetation is a mosaic of Plains Grassy Woodland, Pine Box Woodland, Riverina Plains Grassy Woodland and Riverina Grassy Woodland ecosystems (DSE, 2015).

2.3 Heywood's Lake

Heywood's Lake is situated on the River Murray floodplain between Swan Hill and Robinvale, southeast of Boundary Bend. The site is approximately 1600 Ha in area.

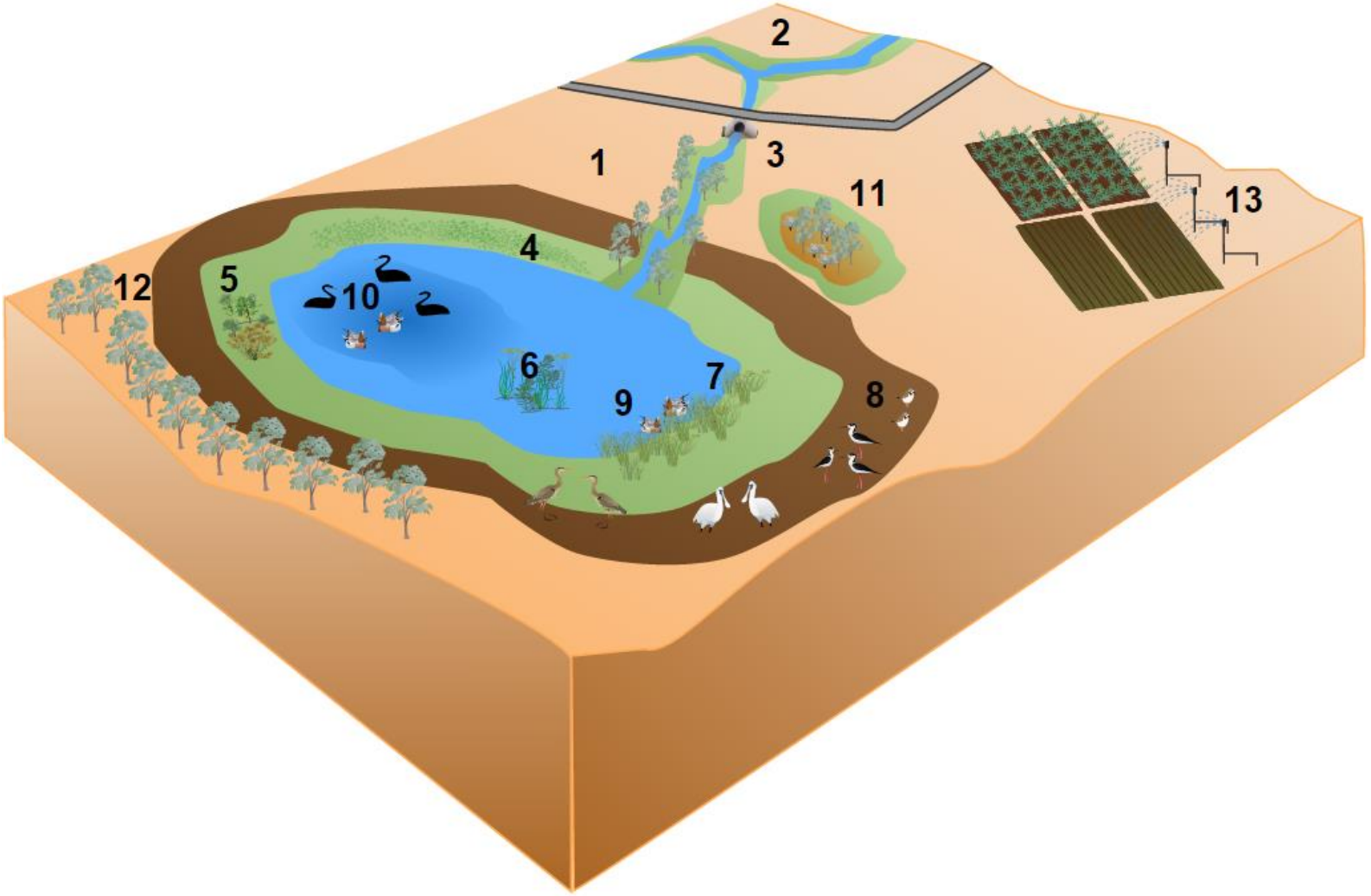
There are three distinct wetlands at the site: Heywood's Lake, Little Heywood's Lake and one small unnamed wetland north of the Murray Valley Highway.

Heywood's Lake and Little Heywood's Lakes are ephemeral deflation basin lakes (EDBLs). EDBLs are naturally dynamic lowland river floodplain environments which fluctuate between terrestrial and aquatic states (Scholz et. al., 2002). They are critical components of floodplain ecosystems that provide habitat for large numbers of plants and animal and provide environmental services, including water purification and flood mitigation (Scholz and Gawne, 2004).

Historically, Heywood's Lake was a popular recreation area, with uses including fishing, swimming, picnicking, bird watching and boating (ANCA, 1996). More recently, dry conditions have limited recreational activities to waterfowl hunting, sightseeing and bird watching. The lunette on the east and south side of Heywood's Lake has historically been excavated, with a large number of Aboriginal remains found (McKane, 1992).

2.4 Conceptualisation of the site

Heywood's Lake has been represented in a conceptual model. This is a visual representation of processes and components within the target area that are discussed throughout this EWMP.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1. Heywood's Lake is an ephemeral deflation basin lake, located high on the River Murray floodplain upon the quaternary aeolian sediments of the Woorinen Formation. It connects to the River Murray only during times of high river flow (92,700 ML/day) (Ecological Associates, 2006), via a combination of a constructed channel and natural flow path.
2. Natural inundation of Heywood's Lake has been affected by River Murray regulation and modification of flow paths at the site. EDBLs are naturally subjected to episodes of rapid flooding, followed by periods of evaporative drying.
3. Heywood's Lake was originally filled approximately every 10 – 15 years (flood thresholds of 155,700 – 166,700 ML/d) via a natural channel along the eastern side of the site. This channel was completely blocked following floods in 1956, preventing floods up to 181,900 ML/d (Gippel, 2006) until the construction of a spoon drain and culvert in the early 1990's lowered the wetland sill level and allowed more frequent inflows.
4. The lake takes several years to dry. When flooded it supports a mosaic of vegetation communities, carbon and nutrient cycling as well as a range of waterbird guilds.
5. During the drying phase the lake supports Lake Bed Herbland (Ecological Vegetation Class (EVC) 107). Following maturation and seeding, seeds are stored in the sediment, or plants die back to tuber-like rootstocks, waiting for the next inundation.
6. During prolonged inundation semi-emergent macrophytes flourish in the still water, supporting algae and biofilm communities and providing important refuge for small native fish and frogs.
7. Inundation of the shallow edges of the lake in spring followed by a gradual drawdown over late spring and summer will support an increased diversity and abundance of aquatic macrophytes.
8. Gradual drawdown of the lake will provide shallow water and exposed mudflats, providing feeding opportunities for large and small wading birds (Royal Spoonbill, Straw-necked ibis, Yellow-billed Spoonbill, Black-winged Stilt, and Black-fronted Dotterel)
9. Dabbling ducks (Australasian Shoveler, Chestnut and Grey Teal, Freckled Duck, Pacific Black Duck, and Pink-eared Duck) feed in the fringing macrophyte habitat.
10. Deep-water foragers (Black Swan, Blue-billed Duck, Eurasian Coot, Hardhead, and Musk Duck) feed in open water habitat in deeper areas of lake.
11. Northeast of Heywood's Lake a smaller lake (Little Heywood's) is perched slightly higher on the floodplain. It is rarely inundated and is dominated by a less flood-tolerant species assemblage of Black Box woodland with an understorey of Cottony Saltbush. Watering of this lake could be provided during prolonged dry conditions, to ensure the survival of the Black Box (*Eucalyptus largiflorens*) trees.
12. Low terraces around Heywood's Lake and the channel support Intermittent Swampy Woodland (EVC 813), and at slightly higher levels, Riverine Chenopod Woodland (EVC 103) that are naturally subject to infrequent flooding.
13. A narrow buffer between agricultural land and the Heywood's Lake reserve may be insufficient to protect ecological values in the reserve from land use impacts.

Graphic developed using software provided by the Integration and Application Network, University of Maryland Centre for Environmental Science (ian.umces.edu/symbols/).

Additionally, Scholz and Gawne (2004) developed a conceptual model for EDBL function which is applicable to Heywood's Lake. The authors note that there may be parts of the model that may be inappropriate to some EDBLs; however, the model provides a useful guide to identifying management targets and the likely outcomes of management actions. The model is presented below:

Conceptual model for Ephemeral Deflation Basin Lake function (Scholz and Gawne, 2004)

1. The first phase occurs as a dry or partially dried lake floods. This initial flooding phase is characterised by high habitat abundance and diversity provided primarily by inundated terrestrial vegetation, such as grasses, and by high productivity fuelled by the inflow of nutrients and organic matter with the floodwaters and by releases from the sediments and the decomposition of inundated terrestrial vegetation. Changes in primary and secondary production following wetland inundation tend to follow a predictable successional sequence.
2. During the late flood phase, fish populations increase due to both immigration and local recruitment, and provide increasing top-down pressure on secondary production. As water levels continue to increase, the inundation of the littoral fringe vegetation, such as lignum, black box and red gum provides additional aquatic habitat, although at this time also much of the habitat structure and complexity across the lakebed provided by inundated grasses and herbs begins to decline as they decompose.
3. During the late wet phase, fish populations are established, the productive pulse fuelled by nutrient releases from the sediments and decomposing vegetation subsides, and habitat structure/complexity is restricted to the littoral fringe.
4. During the drying phase the lake contracts, littoral habitat is exposed, water quality changes (elevated salt, nitrogen and phosphorous concentrations) and become less buffered to diel fluctuations in temperature. During this period aquatic organisms become concentrated and once the lake becomes too shallow to offer fish refuge, avian predation of fish increases. These processes impact on trophic interactions. This process continues until physical conditions become too harsh and the lake ultimately dries.
5. Finally, once the lakebed has been exposed it becomes an important terrestrial habitat for a range of plants and animals.

2.5 Land status and management

There are several agencies and individuals involved in managing the land and water at Heywood's Lake. Land management boundaries are shown in Figure 2.

The land tenure of Heywood's Lake consists of State Forest managed by the Department of Environment, Land, Water and Planning (DELWP), State Wildlife Reserve (Heywood's Lake), managed by Parks Victoria and some areas of private land.

Some areas of the floodplain abut the River Murray and are designated as River Murray Park.

VEAC (2008) recommended that Heywood's Lake remain a Wildlife Reserve (State Game Reserve):

- To conserve and protect species, communities or habitats of indigenous animals and plants; and
- For public recreation (including hunting in season and as specified by the land manager) and education, where this does not conflict with the primary objective.

Table 1 - Stakeholders for the Heywood's Lake EWMP

Group	Role
Parks Victoria	Land manager
Mallee CMA	Regional waterway and environmental management
Department of Environment, Land, Water and Planning	State level environmental management planning, land manager, threatened species manager
Victorian Environmental Water Holder	Manager of Victoria's environmental water entitlements
Local landholders	Assistance in planning and implementation of programs
Wadi Wadi	Indigenous representation

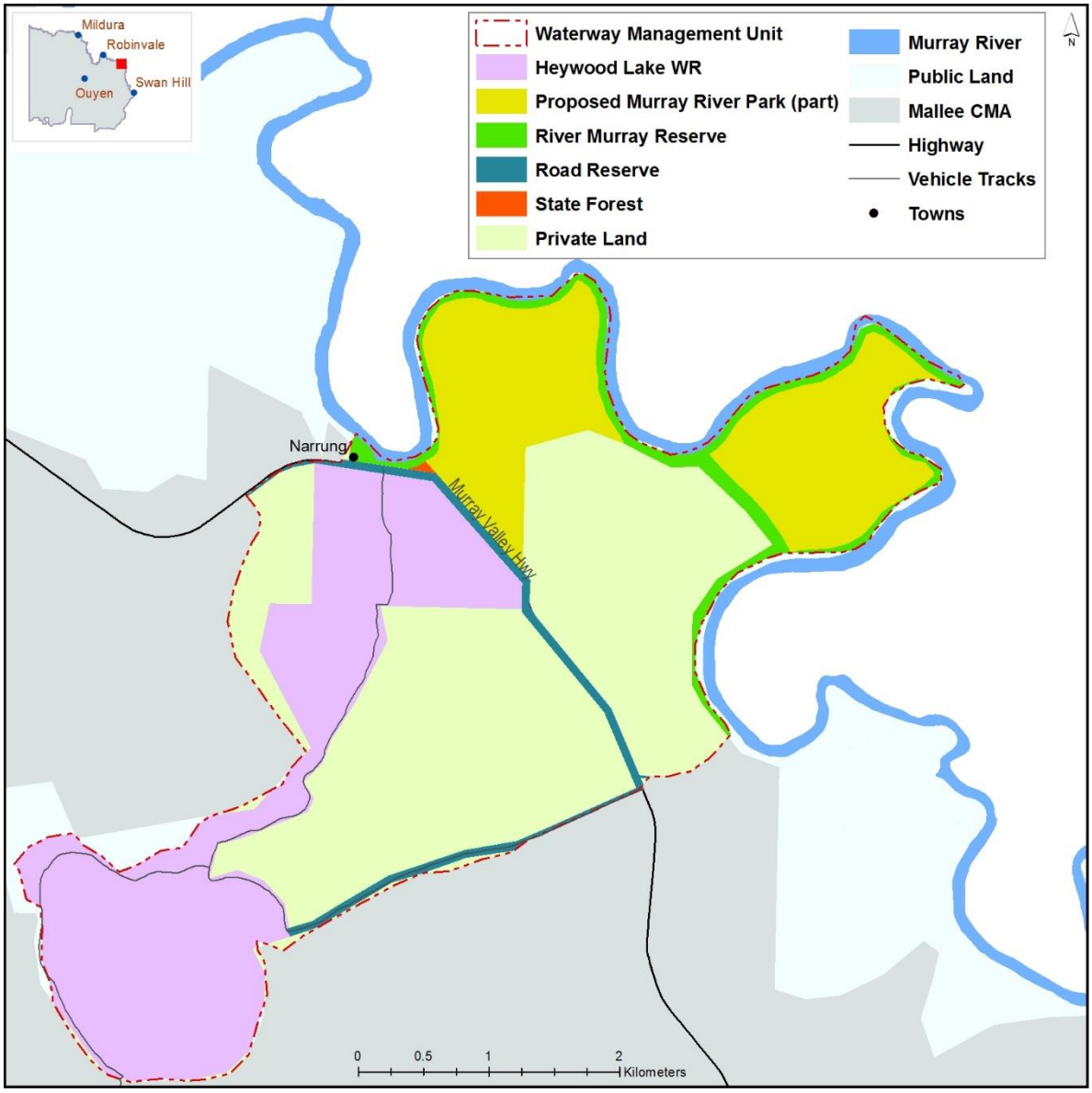

Figure 2 - Land management boundaries within Heywood's Lake

2.8 Wetland characteristics

A brief overview of the main characteristics of the wetlands at Heywood's Lake is provided in Table 2.

Table 2 - Wetland characteristics at Heywood's Lake

Characteristics	Description
Name	Heywood's Lake
Mapping ID (Wetland 1994 layer)	15475 – Heywood's Lake, 25477 – Little Heywood's Lake, 41516 – unknown
Mallee CMA wetland ID	313, 315, 320, 322
Target area size	319 ha
Bioregion	The majority of the site is within the Murray Fans bioregion, a small section falls within Murray Mallee
Conservation status	Directory of Important Wetlands in Australia (Heywood's Lake), reference code VIC009
Land status	State Wildlife Area (State Game Reserve) (Heywood's Lake); River Murray Park; private land; state forest
Land manager	Parks Victoria; DELWP; Private land
Surrounding land use	Nature conservation, grazing, cropping, irrigated agriculture
Water supply	Natural inflows from River Murray
1788 wetland category (Wetland Pre-European (1788) layer)	Deep Freshwater Marsh (Heywood's Lake), Freshwater Meadow (Little Heywood's Lake), Shallow Freshwater Marsh
2013 wetland category (Wetland Current layer)	Temporary freshwater swamp (12765 – Heywood's Lake and Little Heywood's Lake combined), unknown (12770)
Wetland capacity	Heywood's Lake: 162.84 ha, Little Heywood's 24.98 ha
Wetland depth at capacity	Heywood's Lake: 4 - 5 metres Little Heywood's Lake <2 metres

2.9 Management scale

The whole of Heywood's Lake has a water requirement as a floodplain complex, but the focus of this plan is restricted to the target area within Heywood's Lake of 319 ha, shown as the maximum inundation extent in Figure 3.

This target area, consisting of Heywood's Lake (the lake itself) and Little Heywood's Lake, the channel between the River Murray and Heywood's Lake and an area of Lignum Swampy Woodland abutting the channel, is the area that is able to be managed with environmental water.

Wetland #12770 has been excluded from the target area as the wetland sill is poorly defined and unable to be regulated.

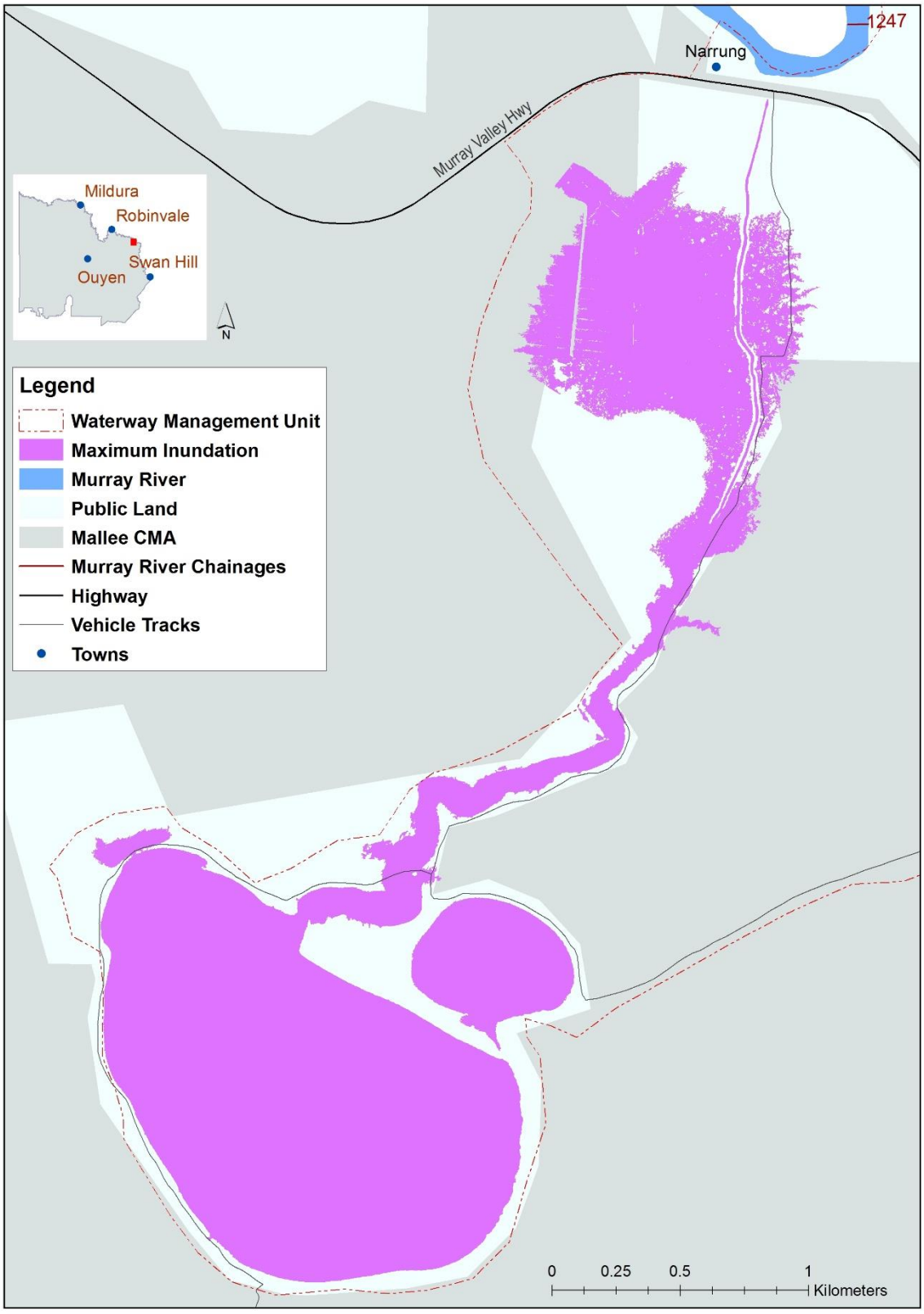

Figure 3 - Target area for the Heywood's Lake EWMP

2.11 Environmental water sources

The Environmental Water Reserve (EWR) is the legally recognised amount of water set aside to meet environmental needs. The Reserve can include minimum river flows, unregulated flows and specific environmental entitlements. Environmental entitlements can be called out of storage when needed and delivered to wetlands or streams to protect their environmental values and health.

The Victorian Minister for Environment, Climate Change and Water appointed Commissioners to Victoria's first independent body for holding and managing environmental water on 1 July 2011 – The Victorian Environmental Water Holder (VEWH) is responsible for holding and managing Victoria's environmental water entitlements, and making decisions on their use.

Environmental water for the target area may be sourced from the water entitlements and their responsible agencies listed in Table 3 and further explained in the Regional Context Document (North, 2014). Recent environmental watering at Heywood's Lake is outlined in the Environmental Watering section of this EWMP.

Table 3 - Summary of environmental water sources available to Heywood's Lake

Water entitlement	Responsible agency
River Murray unregulated flows	Murray-Darling Basin Authority
River Murray surplus flows	
Victorian River Murray Flora and Fauna Bulk Entitlement	Victorian Environmental Water Holder
Commonwealth water	Commonwealth Environmental Water Holder
Donated Water	Victorian Environmental Water Holder

2.12 Related agreements, policy, plans and activities

There is a range of international treaties, conventions and initiatives, as well as National and State Acts, policies and strategies that direct management of the target area. Those with particular relevance to the site and the management of its environmental and cultural values are listed in Table 4. For the functions and major elements of each refer to the Regional Context Document (North, 2014).

Table 4 - Legislation, conventions and listings relevant to the target area

Legislation, agreement or convention	Jurisdiction
Environment Protection and Biodiversity Conservation Act 1999 (EPBC)	National
China-Australia Migratory Bird Agreement (CAMBA)	National (relevant international agreements administered under the *EPBC Act*)
Japan- Australia Migratory Bird Agreement (JAMBA)	
Republic of Korea- Australia Migratory Bird Agreement (ROKAMBA)	
Flora and Fauna Guarantee Act 1988 (FFG)	State

DELWP Advisory Lists of Rare or Threatened Flora and Threatened Fauna (VROT advisory lists)	State

The Mallee Waterway Strategy (Mallee CMA, 2014) identified Heywood's Lake and Little Heywood's Lake as high priority waterways. Additionally, the strategy identifies a number of specific management activities for these wetlands. These activities are:

- Introduce fingerlings to the Heywood Lake system (threatened native species and recreational species) (Management activity number B2.1).
- Lower sill between Heywood Lake and Little Heywood's Lake (Management activity number C1.3).
- Deliver water as per EWMP (Management activity number C1.5).
- Assess cultural heritage values at Heywood Lake and Little Heywood's Lake and consider recommendations in management plans (Management activity number E1.2).
- Review extent of Heywood EWMP (Management activity number F1.1).

The activities identified in the Mallee Waterway Strategy (Mallee CMA, 2014) have been considered in the development of this EWMP. Some recommendations may not be specifically supported, where up to date data or recommendations provide better options for the target area.

Additionally, a number of specific studies have been undertaken incorporating Heywood's Lake. Heywood's Lake was one of the areas investigated in the Mallee Wetland Operational Plans (SKM, 2002a) as well as the Investigation of Water Management Options for the River Murray – Nyah to Robinvale (Ecological Associates 2006).

A Cultural Heritage Assessment was carried out (SKM, 2002b) into the cultural sites and values which may have been impacted upon by a proposed nearby almond plantation expansion. This development has not been implemented, but the study provided important Indigenous cultural heritage context for this EWMP.

Heywood's Lake has also been included in the Index of Wetland Condition (IWC) monitoring. Results from this monitoring are described and considered in this EWMP.

4 Hydrology 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. A wetland's hydrology is determined by the physical form of the wetland, surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration. Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands.

Ecological Associates (2006) suggest that the hydrology at Heywood's Lake is best described using the MSM Bigmod Gauge 414200 River Murray @ downstream of Wakool Junction.

4.1 Wetland hydrology, water management and delivery

Pre-regulation

Prior to river regulation in this reach of the River Murray, the floodplain experienced inundation more frequently and for longer periods.

Under pre-regulation conditions, EDBLs such as Heywood's Lake were subjected to episodes of rapid flooding, followed by more protracted periods of evaporative drying. Heywood's Lake was originally filled via a natural channel that diverted water from the River Murray at chainage 1258.3. McKane (1992) estimated that prior to European settlement, this channel provided inflow events every 10 – 15 years, indicating an inundation threshold of between 155,700 to 166,700 ML/day (Gippel, 2006).

Little Heywood's Lake would have flooded following the filling of Heywood's Lake. The high sill (approximately 57 mAHD) between the two wetlands blocks all but the highest flows and results in a reduced frequency of inundation for Little Heywood's Lake.

Post-regulation

River regulation has not significantly changed the seasonality of flows in this section of the River Murray with high winter and lower summer flows still existing (Figure 4). However, the overall volume of winter flows has been reduced and there has been a reduction in the frequency of small to medium flood events (Maheshwari, Walker and McMahon, 1993). This, combined with the location of Heywood's Lake high on the floodplain, has reduced the frequency of inundation of Heywood's Lake significantly.

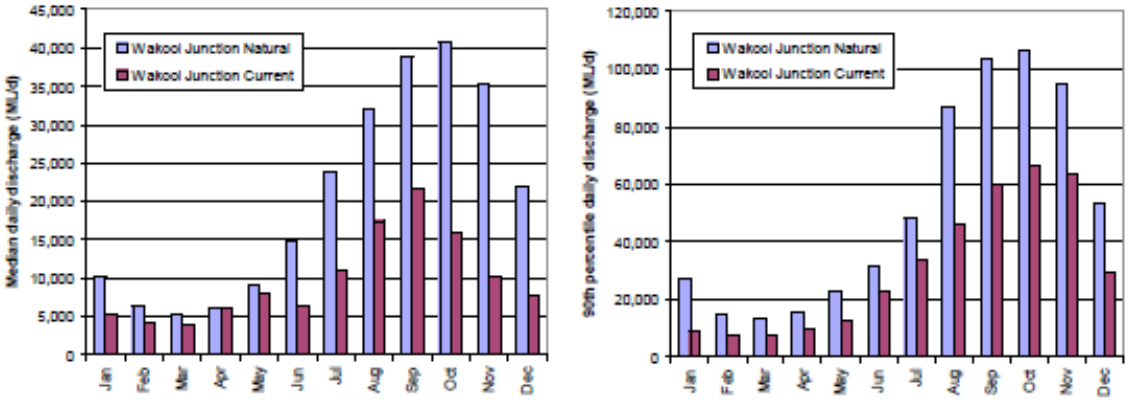

Figure 4 - Distribution of median flows and 90th percentile flows for each month in the River Murray downstream of Wakool Junction for pre-regulated and regulated conditions.

(Ecological Associates, 2006), sourced from MDBC MSM-Bigmod 109-year data

Ecological Associates (2006) reported that Heywood's Lake filled in November 1992, 1993 and 1996. Prior to this the Lake had not received floodwaters since 1956. Following the 1956 flood, the channel entering the floodplain at River Murray chainage 1258.3 was completely blocked; levees were constructed and other land management practices were enacted to prevent flooding (SKM, 2002c; Environment Australia, 2001). This prevented all inflows up to 181,900 ML/day reaching the Lake (Gippel, 2006).

The impact of river regulation has been offset by the excavation of a spoon drain in 1991, which has lowered the wetland sill level. It is estimated that Heywood's Lake is inundated at 92,700 ML/day flow in the River Murray,[1] which is now exceeded on average every eight years (Ecological Associates, 2006). The spoon drain is located on the northern side of Narrung Township Reserve and links to the natural inlet. A culvert was constructed in 1992 under the Murray Valley Highway which allows flow down the channel (SKM, 2002c).

Figure 5 - Culvert under the Murray Valley highway and the spoon drain which allows inundation of Heywood Lake either through flood event or pumping of environmental water

4.2 Environmental watering

Environmental watering has previously occurred at Heywood's Lake on four occasions. Table 5 below outlines the watering events. Estimation of the proportion of the lake inundated was made during waterbird counts undertaken during the watering periods (M. Dedini unpublished data, 2015). Little Heywood's Lake received environmental water in 2017. This data is also presented in Table 5.

[1] This value is derived from anecdotal information and is equal to the 1996 historical flood, when the lake is known to have filled (Ecological Associates, 2006).

Table 5 - A summary of environmental watering at Heywood's Lake and Little Heywood Lake.

Water Year	Lake	Time of inflow	Inflow source	Total volume (ML)	Proportion of lake inundated
2010/2011[2]	Heywood Lake	April to June 2011	Victorian River Murray Flora and Fauna entitlement	5,246.78	Unknown
2011/2012	Heywood Lake	November 2011	Victorian River Murray Flora and Fauna entitlement	1999.104	February 2012 – 80% February 2013 – 70%
2013/2014[3]	Heywood Lake	September to November 2013	VEWH River Murray Unregulated Flow	5,000.2	February 2014 – 100% February 2015 – 60%
2016/2017	Heywood Lake	July to December	Natural inundation	-	100%
2016/2017	Heywood Lake	March to June	VEWH	3, 000.21	100%
2017/2018	Little Heywood Lake	September to November	VEWH	511.556	100%

Temporary infrastructure in the form of a removable flange on the culvert under the Murray Valley Highway was installed to allow water to be pumped from the River Murray through the channel to Heywood's Lake.

The area of inundation for the 2013 watering events is shown in Figure 6.

[2] In March 2011 Heywood's Lake was dry.

[3] In September 2015 the lake the water level of the lake remained just below the level of the Intermittent Swampy Woodland.

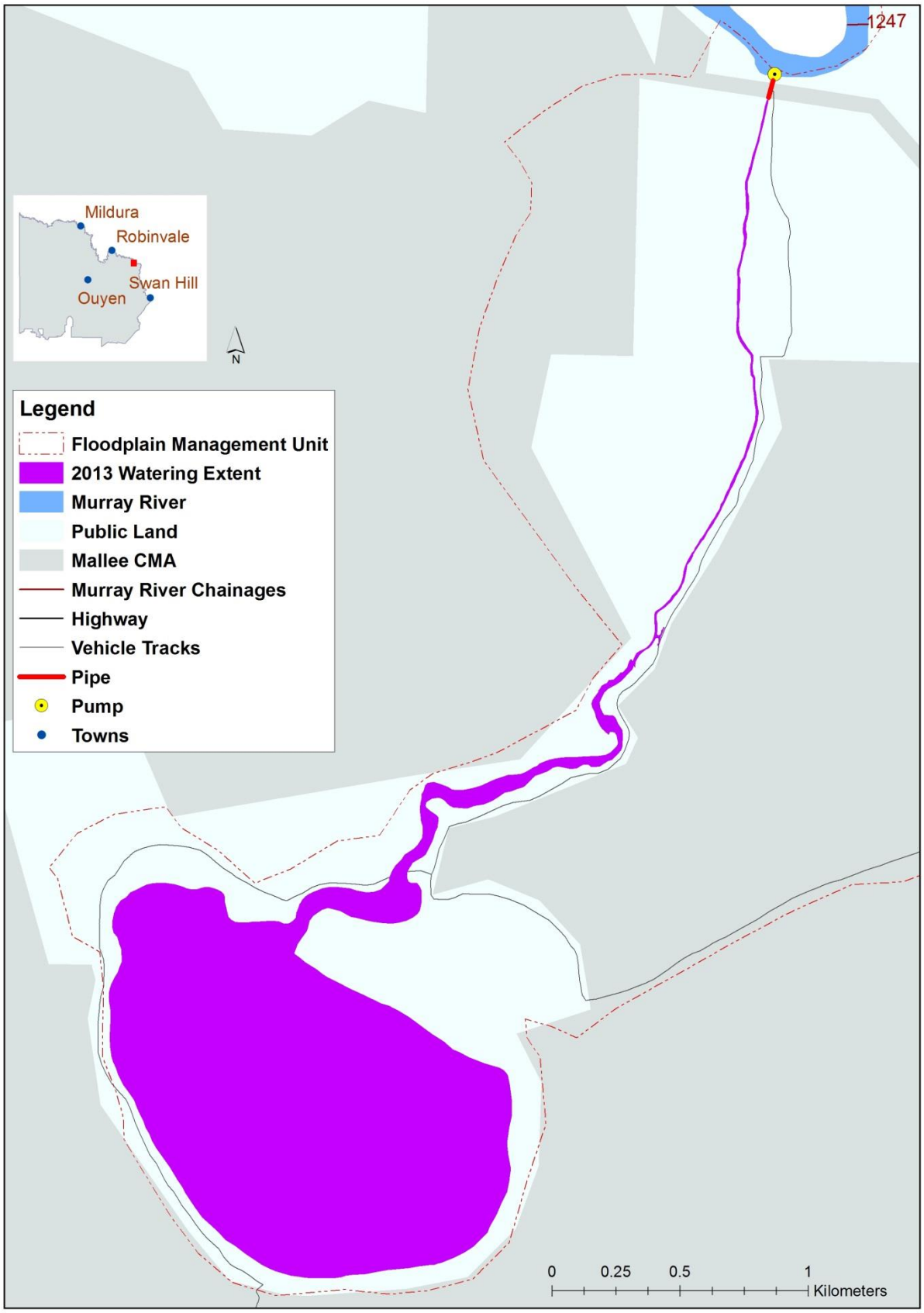

Figure 6 - Area of inundation from the 2013 environmental watering event

The objectives of the 2010/2011 environmental watering targeted improving the health of water stressed River Red Gum (*Eucalyptus camaldulensis*) and Black Box communities; and establishment of lake bed and fringing understorey providing habitat, food sources and breeding resources for wetland dependent species. Improved system productivity and the proliferation of invertebrates and frogs were also identified as targets (Mallee CMA, 2011). Figure 7 shows Heywood's Lake in a dry state prior to the 2011/2012 environmental watering event.

The purpose of the 2011/2012 watering event was to top up the 2010/2011 watering to increase the inundation extent and maintain the depth of the inundation for a greater period (Mallee CMA, 2011).

The objectives for the 2013/2014 watering event focussed on improving the health of the Black Box community and supporting the aquatic lake bed and fringing understorey vegetation that established following the previous watering (Mallee CMA, 2013). It also aimed to provide habitat, food sources and breeding resources for many wetland dependent species (Mallee CMA, 2013).

Figure 7 - Heywood's Lake dry phase, March 2011

Waterbird counts were undertaken annually at Heywood's Lake between 2012 and 2015. The counts indicated that the environmental watering had contributed to large numbers of a wide range of waterbird species and guilds using the lake. Thirty-four bird species were recorded as using Heywood's Lake during the surveys, including 32 waterbird species, with total counts ranging between 279 – 6194 birds. Individual species were recorded as flocking in numbers up to 3030 individuals (Eurasian Coot in 2013) and the listed species, Australian Shoveler, Freckled Duck, Blue-billed Duck, Little Egret, Musk Duck, Pied Cormorant and Eastern Great Egret were recorded as present. Darter were noted to be breeding at the site in 2014. See Appendix 1 for the full list of species sighted and number of individuals per species.

5 Water dependent values

5.1 Environmental values

Heywood's Lake provides a range of shelter and food resources for indigenous fauna, flora and vegetation communities. The types of habitat provided, and the consequently the species that utilise the site, change as water fills the lakes, channel and floodplain and recedes again.

The availability of flora and fauna data for Heywood's Lake is limited. While data from the Victorian Biodiversity Atlas (VBA) (DELWP, 2015a), a previous site plan (SKM, 2002c) and waterbird monitoring undertaken during recent watering events have been referenced (Appendix 1 and Appendix 2), it is recommended that further flora and fauna surveys, including fish and macrophyte surveys are undertaken to improve knowledge of the site's ecological values.

Listings and significance

Fauna

Eighty eight native fauna species have been recorded at Heywood's Lake. Of special interest and management responsibility are the nineteen water dependent fauna species listed in legislation, agreements or conventions (Table 6). Heywood's Lake supports species listed under the China-Australia Migratory Bird Agreement (CAMBA), the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, Victoria's *Flora and Fauna Guarantee Act 1988* (FFG), and the Victorian advisory lists of threatened vertebrate fauna and flora in Victoria (VROT).

Despite only a limited number of listed fauna being identified in VBA records, it is fair to assume that more listed species occur or could occur due to the availability of habitat and nearby sightings.

Table 6 - Listed water-dependent fauna recorded at Heywood's Lake

Common name	Scientific name	Type	International agreements	EPBC status	FFG status	VROT status
Australasian Shoveler	*Anas rhynchotis*	B	-	-	-	V
Australian Bustard	*Ardeotis australis*	B	-	-	L	CR
Blue-billed Duck	*Oxyura australis*	B		-	L	EN
Brown Treecreeper (south-eastern ssp.)*	*Climacteris picumnus victoriae*	B	-	-	-	NT
Eastern Great Egret	*Ardea modesta*	B	-	-	L	V
Freckled Duck	*Stictonetta naevosa*	B		-	L	EN
Freshwater Catfish	*Tandanus tandanus*	F	-	-	L	EN
Growling Grass Frog	*Litoria raniformis*	A	-	VU	L	EN
Little Egret	*Egretta garzetta*	B		-	L	EN
Hardhead	*Aythya australis*	B	-	-	-	V
Major Mitchell's Cockatoo*	*Lophocroa leadbeateri*	B	-	-	-	V
Murray Cod	*Maccullochella peelii*	F	-	VU	L	V
Musk Duck	*Biziura lobata*	B	-	-	-	V
Pied Cormorant	*Phalacrocorax varius*	B	-	-	-	NT
Regent Parrot*	*Polytelis anthopeplus monarchoides*	B	-	VU	L	V
Trout Cod	*Maccullochella macquariensis*	F	-	EN	L	CR
Whiskered Tern	*Chlidonias hybridus*	B	-	-	-	NT
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	CAMBA	-	L	V
Royal Spoonbill	*Platalea regia*	B	-	-	-	NT

Legend:
Lifeform type: Amphibian, Bird, Fish, Invertebrate, Mammal
Convention: China-Australia Migratory Bird Agreement (CAMBA)
EPBC status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Not Listed
FFG status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing
VROT status: presumed Extinct, Regionally Extinct, Extinct in the Wild, CRitically endangered, ENdangered, Vulnerable, Rare, Near Threatened, Data Deficient, Poorly Known, Not Listed

**Species are included as water dependent due to habitat requirements*

Three of the listed bird species at the site, Brown Tree-creeper (*Climacteris picumnus victoriae*), Regent Parrot (*Polytelis anthopeplus monarchoides*), and Major Mitchell's Cockatoo (*Lophocroa leadbeateri*) are considered indirectly water dependent due to habitat requirements (e.g. dependent

on nesting hollows in riparian trees). The sixteen others are directly dependent on water due to food, shelter or breeding requirements.

The Regent Parrot is listed as nationally vulnerable under the EPBC Act, with estimates of only 2,900 birds left in the wild. This species has quite specific habitat requirements, breeding almost exclusively in River Red Gum forest and woodland, typically in large, old and healthy hollow-bearing trees close to water. They require trees that are a minimum of 160 years old (Baker-Gabb and Hurley, 2011). However, Regent Parrots have also been known to breed in Black Box. They mostly feed in large blocks of intact Mallee woodlands usually within 5-10km (maximum 20km) of nest sites, but also consume flower buds of River Red Gum, Black Box and Buloke (*Allocasuarina leuhmanii*) (Baker-Gabb and Hurley, 2011). Regent Parrots are reluctant to fly through open areas and require corridors of vegetation between nesting and foraging sites.

The Hardhead (*Aythya australis*) uses dense shrubby vegetation such as lignum for nesting, and breeding is stimulated by flooding and season. Rogers & Ralph (2011) suggest that breeding primarily occurs between August and December. The Hardhead lives for approximately three to four years in the wild, therefore conditions suitable for breeding should occur every second year to maintain numbers of breeding adults. Although information on breeding is limited it is estimated that fledging occurs at two to three months suggesting that flooding should last for four to six months. Food resources are more abundant for Hardhead when a flood follows a period of wetland drying, suggesting that inter-flood drying for a few months may increase breeding success of the Hardhead (Rogers and Ralph, 2011).

The Freckled Duck (*Stictonetta naevosa*) mainly forages in shallow areas of wetlands (less than 5cm depth), collecting food by filtering sediment and consuming a mix of plants and invertebrates. Though it can filter feed from the surface of deeper water if food is available (Rogers & Ralph 2011). Breeding season is mainly between June and December, though it can occur whenever there is plentiful food and suitable flood conditions. Nests are primarily constructed in flooded lignum (Marchant and Higgins, 1990). A major threat to the species is the loss of suitable habitat, in Victoria, they have been most frequently recorded at Deep Freshwater Marshes, Permanent Open Water and Saline wetlands (Loyn, 1989 cited in DSE, 2000). They are also vulnerable to shooting as they are reluctant to leave a favoured wetland and are also at risk of misidentification (Lyon, 1991, cited in DSE, 2000).

The Blue-billed Duck (*Oxyura australis*) is secretive and prefers stable or permanent deep wetlands with dense and abundant vegetation such as rushes, sedges or lignum. Feeding occurs in open water adjacent to vegetation (Rogers and Ralph, 2011). The breeding season is mostly between September and February, though this varies with hydrological conditions and food availability. Breeding occurs in temporary or permanent waterbodies (Rogers and Ralph, 2011). Like the Freckled Duck, the main threats to the species are the loss of suitable wetlands and hunting (DSE, 2003). Blue-billed Duck was recorded at Heywood's Lake during the February 2016 waterbird counts (Game Management Authority, unpublished data February 2016).

Two Egret species recorded in the target area are the Eastern Great Egret (*Ardea modesta*) and the Little Egret (*Egretta garzetta*). Egrets mainly forage in shallow freshwater wetlands with emergent vegetation and use overhanging trees for nesting, with River Red Gum being their preferred tree. Egrets require shallow water with dense aquatic vegetation for foraging and feed mainly on fish but also consume shrimp, crayfish, frogs and insects (Rogers and Ralph, 2011). Draining of wetlands for agriculture is the main cause of habitat loss for Egrets in Victoria (DSE, 2001).

The Royal Spoonbill (*Platalea regia*) prefers freshwater wetlands including swamps with semi-aquatic or emergent vegetation. It mainly feeds on fish, crustaceans and insects. Foraging occurs in depths of

less than 40cm, often among aquatic or emergent vegetation. The productivity of several of its food sources is increased when wetlands are inundated following a dry period (Rogers and Ralph, 2011).

The deep open water habitat of Heywood's Lake can support breeding by large native fish (Ecological Associates, 2006) and three listed fish species have been recorded at the site, Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*), and Freshwater Catfish (*Tandanus tandanus*). Murray Cod and Trout Cod are considered main channel specialists as this is where they spawn and recruit, though juveniles may possibly be found in the floodplain and lakes (Rogers and Ralph, 2011). The Mallee Waterway Strategy (Mallee CMA, 2014) recommends the introduction of native and recreationally targeted fingerlings into Heywood's Lake.

The Freshwater Catfish is a benthic species and is usually found near the bottom of lakes and slow-flowing rivers, though it can also use channels and floodplains when inundated. They are thought to only inhabit lakes if there is abundant woody debris, submerged and emergent aquatic plants and low turbidity (DSE, 2005a). Their diet consists of benthic molluscs, crustaceans, insects, snails and small fish. As they rely on in stream woody debris for habitat complexity, shelter and increased food supply (Rogers and Ralph, 2011), Heywood's Lake may not completely meet their habitat needs.

Two of the introduced fish species recorded in Heywood's Lake, Common Carp (*Cyprinus carpio*) and Redfin (*Perca fluviatilis*), are known to negatively impact Catfish populations. The presence of Common Carp is thought to degrade habitat for the Catfish by increasing turbidity, nutrient and reducing aquatic vegetation. Redfin may directly predate on Catfish, compete for food and shelter resources and transmit diseases (DSE, 2005a).

One listed Amphibian, the Growling Grass Frog (*Litoria raniformis*), has been recorded at the site. The Growling Grass Frog is found in or around permanent or ephemeral wetlands and prefers wetlands with complex aquatic vegetation communities. Recruitment success is higher at wetlands that remain inundated over spring and summer (> 6 months) though the presence of Common Carp can significantly reduce reproductive success. It has limited capacity to survive dry periods and will move to refugia in permanently inundated wetlands or river channels (Rogers and Ralph, 2011).

Vegetation communities

Heywood's Lake is positioned at the edge of Murray Fans bioregion, with a small portion of the target area (the lunette to the south east of the lake) falling within the Murray Mallee bioregion. Soil colour changes are visible onsite at this transition point. Six EVCs are modelled as present in the Heywood's Lake target area (Figure 8) and one additional EVC had been identified in the 2009 IWC field assessments (DELWP, 2015b).

Table 7 provides a list of the EVCs within the target area. Appendix 3 provides detailed descriptions of the EVCs.

Table 7 - EVCs modelled as present with the Heywood's Lake target area

EVC no.	EVC name	Area modelled as present within target area (ha)	Bioregional Conservation Status	
			Murray Fans	Murray Mallee
107	Lake Bed Herbland *(note that this was modelled as Bare rock/ground)*	142.20	Vulnerable	Depleted
813	Intermittent Swampy Woodland	60.80	Depleted	Vulnerable

823	Lignum Swampy Woodland	60.80	Vulnerable	n/a
808	Lignum Shrubland	7.50	Vulnerable	n/a
103	Riverine Chenopod Woodland	2.60	Endangered	n/a
86	Woorinen Sands Mallee	0.05	n/a	Depleted
97	Semi-arid Woodland	0.01	Vulnerable	Vulnerable

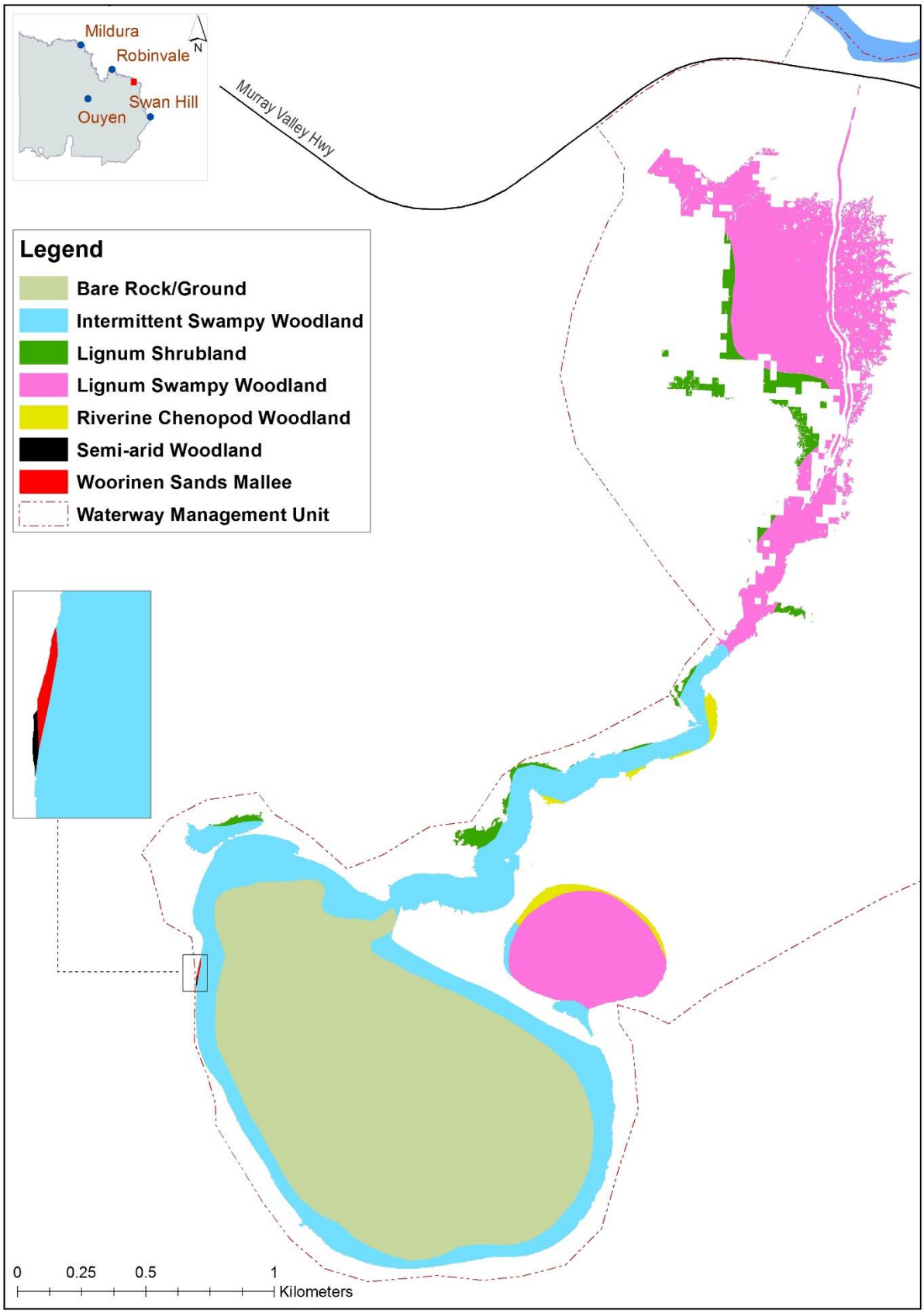
Mildura
Robinvale
Swan Hill
Ouyen
N
Murray Valley Hwy
Legend
Bare Rock/Ground
Intermittent Swampy Woodland
Lignum Shrubland
Lignum Swampy Woodland
Riverine Chenopod Woodland
Semi-arid Woodland
Woorinen Sands Mallee
Waterway Management Unit
0
0.25
0.5
1
Kilometers

Figure 8 - EVCs in the Heywood's Lake target area

Lake Bed Herbland (Figure 9) can be shrub or herb dominated and is present when the wetland is in a dry or drying phase. It is dominated by species that are adapted to drying mud within lake beds (either through tuber-like rootstocks or as seed) (DSE, 2012, 2005a). Lake Bed Herbland is found during the dry phase at Heywood's Lake in the area modelled as bare rock/ground as shown in Figure 8.

Figure 9 - Lake Bed Herbland Heywood's Lake in 2009 (Source: IWC website)

Intermittent Swampy Woodland (EVC 813) surrounds Heywood's Lake itself as well as the channel that leads to the River Murray (Figure 10a). It is a Black Box dominated woodland to 15m tall with a shrubby to rhizomatous sedgy understorey and patches of Tangled Lignum (*Duma florulenta)* (DSE, 2012, 2005a). The maximum inundation duration for this EVC is one to six months (Frood, 2012).

Ecological Associates (2006) described this area as Black Box Woodland, with associated species including Moonah (*Melaleuca lanceolata*), Hedge Saltbush (*Rhagodia spinescens*) and Ruby Saltbush (*Enchylaena tomentosa*). Black Box provides essential habitat and foraging opportunities for a range of species including mammals and reptiles and supports a high proportion of ground foraging and hollow-nesting birds. Black Box Woodlands are particularly important to the endangered Regent Parrot which has been recorded using Black Box hollows for breeding (Baker-Gabb and Hurley, 2011) and the near threatened Brown Treecreeper, (*Climacteris picumnus victoriae*) (Cheal, Lucas and Macaulay, 2011) which has been recorded at this site.

Black Box can tolerate a range of conditions from wet to dry and saline to fresh (Roberts and Marston, 2011). However, under extended periods of dry conditions trees will suffer a decline in health and eventually death (Ecological Associates, 2007).

Figure 10 – (a) Intermittent Swampy Woodland and (b) Riverine Chenopod Woodland at the transition between Heywood's and Little Heywood's Lakes (Sept 2015)

Little Heywood's Lake is dominated by Riverine Chenopod Woodland. Riverine Chenopod Woodland (EVC 103) is a eucalypt woodland to 15m tall with a shrubby and grassy understorey, found on the most elevated of flood-prone riverine terraces and subject to only infrequent shallow flooding (DSE, 2012, 2005a) (Figure 10b and Figure 11).

Lignum Swampy Woodland (EVC 823) is also found at Little Heywood's Lake on the northern side. Lignum Swampy Woodland is a Black Box dominated woodland with River Coobah (*Acacia stenophylla*) and an often dense shrub layer of Tangled Lignum. It is associated with seasonal drainage lines and their accompanying swamps and requires both wet and dry periods (DSE, 2012, 2005a). Lignum Swampy Woodland is present within Little Heywood's Lake and along the channel and floodplain closer to the river (Figure 12).

Lignum dominated EVCs are present in shallow floodplain depressions that are intermittently inundated (Roberts and Marston, 2011). These range from the treeless Lignum Swamp (EVC 104) to a mix of Lignum and Eucalypt or Acacia Woodland (Lignum Swampy Woodland and Intermittent Swampy Woodland, EVC 813). When flooded these areas can provide nesting habitat for platform building birds as well as productive fish habitat (Ecological Associates, 2006). Tangled Lignum has particular ecological value as waterbird breeding habitat (Rogers and Ralph, 2011) making it especially significant at this site. Wetland birds that breed over water, such as Egrets, use flooded Lignum shrublands (Ecological Associates, 2007) for resting and the Hardhead Duck uses Lignum for nesting (Rogers and Ralph, 2011).

Figure 11 - Riverine Chenopod Woodland at Little Heywood's Lake (Sept 2015)

Figure 12 - Lignum Swampy Woodland is present in and along the channel between the River Murray and Heywood's Lake (Sept 2015)

Small areas of Lignum Shrubland (EVC 808) are located on slightly higher land, adjacent to Intermittent and Lignum Swampy Woodland.

In elevated positions along the lunette to the south of Heywood's Lake that are dependent on rainfall for moisture (rather than groundwater or flooding), small areas of Woorinen Sands Mallee (EVC 86) and Semi-arid Woodland (EVC 97) are present.

Figure 13 - The transition from Mallee vegetation (left hand side of image) to woodland (right hand side) occurs as you move to lower elevations from the lunette to Heywood's Lake (Sept 2015)

Flora

Forty three native flora species have been recorded at Heywood's Lake through incidental observations. As a full species survey has not been undertaken it is likely that the true number of species is higher. A full list of flora recorded at Heywood's Lake is provided in Appendix 4.

Four listed flora species have been recorded at the site, Leafless Blue-bush (*Maireana aphylla*) is listed in VROT as poorly known (but likely to belong to a rare or threatened category) and is found in low-lying seasonally inundated areas with heavy soil (Jacobs, 1990). Spiny Lignum (*Duma horrida* subsp. *horrida*) is listed as rare and also requires inundation. Twiggy Sida (*Sida intricata*) and Umbrella Wattle (*Acacia oswaldii*) are both listed as vulnerable under VROT and Umbrella Wattle has been nominated to the FFG Act list, however neither species is directly dependent on inundation.

Waterbirds

Thirty-five species of waterbirds have been recorded at Heywood's Lake (Table 8). Waterbird diversity and abundance are influenced by wetland habitat diversity, with different species and feeding guilds using different habitats for breeding and foraging. 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 waterbird diversity (Taft, Colwell, Isola and Safran, 2002)

Wetlands such as Heywood's Lake that are deep enough to provide open water habitat support diving and fish-eating waterbirds (such as Cormorants, Pelicans, Grebes and Terns) (Ecological Associates, 2006). Shallower areas of the lake (with a depth of 1-2m) support semi-emergent macrophytes which provide highly productive areas of habitat for macroinvertebrates, tadpoles and small or juvenile fish. These areas are frequented by waterfowl and dabbling ducks which graze on the vegetation, biofilms and macroinvertebrates (Ecological Associates, 2006).

Table 8 - Waterbird guilds found at Heywood's Lake and their habitat and resource requirements

Waterbird Group	Food Resource	Habitat Use	Breeding Strategy	Number of Species found at Heywood's Lake following environmental watering 2012 - 2015
Dabbling Ducks (e.g. Chestnut teal, Pink-eared duck, Freckled duck)	Generalists; plankton, small invertebrates, plant material	Shallow water	Solitary	6
Grazing Waterfowl (e.g. Shellduck, Wood Duck)	Plant material, seeds, invertebrates	Shallow water, littoral zone	Colonial or solitary	2
Fish Eaters (e.g. Pelican, Cormorant, Grebe, Darter, Egret)	Fish	Open and deep water	Colonial	14
Small Waders (e.g. Stilt, Plovers, Dotterels)	Small invertebrates, seeds	Littoral zone, mudflats	Solitary	2
Large Waders (e.g. Ibis, Spoonbill)	Macroinvertebrates, fish, amphibians	Littoral zone	Colonial or solitary	3
Deep Water Foragers (e.g. Black Swan and Hardhead)	Plant material, some molluscs, invertebrates	Open deep water, shallow water, littoral zone, mudflats	Colonial or solitary	5
Shoreline Foragers (e.g. Lapwings, Hens)	Plant material, seeds, invertebrates	Littoral zone, mudflats	Solitary or small groups	3

Wetland depletion and rarity

Victoria's wetlands have been mapped and classified in a database known as the 'Wetland 1994' layer (full title: Victorian Wetland Environments and Extent - up to 1994). At the same time, an attempt was made to categorise and map wetland areas occupied prior to European settlement. This is known as the 'Wetland Pre-European (1788)' layer (full title: Wetlands Extent for Victoria Prior to European Settlement – Deduced).

It has been possible to determine the depletion of wetland types across the state between the 1788 and 1994 wetland layers. Comparison between the wetland layers has demonstrated the impact of European settlement and development on Victorian wetlands.

Heywood's Lake target area contains two main wetland types under the Corrick classification: Deep Freshwater Marsh (Heywood's Lake) and Freshwater Meadow (Little Heywood's). These are significant in the Victorian context due to the widespread loss of these types of wetland and are also listed under the Directory of Important Wetlands in Australia (ANCA, 1996).

A large proportion of these wetland types have been lost in Victoria. Forty three per cent of freshwater meadow has been lost across the state (80% in Mallee CMA region) and seventy per cent of deep freshwater marsh (45% in Mallee CMA region) (Table 9).

Table 9 - Changes in area of the wetlands in the target area by Corrick classification. Source: DELWP Biodiversity interactive maps, Mallee Wetland Strategy

Corrick category	Wetland name	Total area	Percentage change in wetland area from 1788 to 1994		
			Change in Victoria	Change in Mallee CMA	Change in Murray Fans bioregion
Deep freshwater marsh	Heywood's Lake	162.84 ha	-70%	-45%	-6%
Freshwater meadow	Little Heywood's Lake	24.98 ha	-45%	-80%	-63%

As identified earlier, the Wetland Current layer (DELWP, 2015c) has combined Heywoods Lake and Little Heywoods Lake into one single wetland listing, and has listed the wetland type as Temporary Freshwater Swamp, this is shown in Figure 14. Site investigations have determined that the two lakes have sufficiently different vegetation assemblages to warrant managing their water regimes separately.

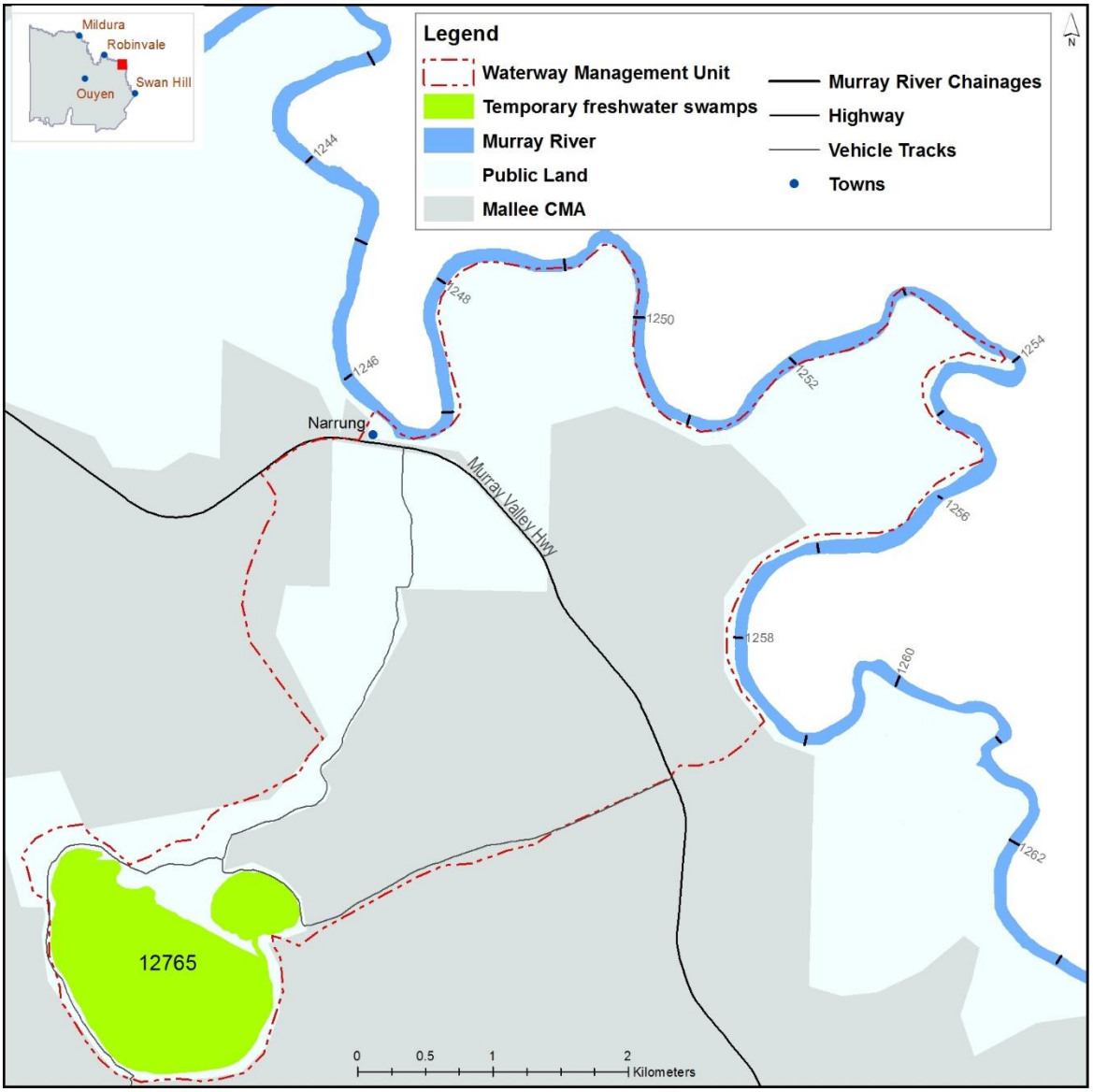

Figure 14 - Wetland types present at Heywood's Lake (Source: Wetland Current GIS layer)

Ecosystem Functions

Wetland ecosystems support distinctive communities of plants and animals and provide numerous ecosystem services to the community (DSE, 2005b). Floodplain wetlands perform important functions necessary to maintain the hydrological, physical and ecological health of river systems.

Four key broad ecosystem functions have been identified for the Heywood's Lake 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 habitats and populations

Wetlands deep enough to provide open water habitat will provide reliable aquatic habitat in dry conditions (Ecological Associates, 2006) therefore Heywood's Lake could be an important refuge for water-dependent biota during dry periods and drought.

The combination of Black Box woodlands, mudflats, semi-emergent macrophyte beds and open water habitat provide a great diversity of feeding, breeding and nursery sites for native water-dependent biota.

Connections across floodplains, adjacent wetlands and billabongs (lateral)

Water levels that engage flood channels, wetlands and floodplain surfaces will promote nutrient and carbon cycling (Robertston, Bacon and Heagney, 2001). Waterbird groups also need to access a variety of habitat types which only become available following inundation.

Diversity of habitat for feeding, breeding and nursery

Seasonal fluctuations in the water levels increase the availability of specific habitat niches for feeding, breeding and nursery areas. The higher water levels proposed in spring and summer will provide a source of food, refuge from predators and nesting sites and materials (Kingsford and Norman, 2002). Receding water levels will expose mudflats required by small waders (Roshier, Robertston and Kingsford, 2002).

Inundation of the wetlands and woodlands will provide roosting and nesting habitat for species such as Darter (Vestjen, 1975) and Cormorant (Loyn, Lumsden and Ward, 2002), while the increase in macrophyte diversity and abundance will increase habitat values for waterbirds and small fish.

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

Wetland inundation will transport nutrients and carbon into the water column, which will become available for consumption by bacteria, algae, macrophytes and macroinvertebrates.

Drying of wetlands, particularly during summer and autumn, exposes sediments and facilitates decomposition and processing of organic matter.

Fluctuations in water levels allow exposure of substrates such as large wood and plant stems through a drying cycle allowing for a mosaic of biofilm species that offer a range of food resources for macroinvertebrates and fish (SKM, 2009).

5.3 Social values

Cultural Value

The Mallee has been occupied for thousands of generations by 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 connection Traditional Owners continue to have with Mallee's natural landscapes.

Given the semi-arid climate of the region, ready access to more permanent water has been a major determinant of human habitation, and as such the highest density of identified Indigenous Cultural Heritage sites are located around or close to areas of freshwater sources.

Within the Mallee CMA region, the River Murray and its associated waterways were important habitation areas for multiple Aboriginal groups, containing many places of spiritual significance. The high number of Indigenous Cultural Heritage sites throughout the Murray floodplain is unique in Victoria, for concentration and diversity. They include large numbers of burial, middens and hunting sites.

In the south of the region, waterways were focal points for the region's Traditional Owners, with many lakes being the site for large gatherings of several social clan groups that afforded trade and cultural exchanges.

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.

Cultural Heritage

Heywood's Lake is of significant cultural value to Indigenous and non-Indigenous people, with the area popular for fishing, swimming, hunting, and as a meeting place.

In regard to Indigenous cultural values, some cultural sites have been documented through various archaeological investigations, but the true extent of the number of types of sites present is still unknown.

The lunette on the east and south side of Heywood's Lake has been excavated, with a large number of Aboriginal remains found (McKane, 1992).

There are burial sites located around the northern section of the lake margin, particularly the immediate area around the inlet channel (Figure 15) (Ahmat, 1992). Ahmat (1992) identified forty-eight aboriginal sites during a survey in 1992.

Figure 15 - The area around the inlet channel into Heywood's Lake is a site of high Indigenous cultural significance with burial sites registered during past surveys (Sept 2015)

5.4 Recreation

Heywood's Lake is a popular recreation area, with uses including fishing, swimming, picnicking, bird watching, boating and hunting (in the game reserve), particularly when the lake is full (ANCA, 1996).

5.5 Economic values

Properties producing potatoes, almonds, citrus, honey, wool and dry land crops occupy the adjoining properties to Heywood's Lake and contribute to the broader economic value of the region.

Significant numbers of visitors may visit Heywood's Lake, while inundated, for licensed waterfowl hunting during prescribed seasons. This may contribute to the local economy on a seasonal basis. Significant numbers of the waterbirds counted during the 2012-2015 surveys were game species.

5.6 Significance

Heywood's Lake and Little Heywood's Lakes are ephemeral deflation basin lakes. EDBLs are naturally dynamic lowland river floodplain environments which fluctuate between terrestrial and aquatic states (Scholz et. al., 2002).

Heywood's Lake is a nationally important wetland listed in the Directory of Important Wetlands for its cultural significance. Thirty-two species of waterbirds were recorded at Heywood's Lake between 2012 and 2015 in response to environmental watering. Over 6,000 individual birds were recorded at

that Lake in 2013 while the Lake was full, while nearly 2,500 individual birds were counted as the environmental water receded and exposed the littoral fringe of the Lake in early 2015.

Nineteen listed species (birds, fish and an amphibian) including sixteen which are water dependent and three which are indirectly water dependent have previously been recorded at the site. Heywood's Lake and Little Heywood's Lake are both listed as high priority wetlands in the Mallee Waterway Strategy (Mallee CMA, 2014).

The combination of Black Box woodlands, mudflats, semi-emergent macrophyte beds and open water habitat found within the target area provide a great diversity of feeding, breeding and nursery sites for native water-dependent biota.

6 Ecological condition and threats

6.1 Current condition

The condition of Heywood's Lake and Little Heywood's Lake was assessed in 2009 using the Index of Wetland Condition. The IWC defines wetland condition as the state of the biological, physical, and chemical components of the wetland ecosystem and their interactions.

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. Each sub-index is given a score between 0 and 20 based on the assessment of a number of measures. The overall IWC score is not a simple summation of the sub-index scores. A formula is used that weights each sub-index according to the contribution it makes to the overall condition of the wetland. The wetland hydrology sub-index for example contributes more to the overall score than the soils sub-index.

IWC assessments on Heywood's Lake and Little Heywood's Lake indicate that all sub-indices except hydrology are in moderate to excellent condition, therefore that the management of a suitable water regime consisting of natural flooding events and supplemented with appropriately planned environmental watering will enhance the significant values and condition at the site.

In 2009 Heywood's Lake was assessed as being in good condition, with a score of seven out of ten. Little Heywood's Lake was also assessed as being in good condition, however, it had a slightly higher score of eight out of ten. The hydrology sub-index was considered to be in very poor condition for both wetlands; however this is overstated given that the construction of the spoon drain, lowering of the wetland sill and delivery of environmental water has improved the watering frequency towards pre-regulation conditions. Importantly, the other sub-indices were rated excellent, except for the biota sub-index which was rated moderate at Heywood's Lake and Good at Little Heywood's Lake. Full results are provided in Table 10 and Table 11.

Table 10 - Heywood's Lake Index of Wetland Condition results (2009)

IWC sub-index	Score /20	Category
Wetland catchment	18	Excellent
Physical form	20	Excellent
Hydrology	0	Very poor
Water properties	20	Excellent
Soils	19.5	Excellent
Biota	14.4	Moderate
Overall IWC score	**7 / 10**	**Good**

Table 11 - Little Heywood's Lake Index of Wetland Condition results (2009)

IWC sub-index	Score /20	Category
Wetland catchment	18	Excellent
Physical form	20	Excellent
Hydrology	0	Very poor
Water properties	20	Excellent
Soils	19.5	Excellent
Biota	17.6	Good
Overall IWC score	**8 / 10**	**Good**

During the IWC condition assessments Heywood's Lake and Little Heywood's Lake were in a dry phase, as indicated by the photos from the assessments, shown in Figure 16 and Figure 17.

Figure 16 - Heywood's Lake, October 2009, showing Lake Bed Herbland identified during the assessment (Source: IWC website)

Figure 17 - Little Heywood's Lake, September 2009, showing the Black Box woodland in dry conditions (Source: IWC website)

Site investigations undertaken in early September 2015 found Heywood's Lake holding a significant amount of water following the watering events in 13/14. Significant aquatic macrophytes beds were evident (Figure 18) and there was an abundance of waterbirds from various guilds (Figure 19 and Figure 20).

Figure 18 - Heywood's Lake (Sept 2015) showing extensive mudflat and submerged aquatic macrophyte habitat

Figure 19 - Heywood's Lake (Sept 2015) hosting a large number of waterbirds from a range of guilds

Figure 20 - Heywood's Lake (Sept 2015) showing extensive submerged aquatic macrophyte and use by small waders

Little Heywood's Lake appeared to be in similar condition to that assessed in 2009, as shown in Figure 22. The high sill between Heywood's Lake and Little Heywood's Lake prevented the environmental watering events from inundating Little Heywood's Lake.

Figure 22 - Little Heywood's Lake (Sept 2009)

Field observations found the Lignum Swamp adjacent to the channel to be in fair to good condition, although watering had not occurred for many years.

6.2 Condition trajectory

The extended dry period at Heywood's Lake associated with infrastructure and land use prior to the early 1990's placed significant stress on the Heywood's Lake ecosystem. The construction of the spoon drain and culverts in the early 1990's significantly enhanced the opportunity for Heywood's Lake to experience a more suitable water regime, however low flows in the Murray system during the Millennium Drought meant that the system remained under significant hydrological stress prior to the environmental watering events described earlier.

Environmental watering undertaken in 2010/11, 2011/2012 and 2013/2014 have improved the conditions of the lake and have protected significant environmental values. Continued environmental watering in accordance with the objectives set out in this EWMP will continue to maintain and enhance the water dependent values of Heywood's Lake. Careful monitoring of the inundation duration of the fringing Black Box will need to be undertaken to ensure that the length of inundation does not exceed the threshold for Black Box.

To date, environmental watering activities have not targeted Little Heywood's Lake. Future watering, subject to the complementary works recommendations in this EWMP being implemented, should include Little Heywood's Lake. Without this watering it is likely that the Black Box Chenopod Woodland and Lignum Swampy Woodland will decline with prolonged dry conditions. Additionally, it is likely that the diversity of fauna species using Little Heywood's Lake has significantly declined due to the prolonged dry conditions.

6.4 Water related threats

Water related threats occurring within the target area and identified through the AVIRA database (identified by a score of 4 or 5) are:

- Invasive fauna (aquatic) – 5 (Carp)
- Changed water regime - 5

Changed water regime

As outlined in the condition section of this EWMP, Heywood's Lake and Little Heywood's Lake have received a score of 0 for the hydrology sub-index of the Index of Wetland Condition. The hydrology sub-index takes into account the impacts of regulation of the primary water source of the wetland (River Murray), other activities which may impact the wetlands water regime, impacts to seasonality, duration and frequency of the water regime and the severity of the effects of these activities. The assessment is subjective.

Introduced fauna (aquatic)

Common Carp are prevalent in Heywood's Lake when it is inundated from high River Murray flows. Carp have been found to contribute to the loss of aquatic vegetation and increased turbidity, resulting in loss of habitat for waterfowl (Purdey and Loyn, 2008) and native fish species. This species also competes with the native fish for habitat and food and has a detrimental effect on water quality (Mallee CMA, 2003).

8 Management objectives

8.1 Management goal

The management goal for the Heywood's Lake EWMP is:

Restore Heywood's Lake to an intermittently flooded deep water wetland that sustains resident aquatic fauna while flooded and supports breeding waterbirds.

8.2 Ecological objectives

Ecological objectives represent the desired ecological outcomes for the site based on the management goal which has been framed around the key values outlined in the environmental values section of the EWMP. In line with policy in the Victorian Waterway Management Strategy the ecological objectives are expressed as the target condition or functionality of each key value. It is acceptable to have two or more ecological objectives with conflicting or competing hydrological requirements, however, the recommended water regime must resolve these conflicts (DEPI, 2014).

The ecological objectives for Heywood's Lake are:

- Maintain Black Box Woodland diversity and productivity (EVCs 103 and 813).
- Promote diverse aquatic macrophyte zones.
- Provide open water habitat to encourage diversity and abundance of deep water foraging and piscivorous waterbirds
- Provide shallow water habitat that supports foraging, nesting and recruitment of dabbling ducks and large and small waders.
- Encourage a productive aquatic ecosystem through the release of nutrients and organic matter from the sediments and decomposition of inundated terrestrial vegetation through inundation of the wetlands following a dry phase.

Ecological objective	Justification	Wetland
Maintain Black Box Woodland diversity and productivity (EVCs 103 and 813)	The health of Black Box is essential to maintaining a functioning floodplain and wetland system. They provide breeding and feeding habitat for floodplain fauna, particularly waterbirds and hollow-dependent species.	Heywood's Lake and Little Heywood's Lake
Promote diverse aquatic macrophyte zones	Semi-emergent macrophytes provide highly productive wetland habitats. The soft-leaved plants and their biofilms provide shelter and flood for macroinvertebrates, tadpoles and small fish. Waterfowl and dabbling ducks, will graze on the vegetation and prey on macro-invertebrates (Ecological Associates, 2006). Species likely to be supported include Australian Shoveler, Pink-eared Duck, Black Swan and Freckled Duck (Ecological Associates, 2006).	Heywood's Lake
Provide open water habitat to encourage diversity and abundance of deep water foraging and piscivorous waterbirds	Open water provides habitat for diving waterbirds such as Musk Duck and Blue-billed Duck and fish-eating waterbirds such as Cormorant and Pelican (Ecological Associates, 2006).	Heywood's Lake
Provide shallow water habitat that supports foraging, nesting and recruitment of dabbling ducks and large and small waders	Thirty-five species of waterbirds have been found at the lake.	Heywood's Lake and Little Heywood's Lake
Encourage a productive aquatic ecosystem through the release of nutrients and organic matter from the sediments and decomposition of inundated terrestrial vegetation through inundation of the wetlands following a dry phase	During dry periods, organic matter such as leaf litter is slowly decomposed by bacteria, releasing carbon and nutrients which accumulate in the soil. 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 an increased productivity, with an increase in bacteria and invertebrates. (Ecological Associates, 2013) This results in abundant food for fish, birds and other animals.	Heywood's Lake and Little Heywood's Lake

8.3 Hydrological objectives

The conceptual model for ephemeral deflation basin lakes (Scholz and Gawne, 2004) highlights the significance of managing EDBLs such as Heywood's Lake to ensure both wet and dry lake phases. The five states in the cycle of flooding and drying of EDBLs each have importance to ecosystem function as outlined in the model.

Hydrological objectives describe the components of the water regime required to achieve the ecological objectives for the target area. The hydrological requirements to achieve each of the ecological objectives are presented in Table 12.

Black Box woodlands require flooding to occur every three to seven years with durations of two to six months. This species can tolerate shorter flood durations but plant vigour will suffer. Although timing of flood events is not crucial for Black Box it will affect understorey and other woodland biota. Black

Box trees may survive prolonged periods of 12 to 16 years with no flooding but tree health will suffer and the woodland will have low productivity (Roberts and Marston, 2011).

Flooding is unreliable but can cover extensive areas of Intermittent Swampy Woodland when it occurs (DSE, 2005c). Hydrological objectives for the Intermittent Swampy Woodland have been focussed around the water requirements of the Black Box as the dominant structural species within the EVC at this site.

Lignum can tolerate a wide range of wet and dry conditions as well as moderate salinity levels. Flood requirements vary with frequencies of one to three years needed to maintain large shrubs with vigorous canopy and flooding every three to five years for maintenance of healthy shrubs. Intervals of seven to ten years can be tolerated by small shrubs but growth will decline and plants in this state do not accommodate nesting by birds. Durations of three to seven months sustain vigorous canopy, but waterlogging is detrimental. Although timing of flooding is not crucial for Lignum, following natural seasonality is encouraged to provide for understorey and wetland plants (Roberts and Marston, 2011).

A flooding regime dominated by spring rather than summer flooding promotes higher macrophyte diversity and abundance (Robertston, Bacon and Heagney, 2001). Semi-emergent macrophytes occupy shallower water that is generally flooded to a depth of one to two metres (Ecological Associates, 2006).

In general, a depth of more than two metres with flood events lasting more than two years is required to exclude macrophytes and create open water (Ecological Associates, 2006).

Flooding of wetland and floodplain vegetation in spring and summer provides a source of food, refuge and nesting sites and materials for waterbirds (Kingsford and Norman, 2002). Food availability is enhanced in wetlands that have been subjected to dry periods of one or more years prior to filling (Briggs, Thomas and Lawler, 1997). Receding waters levels over summer provide shallow open water and mudflats which are important foraging habitat for wading birds (Ecological Associates, 2013).

Whilst the watering requirements of individual species or communities found at Heywood's Lake may indicate a higher watering frequency, the proposed watering regime of Heywood's Lake is driven by the EDBL conceptual model and review of the systems pre-regulation hydrology.

Table 12 - Hydrological objectives for Heywood's Lake

Ecological Objectives	Hydrological Objectives												
	Mean frequency of events (No. per 10 years)			Tolerable interval between events		Duration of ponding (months)			Preferred timing of inflows	Target supply level (mAHD)	Volume to fill to TSL (ML)	Volume to maintain at TSL (ML)	Total volume per event (ML)
	Min.			Min.									
Maintain Black Box Woodland diversity and productivity (EVCs 103 and 813)	1	2	3	3	10	2	4	6	Winter/ Spring	56.8* 57.0*	5,200**	2,000**	8,000
Promote diverse aquatic macrophyte zones	2	5	10	0	1	1	6	12	Spring/ Summer	53.5	Provided by natural drawdown/evaporative losses following watering to meet Black Box objective		
Provide open water habitat to encourage diversity and abundance of deep water foraging and piscivorous waterbirds	2	3	3		8	24			n/a	54 - 56.8			
Provide shallow water habitat that supports foraging, nesting and recruitment of dabbling ducks and large and small waders***										54			
Encourage a productive aquatic ecosystem through the release of nutrients and organic matter from the sediments and decomposition of inundated terrestrial vegetation through inundation of the wetlands following a dry phase***										56.8			

* Heywood's and Little Heywood's **Volumes provided based on watering events from 2010/11 (empty to full inundation) and 2011/12 (top up of previous event), ***Ecological objective met through other hydrological objectives

Watering regime

The wetland watering regime has been derived from the ecological and hydrological 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 maximum and minimum tolerable watering scenarios. The minimum watering regime is likely to be provided in drought or dry years, the optimum watering regime in average conditions and the maximum watering regime in wet or flood years.

The optimal watering regime is described below. 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.

Optimal watering regime

Heywood's Lake

Fill Heywood's Lake to 56.8 mAHD to inundate the fringing Intermittent Swampy Woodland community every eight years during winter/spring. Allow the water level to decrease slowly over summer to expose fringing vegetation and mud flats. Provide a top up in the second year to 54 mAHD to ensure that enough depth is retained for two years to support the formation of open water habitat. Following the two years of available open water habitat, allow Heywood's Lake to enter drying phase.

Little Heywood's Lake

Inundate Little Heywood's Lake every eight years to 56.8 mAHD for up to four months during winter/spring.

9 Managing risks to achieving objectives

Threat	Likelihood	Consequence	Risk: H, M, L (likelihood x consequence	Management measure	Residual risk
Failure to meet ecological objectives	Possible	High	H	Monitoring program in place. Adaptive approach.	Low
Flows in Murray not high enough to allow pumping to spoon drain in line with frequency of inundation recommendations	Possible	High	H	Have provided three watering regime scenarios so watering regime can be adjusted based on seasonal conditions. Adaptive management.	Low
Species, communities or ecological functions have been overlooked in water regime due to lack of data	Unlikely	High	L	n/a	
Inundation duration too long or too short	Possible	High	H	Monitoring program in place. Adaptive approach as additional baseline and monitoring outcome data is available. Install depth gauges and telemetry.	Low
Water regime significantly enhances habitat for Carp	Likely	Moderate	H	Monitoring of Carp and waterbird populations. Review of inlet and pumping equipment to screen Carp.	Moderate
Water regime does not reflect needs of recreational users, particularly hunters associated with game reserve use	Possible	Moderate	M	Engagement program to identify issues and to promote the key objectives for watering.	Low
High flow event in River Murray not sustained for entire environmental water delivery	Possible	High	H	Adaptive approach may need to revise objectives being targeted by particular events.	Low
Inundation event coincides with Blue-green algae event	Possible	Moderate	M	Monitoring for Blue-green algae throughout watering event. Management in accordance with regional Blue-green algae response plan.	Low

Threat	Likelihood	Consequence	Risk: H, M, L (likelihood x consequence	Management measure	Residual risk
Criminal damage or theft of water delivery infrastructure	Unlikely	Moderate	L	n/a	
Maintenance required to delivery infrastructure (pump/channel etc.) during proposed watering event	Possible	High	H	Include maintenance of channel on annual inspection checklist. Ensure pump contractors are appropriately qualified and have appropriate quality assurance processes in place.	Low
Monitoring program is unable to detect improvement in short to medium term	Possible	High	H	Approximate engagement with key stakeholders confirming expected outcomes, timeframes and assumptions.	Low
Water regime for Little Heywood's Lake unable to be delivered due to physical limitations of equipment or site	Possible	Very High	H	Studies to confirm flow path and best option for delivery of water to Little Heywood's Lake undertaken prior to programming of environmental water delivery.	Low
Flooding of private land	Possible	High	H	Ensure appropriate monitoring of pumped flows, use LiDAR to estimate inundation levels. Investigate need for remedial works on spoon drain and channel to stop over topping or leakage. Obtain deeds of agreement that enable environmental watering of private land.	Low

10 Environmental water delivery infrastructure

10.1 Constraints

The infrastructure required to deliver environmental water to Heywood's Lake consists of a flange connected to a culvert and a hard stand for a temporary pump. Pumping from the River Murray through the culvert to the spoon drain can commence when flows in the River Murray have reached 20,000 ML/day. Greater pumping efficiency can be obtained when flows are up to 40,000 ML/day. Approximately 50 ML/day can be pumped through the culvert. Delivery rates in excess of 50ML/d this will over top the inlet channel. Previous watering events have operated for periods of six weeks. The spoon drain and natural channel between the River Murray and Heywood's Lake runs for approximately 3 km.

The high sill between Little Heywood's Lake and Heywood's Lake currently prevents watering of Little Heywood's Lake.

10.2 Infrastructure or complementary works recommendations

It is recommended that the temporary flange on the culvert under the Murray Valley Highway be replaced with a permanent fixture to allow an increase in the capacity to pump water through the culvert. This would potentially shorten the period of pumping time associated with environmental water and would assist with ameliorating the risk that River Murray flows drop below the threshold level suitable for pumping.

The final infrastructure or complementary works recommendation relates to watering Little Heywood's Lake. The Mallee Waterway Strategy (Mallee CMA, 2014) recommends that the sill (at approximately 57 mAHD) between Little Heywood's Lake and Heywood Lake be lowered to allow watering of Little Heywood's Lake. An investigation into whether this is the best option for watering Little Heywood's Lake, or alternatively investigating if direct pumping from the channel would be a more efficient means of delivering environmental water to Little Heywood's Lake is required. Finalising this investigation and implementing appropriate recommendations would increase the achievable inundation extent to the area shown in Figure 23.

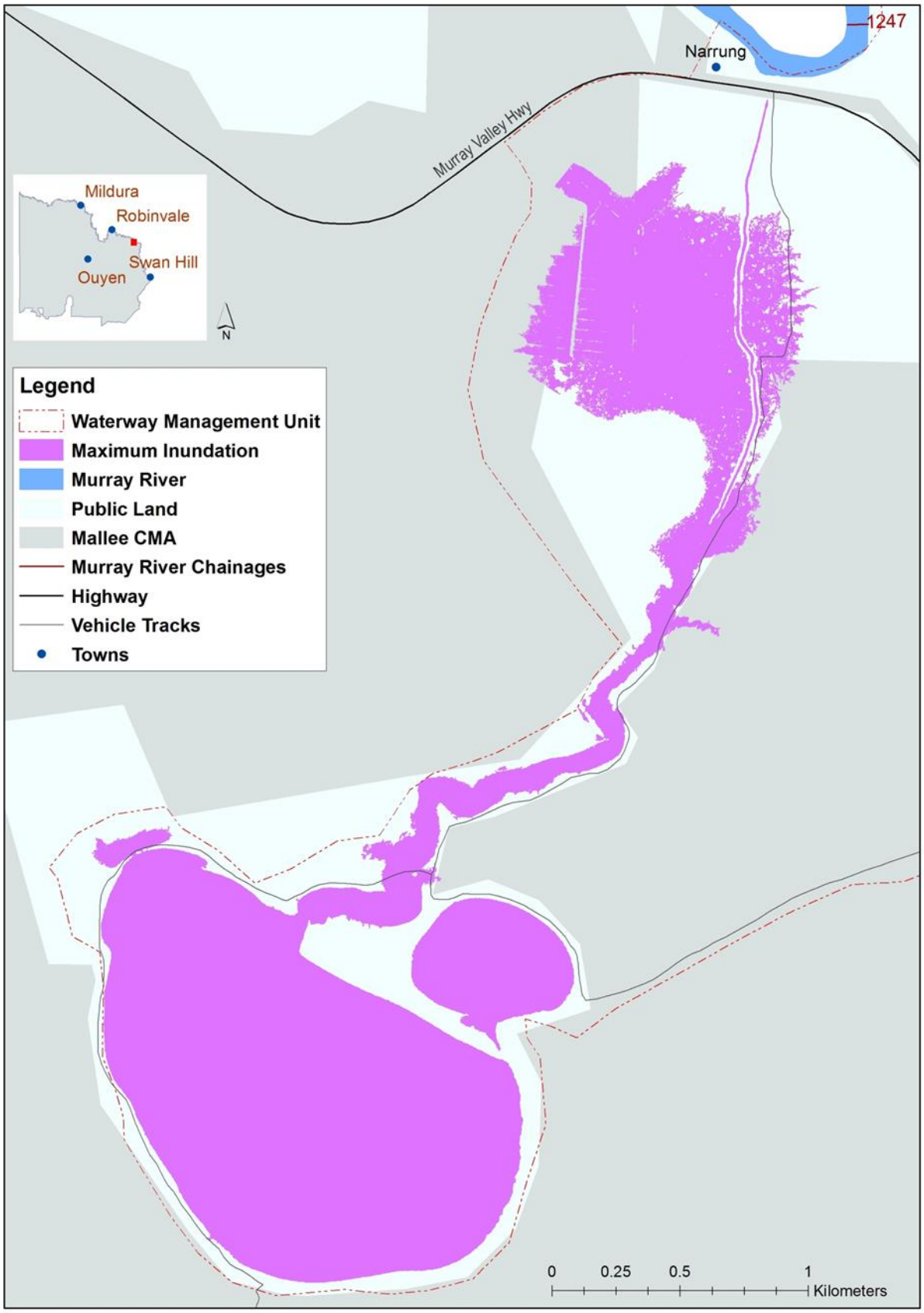

Figure 23 - Proposed inundation extent, including Little Heywood's Lake

11 Demonstrating outcomes

11.1 Monitoring priorities at the site

The following priorities for monitoring have been identified for the Heywood's Lake target area:

- Index of wetland condition monitoring should be undertaken within the target area wetlands on a five-yearly basis.
- Monitoring of waterbird diversity, abundance and breeding within the target area should occur during each of the watering events.
- Monitoring of inundation extent over time following each watering event should occur. This will be particularly important to ensure that the Black Box community's inundation thresholds are not exceeded and also to ensure that the duration thresholds for creating open water habitat are reached.
- Telemetry on depth gauges should be used to continuously monitor depth through the wetting and drying phases of the water regime.
- Photo point monitoring of tree health within the woodlands should be undertaken.

12 Consultation

This Plan has been developed in collaboration with key stakeholders. Details of consultation undertaken to date is outlined in Table 13.

Table 13 - Consultation undertaken as part of the development of the Heywood's Lake EWMP

Meeting date	Stakeholder	Details
May 2016	Parks Victoria	Plan presentation
June 2016	Department of Environment Land Water and Planning	Plan presentation
June 2016	Mildura BirdLife	Plan presentation
June 2016	Murray Lower Darling Rivers Indigenous Nations	Plan presentation
June 2016	Mid-Murray Field Naturalists	Plan presentation
June 2016	Department of Environment Land Water and Planning	Plan presentation

13 Knowledge gaps and recommendations

Best options for watering of Little Heywood's Lake

The Mallee Waterway Strategy (Mallee CMA, 2014) has recommended that the sill between Heywood's Lake and Little Heywood's Lake be lowered to allow watering events at Heywood's Lake to spill into Little Heywood's Lake. An improved understanding of the connection points, sill levels required and height of inundation required at Heywood's Lake to allow this connection would be beneficial. It is possible that pumping water directly into Little Heywood's Lake at the recommended frequency may be a more efficient use of environmental water. Additionally, there is some concern about exceeding the duration thresholds for flooding of the Black Box woodlands if high levels were required to enable connection between the two lakes. This is the highest priority knowledge gap and should be investigated prior to any alteration to the wetland sill at Little Heywood's Lake.

Land use impacts

It is unclear if surrounding land use is impacting the water dependent values within the target area. A narrow buffer of public land surrounds the lakes and surrounding land use impacts could include:

- Spray drift from cropping activities impacting water quality or vegetation health.
- Sediment input into the wetland associated with cropping and grazing activities.
- Altered drainage or local runoff associated with channels and levees.

Investigation into these likely impacts would be useful to understand the relative impacts of land use, compared with the threats of changed water regime.

Spells analysis for inundation thresholds from Swan Hill gauge

Hydrology information for this plan was relatively limited, with spells analysis being unavailable due to the high inundation threshold for this wetland. Spells analysis and field confirmation of the inundation threshold would be useful to inform review of this EWMP. Additionally, the pre-regulation wetland sill no longer functions and the spoon drain has created an alternate wetland sill. This should be considered along with the spells analysis in review of the EWMP.

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Abbreviations and acronyms

CAMBA	China-Australia Migratory Bird Agreement
CMAs	Catchment Management Authorities
DELWP	Department of Environment, Land, Water and Planning
EDBL	Ephemeral Deflation Basin Lake
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
EWH	Environmental Water Holder
FSL	Full Supply Level
MDBA	Murray-Darling Basin Authority (formally Murray-Darling Basin Commission)
TSL	Targeted Supply Level
VBA	Victorian Biodiversity Atlas

Appendix 1 – Bird count results following environmental watering 2012 – 2015

	Date	25 Feb 2012	18 Feb 2013	19 Feb 2014	23 Feb 2015
	Proportion of lake inundated	80%	70%	100%	60%
	Percentage of the lake counted	70%	unknown		90%
Species		**Number of individuals counted**			
Australasian Grebe	*Tachybaptus novaehollandiae*	125	240	2	85
Australasian Shoveler^	*Anas rhynchotis*		55		41
Australian Pelican	*Pelecanus conspicillatus*				250
Australian Shelduck	*Tadorna tadornoides*		8	2	
Australian Wood Duck	*Chenonetta jubata*	708	179	68	23
Black Swan	*Cygnus atratus*		152		70
Black-fronted Dotterel	*Elseyornis melanops*		32		
Black-tailed Native-hen	*Tribonyx ventralis*		540		
Black-winged Stilt	*Himantopus himantopus*		22		
Blue-billed Duck^	*Oxyura australis*	6	32		7
Chestnut Teal	*Anas castanea*				
Darter	*Anhinga novaehollandiae*		2	6	
Eurasian Coot	*Fulica atra*	15	3030	6	360
Freckled Duck^	*Stictonetta naevosa*		5		5
Great Cormorant	*Phalacrocorax carbo*		3	34	710
Great Crested Grebe	*Podiceps cristatus*	2			8
Eastern Great Egret^	*Ardea modesta*		1		2
Grey Teal	*Anas gracilis*	120	944	72	510
Hardhead	*Aythya australis*		27		31
Hoary-headed Grebe	*Poliocephalus poliocephalus*	15	207		12
Little Black Cormorant	*Phalacrocorax sulcirostris*			32	60
Little Egret^	*Egretta garzetta*				1
Little Pied Cormorant	*Microcarbo melanoleucos*			31	
Masked Lapwing	*Vanellus miles*		3		21
Musk Duck^	*Biziura lobata*	4	12		4
Pacific Black Duck	*Anas superciliosa*	106	505	3	41
Pied Cormorant^	*Phalacrocorax varius*			2	30
Pink-eared Duck	*Malacorhynchus membranaceus*		190		45
Royal Spoonbill	*Platalea regia*				7
Swamp Harrier	*Circus approximans*		2	3	
Whistling Kite	*Haliastur sphenurus*			11	
White-faced Heron	*Egretta novaehollandiae*		2	7	4
White-necked Heron	*Ardea pacifica*		1		
Yellow-billed Spoonbill	*Platalea flavipes*				4
	Total	**1101**	**6194**	**279**	**2331**

^listed as significant due to threatened status

Source: M. Dedini unpublished data, 2015

Appendix 2 – Fauna species list

Scientific name	Common name	Type	No. of records
Australasian Grebe	*Tachybaptus novaehollandiae*	B	2
Australasian Shoveler	*Anas rhynchotis*	B	1
Australian Bustard	*Ardeotis australis*	B	1
Australian Magpie	*Gymnorhina tibicen*	B	1
Australian Pelican	*Pelecanus conspicillatus*	B	1
Australian Pratincole	*Stiltia isabella*	B	1
Australian Raven	*Corvus coronoides*	B	1
Australian Wood Duck	*Chenonetta jubata*	B	2
Black Swan	*Cygnus atratus*	B	1
Black Wallaby	*Wallabia bicolor*	M	1
Black-fronted Dotterel	*Elseyornis melanops*	B	1
Black-winged Stilt	*Himantopus himantopus*	B	1
Blue Bonnet	*Northiella haematogaster*	B	1
Bony Bream	*Nematalosa erebi*	F	1
Brown Songlark	*Cincloramphus cruralis*	B	1
Brown Treecreeper (south-eastern	*Climacteris picumnus victoriae*	B	1
Burton's Snake-Lizard	*Lialis burtonis*	R	1
Chestnut-crowned Babbler	*Pomatostomus ruficeps*	B	2
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	B	1
Common Starling	*Sturnus vulgaris**	B	1
Crested Pigeon	*Ocyphaps lophotes*	B	1
Darter	*Anhinga novaehollandiae*	B	1
Eastern Great Egret	*Ardea modesta*	B	1
Eurasian Coot	*Fulica atra*	B	2
European Carp*	*Cyprinus carpio*	F	1
Fat-tailed Dunnart	*Sminthopsis crassicaudata*	M	1
Feathertail Glider	*Acrobates pygmaeus*	M	1
Flathead Gudgeon	*Philypnodon grandiceps*	F	1
Fork-tailed Swift	*Apus pacificus*	B	1
Freshwater Catfish	*Tandanus tandanus*	F	1
Galah	*Eolophus roseicapilla*	B	2
Goldfish*	*Carassius auratus*	F	1
Great Cormorant	*Phalacrocorax carbo*	B	1
Great Crested Grebe	*Podiceps cristatus*	B	1
Grey Shrike-thrush	*Colluricincla harmonica*	B	1
Grey Teal	*Anas gracilis*	B	2
Growling Grass Frog	*Litoria raniformis*	A	1
Hardhead	*Aythya australis*	B	1
Hoary-headed Grebe	*Poliocephalus poliocephalus*	B	1
Little Corella	*Cacatua sanguinea*	B	1
Little Eagle	*Hieraaetus morphnoides*	B	1
Little Black Cormorant	*Phalacrocorax sulcirostris*	B	1
Little Pied Cormorant	*Microcarbo melanoleucos*	B	1

Scientific name	Common name	Type	No. of records
Major Mitchell's Cockatoo	*Lophocroa leadbeateri*	B	1
Mallee Ringneck	*Barnardius zonarius barnardi*	B	1
Masked Lapwing	*Vanellus miles*	B	1
Australian Shelduck	*Tadorna tadornoides*	B	1
Mulga Parrot	*Psephotus varius*	B	1
Musk Duck	*Biziura lobata*	B	1
Murray Cod	*Maccullochella peelii*	F	1
Pacific Black Duck	*Anas superciliosa*	B	2
Pallid Cuckoo	*Cuculus pallidus*	B	1
Pied Butcherbird	*Cracticus nigrogularis*	B	1
Pied Cormorant	*Phalacrocorax varius*	B	1
Pink-eared Duck	*Malacorhynchus membranaceus*	B	1
Rainbow Bee-eater	*Merops ornatus*	B	1
Redfin*	*Perca fluviatilis*	F	1
Red-rumped Parrot	*Psephotus haematonotus*	B	1
Regent Parrot	*Polytelis anthopeplus monarchoides*	B	1
Rufous Songlark	*Cincloramphus mathewsi*	B	1
Rufous Whistler	*Pachycephala rufiventris*	B	1
Southern Legless Lizard	*Delma australis*	R	2
Southern Whiteface	*Aphelocephala leucopsis*	B	1
Straw-necked Ibis	*Threskiornis spinicollis*	B	1
Sulphur-crested Cockatoo	*Cacatua galerita*	B	1
Trout Cod	*Maccullochella macquariensis*	F	1
Weebill	*Smicrornis brevirostris*	B	1
Western Carp Gudgeon	*Hypseleotris klunzingeri*	F	1
Western Grey Kangaroo	*Macropus fuliginosus*	M	1
Whiskered Tern	*Chlidonias hybridus*	B	1
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	1
White-browed Babbler	*Pomatostomus superciliosus*	B	1
White-faced Heron	*Egretta novaehollandiae*	B	2
White-necked Heron	*Ardea pacifica*	B	1
White-plumed Honeyeater	*Lichenostomus penicillatus*	B	1
White-winged Triller	*Lalage sueurii*	B	1
Willie Wagtail	*Rhipidura leucophrys*	B	1
Yabbie	*Cherax destructor*	I	1
Yellow-throated Miner	*Manorina flavigula*	B	1

Legend:
Lifeform type: Invertebrate, Fish, Amphibian, Reptile, Bird, Mammal

**Introduced species*

Sources: DELWP, 2015a; SKM, 2002c; Ecological Associates, 2006

Appendix 3 – Ecological vegetation classes

EVC no.	EVC name	Bioregional Conservation Status		Description
		Murray Fans	Murray Mallee	
86	Woorinen Sands Mallee	n/a	Depleted	Mallee shrubland to 7 m tall, typically supporting a hummock grass (Triodia spp.) dominated understorey. This EVC could be considered intermediate between the heavier soil mallee woodlands and the lighter sandy soil mallee vegetation predominant on Lowan (siliceous) sand.
97	Semi-arid Woodland	Vulnerable	Vulnerable	Non-eucalypt woodland or open forest to 12 m tall, of low rainfall areas. Occurs in a range of somewhat elevated positions not subject to flooding or inundation. The surface soils are typically light textured loamy sands or sandy loams.
103	Riverine Chenopod Woodland	Endangered	n/a	Eucalypt woodland to 15 m tall with a diverse shrubby and grassy understorey occurring on most elevated riverine terraces. Confined to heavy clay soils on higher level terraces within or on the margins of riverine floodplains (or former floodplains), naturally subject to only extremely infrequent incidental shallow flooding from major events if at all flooded.
107	Lake Bed Herbland	Vulnerable	Depleted	Herbland or shrubland to 0.5 m tall dominated by species adapted to drying mud within lake beds. Some evade periods of prolonged inundation as seed, others as dormant tuber-like rootstocks. Occupies drying deep-cracking mud of lakes on floodplains. Floods are intermittent but water may be retained for several seasons leading to active growth at the 'drying mud stage'.
808	Lignum Shrubland	Vulnerable	n/a	Relatively open shrubland of species of divaricate growth form. The ground-layer is typically herbaceous or a turf grassland, rich in annual/ephemeral herbs and small chenopods. Characterised the open and even distribution of relatively small Lignum shrubs. Occupies heavy soil plains along River Murray, low-lying areas on higher-level (but still potentially flood-prone) terraces.
813	Intermittent Swampy Woodland	Depleted	Vulnerable	Eucalypt woodland to 15 m tall with a variously shrubby and rhizomatous sedgy - turf grass understorey, at best development dominated by flood stimulated species in association with flora tolerant of inundation. Flooding is unreliable but extensive when it happens. Occupies low elevation areas on river terraces (mostly at the rear of point-bar deposits or adjacent to major floodways) and lacustrine verges (where sometimes localised to narrow transitional bands). Soils often have a shallow sand layer over heavy and frequently slightly brackish soils.
823	Lignum Swampy Woodland	Vulnerable	n/a	Understorey dominated by Lignum, typically of robust character and relatively dense (at least in patches), in association with allow Eucalypt and/or Acacia woodland to 15 m tall. The ground layer includes a component of obligate wetland flora that is able to persist even if dormant over dry periods.

Appendix 4 – Flora species list

Scientific name	Common name	No. of records
Acacia oswaldii	Umbrella Wattle	1
Abutilon otocarpum	Desert Lantern	1
Alectryon oleifolius subsp. *canescens*	Cattle Bush	2
Amyema miquelii	Box Mistletoe	1
*Asparagus asparagoides**	Bridal Creeper	1
Atriplex eardleyae	Small Saltbush	1
Atriplex leptocarpa	Slender-fruit Saltbush	1
Atriplex lindleyi	Flat-top Saltbush	1
Atriplex lindleyi subsp. *inflata*	Corky Saltbush	1
Atriplex suberecta	Sprawling Saltbush	1
*Avena fatua**	Wild Oats	1
Callitris sp.	Cypress-pine	1
Carex inversa	Knob Sedge	1
Chenopodium curvispicatum	Cottony Saltbush	1
Convolvulus erubescens s.l.	Pink Bindweed	1
Convolvulus remotus	Grassy Bindweed	1
Crassula colorata	Dense Crassula	1
Duma florulenta	Tangled Lignum	1
Duma horrida	Spiny Lignum	1
Einadia nutans	Nodding Saltbush	1
Enchylaena tomentosa var. *tomentosa*	Ruby Saltbush	1
Enteropogon acicularis	Spider Grass	1
Eucalyptus camaldulensis	River Red Gum	1
Eucalyptus largiflorens	Black Box	5
Eucalyptus microcarpa	Grey Box	3
Euphorbia drummondii spp. agg.*	Flat Spurge	1
Eutaxia microphylla	Common Eutaxia	1
Exocarpos sparteus	Broom Ballart	1
Hakea leucoptera subsp. *leucoptera*	Silver Needlewood	1
Hordeum sp.*	Barley Grass	1
Maireana aphylla	Leafless Bluebush	1
Maireana brevifolia	Short-leaf Bluebush	1
Malva preissiana s.l.	Australian Hollyhock	1
*Marrubium vulgare**	Horehound	1
Melaleuca lanceolata	Moonah	1
Mesembryanthemum spp.*	Ice Plant	1

Morgania glabra spp. agg.	Blue Rod	1
Nitraria billardieri	Nitre-bush	1
*Polycarpon tetraphyllum**	Four-leaved Allseed	1
Rhagodia gaudichaudiana	Cottony Saltbush	1
Rhagodia spinescens	Hedge Saltbush	2
Rytidosperma caespitosum	Common Wallaby-grass	1
Salsola tragus subsp. *tragus*	Prickly Saltwort	1
Sclerolaena diacantha	Grey Copperburr	1
Sclerolaena obliquicuspis	Limestone Copperburr	2
Senna form taxon 'coriacea'	Broad-leaf Desert Cassia	1
Sida corrugata	Variable Sida	1
Sida intricata	Twiggy Sida	1
Silene apetala var. *apetala**	Mallee Catchfly	1
Solanum spp.	Nightshade	1
Spergularia rubra s.l.*	Red Sand-spurrey	1
Vittadinia sp.	-	1

**Introduced species*

Sources: DELWP, 2015a; Ecological Associates, 2007; SKM, 2002c