Lake Hawthorn Environmental Water Management Plan

Document control

Revision and Distribution

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Figure 1. A view southward across Lake Hawthorn after a rainfall event in January 2016.

Abbreviations and Acronyms

AHD	Australian Height Datum
CAMBA	China-Australia Migratory Bird Agreement
CMAs	Catchment Management Authorities
CTF	Commence to Flow
DELWP	Department of Environment, Land, Water and Planning
EVC	Ecological Vegetation Class
EPBC Act	Environment Protection and Biodiversity Conservation Act
EWMP	Environmental Water Management Plan
G-MW	Goulburn-Murray Water
IWC	Index of Wetland Condition
JAMBA	Japan-Australia Migratory Bird Agreement
MDBA	Murray-Darling Basin Authority (formally Murray-Darling Basin Commission, MDBC)
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
TSL	Targeted Supply Level

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 waterway values were used to group them into planning units. This EWMP has been developed for the Lake Hawthorn and Lake Ranfurly WMU Sub-unit, with part of Lake Hawthorn comprising the target area. The EWMP will help to guide future environmental watering activities for this area.

The sub-unit is located in the Murray Scroll Belt Bioregion within the Mallee Catchment Management Authority (Mallee CMA) region on the north-western edge of Mildura and covers 1034 ha.

Lake Hawthorn is primarily used as an irrigation drainage and urban storm water runoff disposal site. It is also part of the Lake Hawthorn Drainage Diversion Scheme, with excess water above 34.85 mAHD pumped to Wargan Basins under defined operating rules. These schemes are determined by Lower Murray Water, Goulburn-Murray Water and Mildura Rural City Council. The Mallee Catchment Management Authority acknowledges this will be the primary use for the site going forward and understands that any ecological and hydrological objectives recommended herein are secondary to the sites primary purpose. However, opportunities to protect the environmental values and improve conditions may be provided through delivery of environmental water at this site. Lake Ranfurly is not within the target area of this EWMP as it is primarily used as an evaporation basin for the Mildura-Merbein Groundwater Interception Scheme.

The Lake Hawthorn target area represents a valuable and productive saline wetland environment that is capable of supporting large numbers of waterbirds. Its position on the Murray River floodplain offers important feeding, foraging and loafing habitat. This offers an extension of Murray River habitat as it is connected with the Murray River by healthy stands of Black Box and Lignum communities that allow movement of waterbirds between fresh and saline wetland environments. Lake Hawthorn is also highly valued by the local community.

Furthermore, the area is recognised for its potential to support a large number of migratory shorebird species of international importance. The Red-necked Stint (*Calidris ruficollis*) has been recently recorded at Lake Hawthorn, a shorebird known for its annual northward migration to breeding grounds in Siberia and Alaska. More than 80% of the global population of this species migrates to Australia for the non-breeding season. Similarly, the migratory Curlew Sandpiper (*Calidris ferruginea*), which was listed as Critically Endangered in 2015 under the EPBC Act, has been recorded at Lake Ranfurly, and may find opportunistic foraging habitat at Lake Hawthorn.

The whole 1034 ha has a water requirement as a floodplain complex (Mallee CMA, 2014), but the focus for this plan is restricted to a target area of approximately 148 ha. The target area for this plan is part of the bed of Lake Hawthorn. A smaller floodplain wetland (#7329 998173) has been excluded from the target area as its current condition is deemed satisfactory.

The long-term management goal for the Hawthorn/Ranfurly EWMP is:

> *To provide a flow regime to the target area that provides permanent shallow wading habitat for internationally important migratory shorebirds and a diverse population of resident native waterbirds.*

To achieve this, ecological and hydrological objectives, were developed to sustain two key ecological components of Lake Hawthorn:

- Reintroduce saline marsh habitat, particularly benthic herblands including *Ruppia* beds; and
- Provide suitable wading, feeding, foraging and loafing habitat for shorebirds

The following watering regimes have been developed to sustain and improve the ecological components of the target area. Each is aimed at maintaining the water level in Lake Hawthorn between 33.0 mAHD and 33.3 mAHD through delivery of environmental water when inflows from other sources are insufficient.

Annual Rainfall Value	Water Regime – Lake Hawthorn
Dry Year (e.g. <225 mm)	Provide environmental water via irrigation infrastructure to permanently inundate the target area and achieve a water level of 33.3 mAHD to encourage germination of *Ruppia* spp. and visitation by shorebirds. Allow natural recession of a maximum of 0.3 m (to 33.0 mAHD) before delivering a top-up volume as necessary to return the lake to 33.3 mAHD.
Average Year (e.g. ~290 mm)	Provide environmental water via irrigation infrastructure to permanently inundate the target area and to maintain a water level of 33.3 mAHD to encourage germination of *Ruppia* spp. and visitation by shorebirds. Allow natural recession of a maximum of 0.3 m (to 33.0 mAHD) to expose mudflats for foraging shorebirds and to promote *Ruppia* spp. germination, before delivering a top-up volume as necessary to return the lake to 33.3 mAHD.
Above Average Year (e.g. >350 mm)	Monitor water level. Deliver environmental water if necessary, to sustain a water level of 33.3 mAHD to maintain *Ruppia* spp. beds. Allow natural recession of a maximum of 0.3 m (to 33.0 mAHD) before delivering a top-up volume as necessary to return the lake to 33.3 mAHD.

CDM Smith (2015) completed a preliminary salinity impact assessment on the proposed environmental watering regimes for Hawthorn/Ranfurly. The study identified no significant impact at Morgan is expected to arise from delivery under the above regime. Ongoing review of available data is recommended to identify any potential trends.

1.0 Introduction

This Environmental Water Management Plan (EWMP) has been prepared by the Mallee CMA to establish the long-term environmental water management goals of Lake Hawthorn.

The key purposes of the EWMP are to:

- Identify the long-term objectives and water requirements for the wetland, recognised as a medium priority in the *Mallee Waterway Strategy (MWS)*;
- Provide a medium for community consultation, including for the long-term objectives and water requirements of the wetland;
- Inform the development of seasonal watering proposals and seasonal watering plans;
- Inform long-term watering plans that will be developed under Murray-Darling Basin Plan requirements.

2.0 Site overview

2.1 Site Location

The Mallee CMA region is located in the north-west of Victoria and is the largest catchment in the state. Its area of responsibility covers approximately 39,000km² with an estimated regional population of 65,000. The catchment runs along the Murray River from Nyah to the South Australian border, and as far south as Birchip and Rainbow (MCMA 2014). Major towns include Mildura, Birchip, Sea Lake, Ouyen, Robinvale, Red Cliffs and Merbein. The region is semi-arid with an annual rainfall of around 250mm and average daily temperatures (at Mildura) ranging from 32°C in summer to 15°C in winter (MCMA 2006).

The Mallee CMA region consists of approximately 40% public land consisting mainly of national parks, reserves and large reaches of riverine and dryland forest. The rest of the region is important for dryland farming of sheep and cereals, and irrigated horticulture (MCMA 2006).

In 2006 the Mallee CMA engaged consultants Ecological Associates to investigate water management options for the Murray River floodplain from Robinvale to Wallpolla Island. One of the major outcomes of these investigations was the development of a system of Floodplain Management Units (FMUs). These divide the floodplain into management units in which water regimes can be managed independently of another FMU. FMUs are relatively consistent in their ecological values and land uses. The Mallee CMA has used FMUs to inform planning and development of environmental water management plans to achieve more 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 (WMU) for planning within its Mallee Waterway Strategy (MCMA 2014) (Figure 1).

This plan has been prepared for Lake Hawthorn within the Lake Hawthorn & Lake Ranfurly FMU (or WMU sub-unit) (Figure 2). This WMU sub-unit is hereafter referred to as Hawthorn/Ranfurly in this document, and is located between 870.5 and 875 river km, 3km downstream of Lock 10 and approximately 3 km north-west of the Mildura CBD. Lake Hawthorn is referred to by name in this document where the lake itself is described. Hawthorn/Ranfurly falls within the Merbein WMU. Merbein covers a series of unconnected sub-units from Lock 10 in Wentworth to Lock 11 in Mildura. For a map of the Merbein WMU, refer to the *Mallee Waterway Strategy 2014-22*.

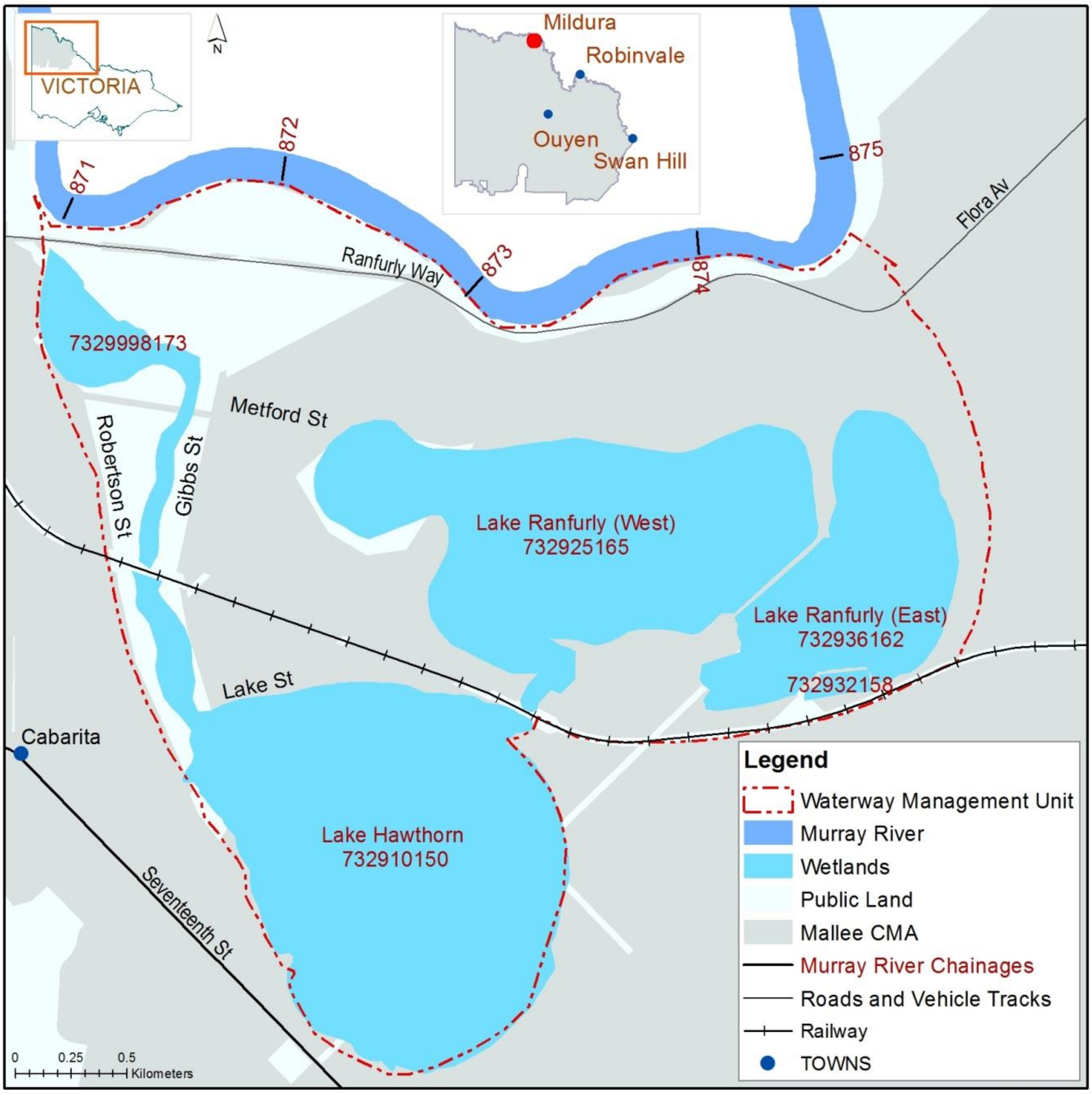


Figure 2. Map of the Lake Hawthorn& Lake Ranfurly WMU sub-unit

2.2 Catchment Setting

Hawthorn/Ranfurly is located in the Murray Scroll Belt Bioregion. The Murray Scroll Belt Bioregion is characterised by an entrenched river valley and associated floodplain and lake complexes of numerous oxbow lakes, billabongs, ephemeral lakes, swamps and active meander belts. Alluvium deposits from the Cainozoic period gave rise to the red brown earths, cracking clays and texture contrast soils (Dermosols, Vertosols, Chromosols and Sodosols) supporting Alluvial-Plain Shrubland, Riverine Grassy Chenopod Woodland and Riverine Grassy Forest ecosystems (DELWP 2015).

Surrounding land use is mainly residential, irrigated horticulture and dryland farming (SKM 2001). The eastern shore of Lake Hawthorn has also been used for stock grazing in the past which has contributed to reduced vegetation cover and poor habitat for native fauna (Lloyd Environmental 2007). The WMU sub-unit consists largely of agency managed land with areas of crown land and public recreation reserve.

Key features of the sub-unit include Wetland #7329 998173, Lake Ranfurly and Lake Hawthorn; these are described below.

2.2.1 Wetland #7329 998173

Wetland #7329 998173 is a natural floodplain wetland in a section of Black Box floodplain that has suffered reduced connectivity to the Murray River by construction of levees, although a limited connection exists via an old regulator structure. This wetland would have connected with the river during high flows, and flow through to Lake Hawthorn would be achieved. The wetland is approximately 27 ha. Cumbungi (*Typha* spp.) has established in some places, where drainage water is received. Reports have suggested the presence of a freshwater lens (CDM Smith 2015) below this wetland, which may explain its apparently healthy condition, regardless of altered hydrology.

2.2.2 Lake Hawthorn

The target area for this plan is Lake Hawthorn, which is a natural floodplain wetland that filled under high Murray River flows prior to river regulation in 1915 (Ecological Associates 2007b). In high flow conditions the lake would fill from the Murray River, via wetland # 7329 998173 (Figure 2). Levee banks now limit connectivity to the wetland and, subsequently, Lake Hawthorn from the Murray River (Ecological Associates 2007b). The lake is approximately 255 ha in area. Although it was originally a freshwater wetland, it is now classified as a semi-permanent saline wetland due to its use as an irrigation and urban drainage basin (Lloyd Environmental 2007). Lake Hawthorn has previously been recognised as having a diverse fish community, and supported threatened species listed under the FFG and EPBC Acts (Ecological Associates 2007b). Most notably, the lake was one of only four known Victorian habitats for the critically endangered Murray Hardyhead prior to it drying out during the millennium drought of 2002 – 2009.

2.2.3 Lake Ranfurly

Lake Ranfurly is a natural floodplain deflation basin which filled under high Murray River flows, although levee banks now restrict flooding of the lake (Ecological Associates 2007b). The lake is divided into two sections, east and west, by a causeway when water levels are low (SKM 2001). Lake Ranfurly East is approximately 80 ha and Lake Ranfurly West is approximately 140 ha.

Lake Ranfurly was originally a freshwater wetland but is now classified as a semi-permanent saline wetland due to its use for irrigation drainage disposal and groundwater inputs from the Mildura-Merbein Salt Interception Scheme (SKM 2001). Water in Lake Ranfurly West is hypersaline and has frequently reached levels exceeding 100,000 EC (Bluml 1991). Lake Ranfurly East receives less corrosive groundwater and urban stormwater run-off which maintains salinity levels lower than that of the western section, but still in excess of 60,000 EC (SKM 2001). Lake Ranfurly is listed in the Directory for Important Wetlands in Australia due to its significant waterbird population, many of which are listed in State, Federal and International Acts and agreements (SKM 2001).

2.2.4 Commonalities between Lake Hawthorn and Lake Ranfurly

The land closely surrounding both lakes is saline and supports salt tolerant species such as Austral Seablite (*Suaeda australis*) and Ruby Saltbush (*Enchylaena tomentosa*). The introduced weed, African Boxthorn (*Lycium ferocissimum*) also occurs in the area (Ecological Associates 2007b). At Lake Ranfurly, narrow strips of Black Box (*Eucalyptus largiflorens*) and Eumong (*Acacia stenophylla*) survive on higher ground.

While Lake Ranfurly is known for its waterbird populations, both Lake Hawthorn and Lake Ranfurly offer extensive feeding grounds and expansive wading zones for waterbirds. Birds are able to adapt to irruptive or pulsed resources (Whelan, Wenny & Marquis 2008), and thus may mobilise to Lake Hawthorn during an inundation phase in preference to the dry Lake Ranfurly. Lake Hawthorn may offer a more feasible option for the delivery of environmental water due to the intermittent use of Lake Ranfurly as an evaporation basin for the Mildura-Merbein Salt Interception Scheme (see section 2.8).

2.3 Groundwater Conditions

2.3.1 Stratigraphy

Groundwater interaction at Hawthorn/Ranfurly is significant and so it is important to describe the local groundwater conditions and stratigraphy in this EWMP. In order of increasing depth, the major stratigraphic units encountered within the area include the Woorinen Formation, Coonambidgal Clay, Monoman Formation, Blanchetown Clay, Parilla Sands and Lower Parilla Clay.

The Woorinen Formation is identified by its orange brown sand and silty clay formed through aeolian wind deposition and pedogenesis. The various units within this formation are a result of post depositional watertable fluctuations and weathering; containing, calcrete, gypsum and carbonaceous material. Its thickness ranges from 2 to 3m (AWE 2009, cited in CDM Smith 2015).

The Coonambidgal Clay is identified by its fine silts and stiff, low plasticity clays. It acts as an aquitard (a layer of rock or sediment that prevents the flow of groundwater from one aquifer to another) at the top of the sedimentary sequence within the Murray River trench (SKM 2013A). The Coonambidgal Clay surrounding Lake Hawthorn predominantly consists of clays rather than silts and is estimated to be 5 m thick to the south and 10 m thick to the north.

The Monoman Formation is identified by its grey to brown fine to coarse sands and clays and forms the floodplain aquifer (a layer of permeable rock, soil or sediment that yields water). In the floodplain the aquifer is semi-confined by the Coonambidgal Clay and variably connected to the Parilla Sands aquifer. Surrounding Lake Hawthorn, it is estimated that its thickness ranges between 3 and 15 m. In some instances, the Monoman Formation is difficult to distinguish from the Parilla Sand as it is lithologically similar, meaning that their physical characteristics (visible at outcrop, in hand or core samples or with low magnification) are similar.

The Blanchetown Clay is identified by its mottled green to brown and red sandy clays. It is a lacustrine unit (relating to a lake) that acts as a regional aquitard. In the study area its distribution and thickness is influenced by tectonic movements during and after the Tertiary marine transgression. Through this a series of structural troughs and ridges were formed resulting in thicker deposits of Blanchetown Clay being deposited in the troughs whilst thinner sequences were deposited on the ridges (Thorne et al 1990).

The Upper Parilla Sands are identified by their unconsolidated to weakly cemented, fine to coarse quartz sands.

The Lower Parilla Sands are identified by fine, well-sorted sands or silty-sands, and is marked by a colour change to dark grey in the Upper Parilla Sands.

The Lower Parilla Clay along with the underlying Bookpurnong Beds forms the regional aquitard and underlies the Parilla Sand.

Incision of the Murray Trench caused the River system to flow through valleys eroding into Blanchetown Clays in the troughs and Parilla Sands on the ridges. Scout hole drilling data (SKM 2013A) indicates complete erosion of the Blanchetown Clays in the river trench within the area, although the extent to which it persists beneath Lake Hawthorn is unknown. Occurring across both the highland and floodplain the Parilla Sands underlie the Monoman Formation and form the regional aquifer.

Thickness of stratigraphic units present beneath the wetlands can be seen in Figure 3.

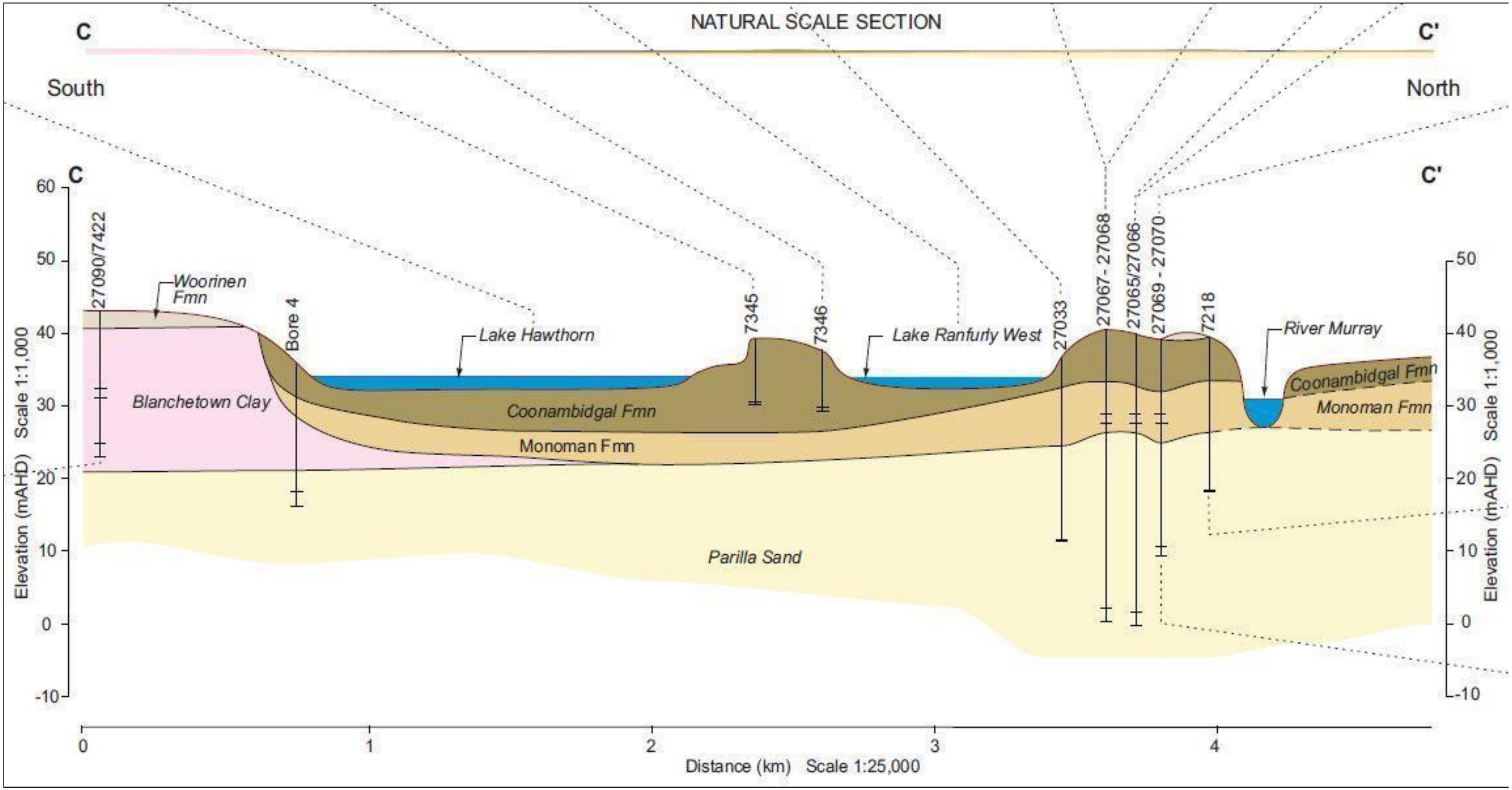


Figure 3. Geological Cross Section displaying stratigraphic units (AWE 2009, p.15)

2.3.2 Groundwater Interactions

Stream Conditions

It has been suggested that the reach of the Murray River adjacent to this WMU experienced gaining stream conditions during the 1990s, and losing stream conditions between 2001 and 2009, with a return to gaining conditions since the natural flood events in 2010 and 2011 (AWE 2014, p.21). Analysis of the 2012 NanoTEM survey data suggests the reach immediately adjacent to Lake Hawthorn indicated "the likelihood of low salt inflow" between 871 and 873 river kms, and higher potential for salt loads upstream and downstream of this location (AWE 2014, p.22).

Groundwater Salinity

Groundwater salinity levels vary throughout the WMU, with low salinity recorded beneath Wetland #7329 998173, which in conjunction with the NanoTEM data suggests the presence of a fresh water lens at this location. It is possible that this lens may provide a buffer against instream salinity impacts (AWE 2014, p.29). High groundwater salinity has been recorded beneath Lake Ranfurly, and elevated salinity beneath Lake Hawthorn.

Groundwater and Lake Hawthorn

A connection between Lake Hawthorn and the groundwater is suggested by CDM Smith (2015, p.5-9), as groundwater levels were lowest shortly after the lake dried out, and rose again in subsequent wet years (2010). However, groundwater levels would be expected to be lower in the period leading up to 2010 because all inputs to groundwater, such as rainfall and irrigation, were low during this time. Subsequent rises would also be expected during wetter years in 2011 and 2012 due higher inputs from rainfall and flooding. It is expected that the lake receives groundwater when water levels are low (although the contribution to water balance is negligible), and it may recharge the aquifer when water levels are high (Ecological Associates 2015, p.6).

An interpretation of contours from July 2013 monitoring data suggests a flow-through effect on the floodplain, with the highest groundwater levels at 35.5 m AHD to the southwest, falling to around 32.5 m AHD to the north of Lake Ranfurly (Figure 4). Salinity impact is dependent upon the level of connectivity between Lake Hawthorn, the floodplain aquifer (Monoman formation), and the Murray River.

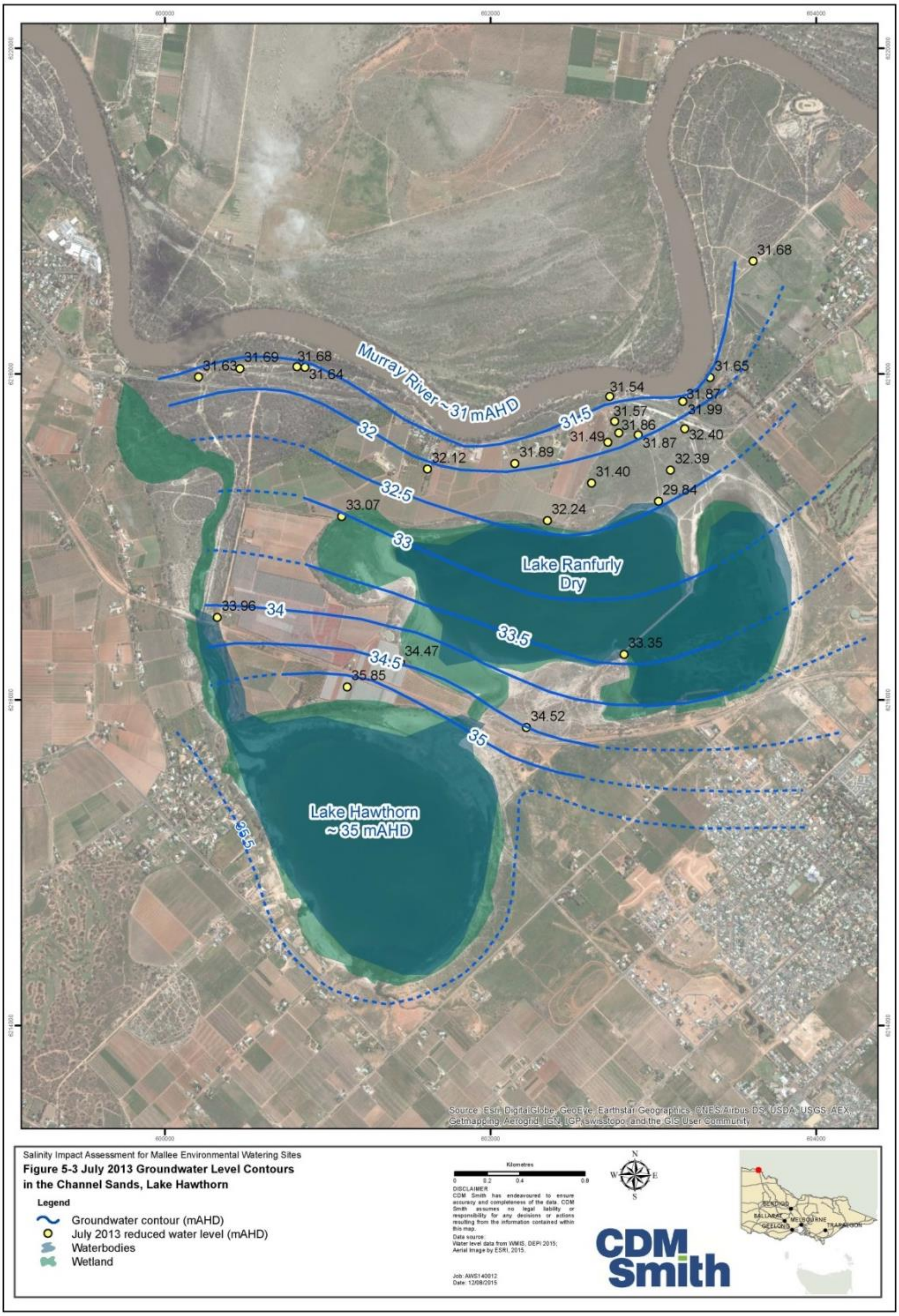


Figure 4. July 2013 Groundwater Level Contours in the Channel Sands, Lake Hawthorn (CDM Smith 2015)

2.4 Conceptualisation of the Site

A conceptual representation of Lake Hawthorn is presented in Figure 5, indicating its position in the landscape and connection to the Murray River via Wetland #7329 998173. The diagram includes key ecological processes, water dependent values and threats to those values. The interactions between the values and threats are further discussed throughout this plan.

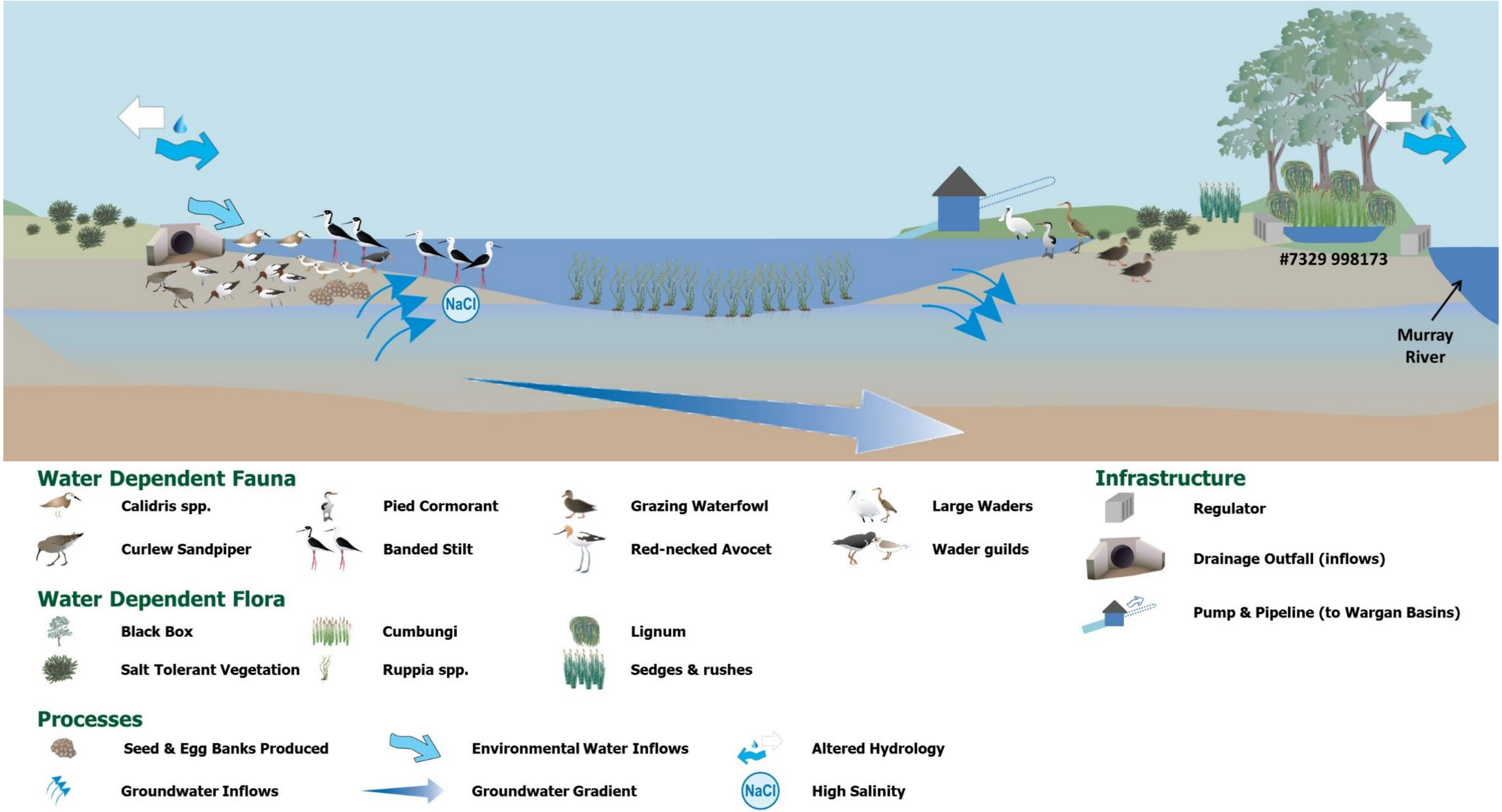


Figure 5. Conceptual model of the threats and values associated with Lake Hawthorn

Levee banks and regulators restrict natural flooding of Wetland #7329 998173 and restrict through-flows to Lake Hawthorn. Vegetation surrounding Lake Hawthorn is largely comprised of salt tolerant species with Black Box and Lignum on the higher elevations surrounding Wetland #7329 997173.

Freshwater inflows to the system will be delivered as environmental water via existing irrigation infrastructure to provide inundation of part of the lake bed. This flooding leads to the rapid release of nutrients from the soils, production of seed and egg banks, and increases in productivity of aquatic macrophytes and invertebrates. *Ruppia* spp. is known to successfully re-establish in Lake Hawthorn after inundation, which provides habitat for invertebrates. A pulse in aquatic macrophytes and invertebrates provides food and foraging habitat for waterbirds. A shallow environment with a fluctuating water level will expose mud banks for foraging by migratory shorebirds . The wetland becomes more productive and surrounding vegetation such as rushes benefit from periodic inundation as water levels rise and fall.

Saline irrigation drainage and urban stormwater drainage provide inflows, particularly in wet years, with excess drainage water diverted by pumping to Wargan Basins when necessary. Groundwater discharge can impact the wetland, increasing salinity levels NaCl. When salinity levels increase in the lake, clay particles flocculate and settle, improving water clarity. This improves light penetration and promotes growth of algae, microbes, and aquatic vegetation such as Ruppia in shallow water, which in turn supports zooplankton (Young 2001) and provides a food source for waterbirds . A shallow water environment in Lake Hawthorn can provide an important habitat niche, as saline wetlands have the capacity to support “about ten times as many waterbirds as the freshwater wetland” (Young 2001). This is suggested by Young (2001), to reflect a greater abundance of invertebrates as a food source.

Lake Hawthorn’s proximity to the Murray River, and a corridor through high quality floodplain vegetation including Lignum Swampy Woodland , means resident native waterbirds can readily transition between feeding grounds at the lake, through breeding grounds on the floodplain, to deep flowing water at the river.

2.5 Land Status and Management

Multiple land managers are responsible for different areas of Hawthorn/Ranfurly. These include Parks Victoria, Mildura Rural City Council, Lower Murray Water and Goulburn-Murray Water. Three agencies are currently responsible for management of the lake, these agencies are:

- Mildura Rural City Council (MRCC);
- Goulburn-Murray Water (G-MW); and
- Lower Murray Water (LMW)

Land tenure in the sub-unit is indicated in Figure 6 and highlights that much of the sub-unit is comprised of freehold land, despite the unimpeded access and use of the wetland surrounds by many different sections of the community. Land status is indicated in Figure 7, highlighting many stakeholders and land managers. Table 1 lists the key stakeholders and their responsibilities and/or interest in relation to Lake Hawthorn and Lake Ranfurly.

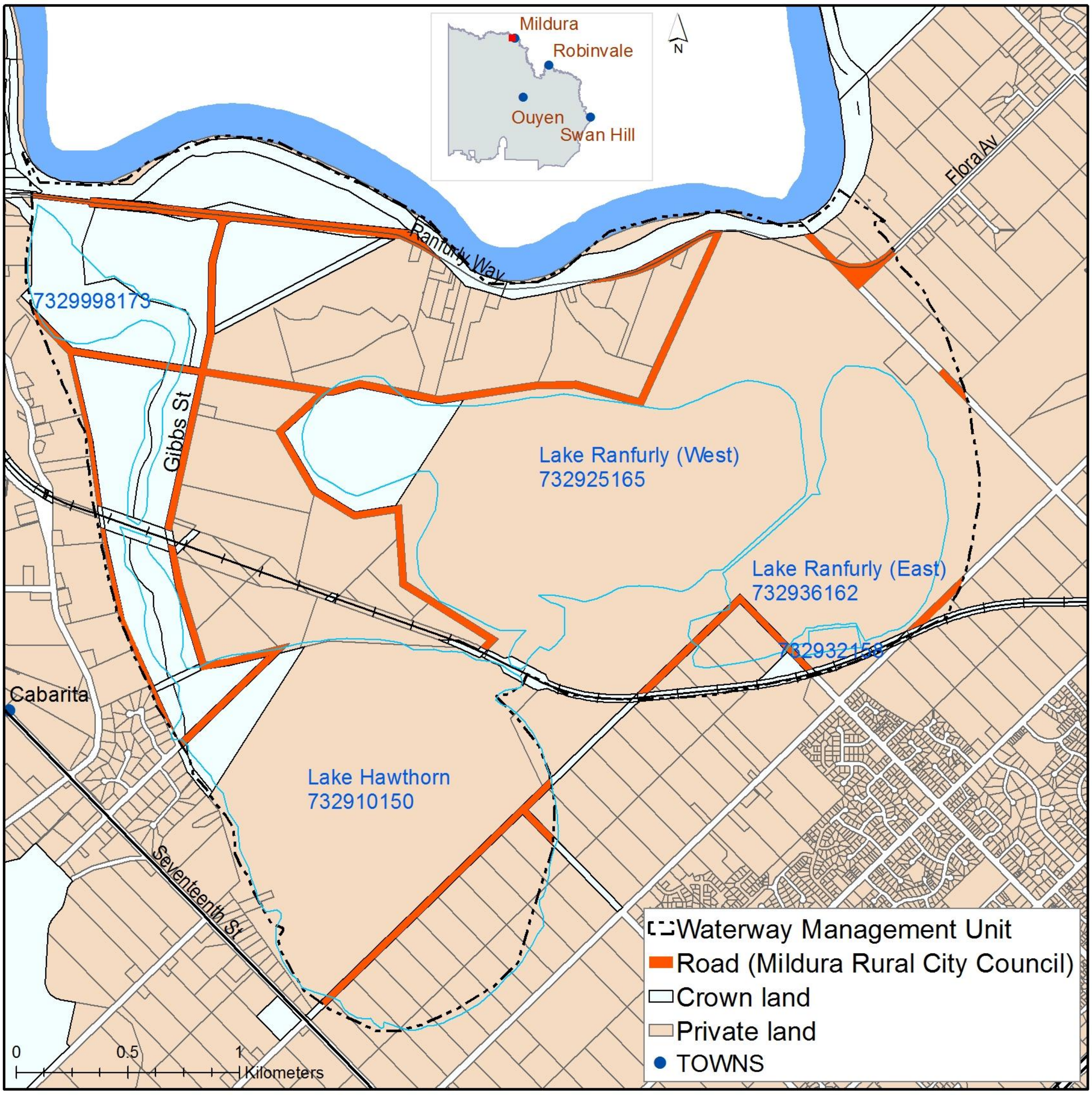


Figure 6. Land Tenure Map

mallee catchment management authority

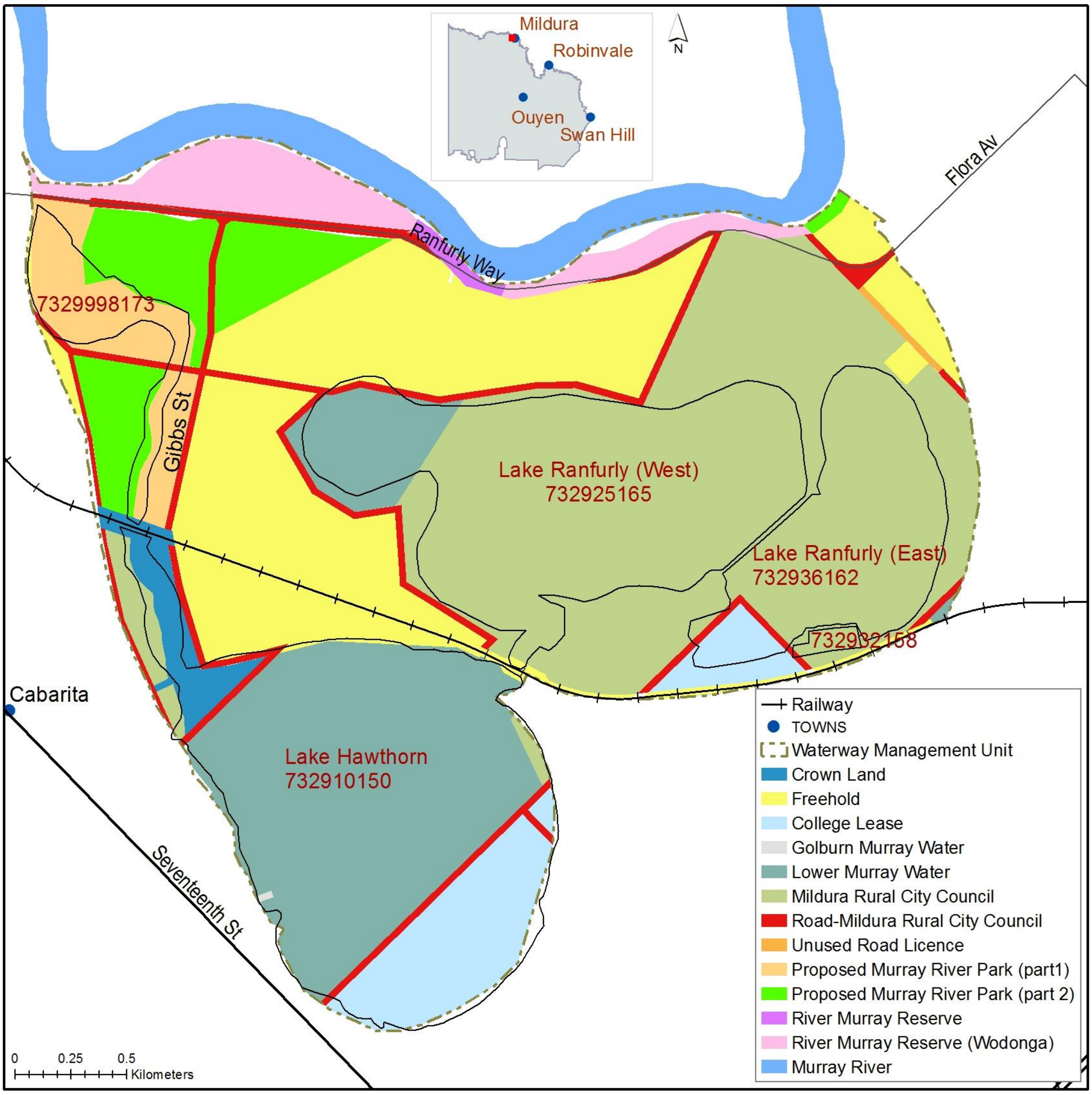


Figure 7. Land Status Map

Table 1. Stakeholders for Lake Hawthorn and Lake Ranfurly

Stakeholder	Responsibilities
Parks Victoria	Land Manager. Parks Victoria is responsible for Conserving Victoria's Special Places with the aim to ensure that our valued parks, and the natural assets and cultural heritage they hold, can be enjoyed now and by future generations. A section of the land adjacent to the Murray River is managed by Parks Victoria as part of the Murray River Park (VEAC 2008b), and the area surrounding Wetland 7329 998173 is under the implied management of Parks Victoria.
Mallee CMA	The Mallee CMA's responsibility is to ensure that natural resources in the region are managed in an integrated and ecologically sustainable way, including the regional environmental management of Lake Hawthorn & Lake Ranfurly. The Mallee CMA is the Environmental Water Manager.
Department of Environment, Land, Water and Planning	DELWP is responsible for state level environmental water management planning, land manager and threatened species manager
Goulburn-Murray Water	Goulburn-Murray Water operates the Lake Hawthorn Drainage Diversion Scheme and the Mildura-Merbein Salt Interception Scheme which borders Lake Hawthorn to the east.
Lower Murray Water	Most of the land occupied by Lake Hawthorn is freehold, with a drainage overlay. Lower Murray Water is responsible for disposal of irrigation drainage from the former First Mildura Irrigation Trust area, and from the Merbein Irrigation District. Lower Murray Water continues implementation and development of its Environmental Management System. Lower Murray Water is responsible for managing recreational access to the lake (Lumb 2015).
Department of Education	Land owner of the College Lease areas (blocks of private land in the south of Lake Hawthorn and Lake Ranfurly (Figure 6))
Mildura Rural City Council	Mildura Rural City Council is the Local Government agency. Council is Committee of Management for some areas, and provides assistance in planning and implementation of programs. Council also provides a conduit for community feedback, guides urban stormwater drainage management, and is responsible for managing road reserves within the WMU sub-unit. Council manages recreational infrastructure.
Vic Roads	Roads under Vic Roads management pass through the area.
Vic Rail	A railway line passes through the area.
Aboriginal Communities	Indigenous Representation
Cabarita Inc	Landcare Group, provides assistance in planning and implementation of programs
Local Landholders & Residents	Land users, provide assistance in planning and implementation of programs
Birdlife Mildura	Bird observer group, land user

2.6 Wetland Characteristics

A brief overview of the main characteristics of wetlands at Hawthorn/Ranfurly is provided in Table 2 and wetland types are shown in Figure 8.

Table 2. Wetland characteristics at Hawthorn/Ranfurly

Characteristics	Description
Name	Lake Hawthorn and Lake Ranfurly sub-unit of the Merbein Waterway Management Unit
Individual wetlands within Lake Hawthorn & Lake Ranfurly WMU Sub- Unit (numbers follow Corrick numbering system in Wetlands 1994 layer)	Unnamed wetland #7329 998173 Lake Hawthorn #7329 10150 Lake Ranfurly West # 7329 25165 Lake Ranfurly East #7329 36162 Sewerage Treatment Ponds #7329 32158
Area	Total area of whole WMU Sub-unit 1034 ha Total of all wetlands 510 ha • Wetland #7329 998173 (27 ha) • Lake Hawthorn (228 ha) • Lake Ranfurly West (169 ha) • Lake Ranfurly East (83 ha) • Sewerage Treatment Ponds (2.7 ha)
Bioregion	Murray Scroll Belt
Conservation status of EVCs	Vulnerable (Lakes Hawthorn & Ranfurly), Depleted (Wetland #7329 998173)
Land status	Public Land (variety of tenures and purposes), Regional Park
Land manager	Lower Murray Water, Mildura Rural City Council, Goulburn-Murray Water, Parks Victoria
Surrounding land use	Urban, irrigated and non-irrigated cropping
Water supply	Irrigation drainage water from Merbein, Mildura and Irymple districts, urban stormwater, Murray River high flows, groundwater inflows from regional and perched water tables.
1788 wetland category	Lake Hawthorn, Lake Ranfurly (west), Lake Ranfurly (east) - Permanent Open Freshwater, #7329 996173 Deep Freshwater Marsh
1994 wetland category and sub- category	Lake Hawthorn, Lake Ranfurly (west), Lake Ranfurly (east) - Semi-permanent Saline, #7329 996173 - Deep Freshwater Marsh
Wetland depth at capacity	Lake Hawthorn 1.92 m / Lake Ranfurly <1.5 m

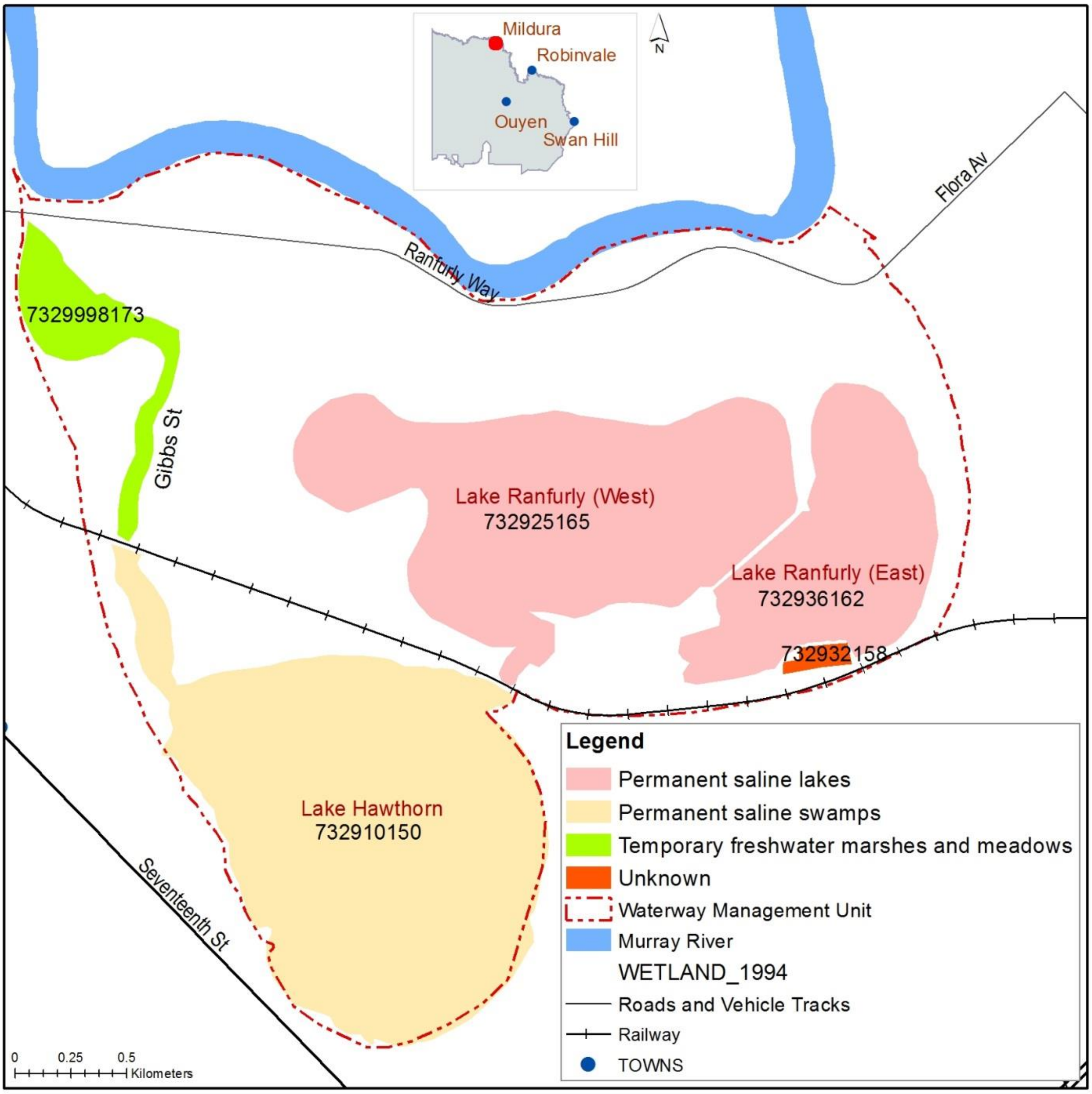


Figure 8. Hawthorn/Ranfurly Wetlands

2.7 Management Scale

The whole 1034 ha has a water requirement as a floodplain complex (Mallee CMA, 2014), but the focus for this plan is restricted to a target area of approximately 148 ha. The target area is part of Lake Hawthorn in which environmental water is able to be managed efficiently.

Lake Ranfurly (East and West) has been excluded from the target area. The primary use of Lake Ranfurly is as an evaporation basin for the Mildura-Merbein Salt Interception Scheme (see section 2.8) and delivery of environmental water to this site may impact on this use.

Wetland #7329 998173 has been excluded from the target area as the health of this wetland and surrounds appears to be sound and does not require management intervention.

The proposed watering regime will require delivery of environmental water to Lake Hawthorn via existing irrigation infrastructure to maintain a minimum water level (see section 0). This phase will provide wetlands that function as habitat for a diverse range of waterbirds, whilst leaving sufficient filling area for storm water events, and capture of irrigation drainage.

2.8 Related Agreements, Policy, Plans and Activities

Hawthorn/Ranfurly is situated on the Victorian floodplain of the Murray River which is the subject of investigation for many purposes. These include Salinity Management Plans, flow studies and Land Conservation Council Reviews. In 2008 an investigation into River Red Gum Health by the Victorian Environmental Assessment Council (VEAC 2008b) resulted in a section of Lake Hawthorn and Lake Ranfurly close to the Murray River being changed from Recreation and Drainage land status to Murray River Park in 2010.

Hawthorn/Ranfurly is within an area covered by the Regional Riparian Action Plan (DEWLP 2015A) and has the potential to attract future funding and works through that plan, which incorporates a range of actions to enhance the riparian habitat of Mallee waterways.

Lake Hawthorn is used as a disposal basin for urban stormwater by Mildura Rural City Council, and irrigation drainage by Lower Murray Water. Mildura Rural City Council prepared the *Lake Hawthorn Management Plan* in 2016 intended to guide future management of the area, consider the diverse range of issues associated with the site and its ongoing use as an irrigation drainage and urban stormwater disposal basin.

The Mildura-Merbein Salt Interception Scheme was established in 1979 to intercept highly saline groundwater which would otherwise enter the Murray River. This scheme is managed by Goulburn-Murray Water (Sunraysia Drainage Coordination Group 2005), and is operated intermittently. Groundwater is discharged to Lake Ranfurly as part of the scheme, with excess going to Wargan Basins.

The Lake Hawthorn Drainage Diversion Scheme was set up in 1968 to allow disposal of saline drainage water to Wargan Basins and reduce the likelihood of the lake becoming overfull and water being released to the Murray River. This scheme is also operated by Goulburn-Murray Water and is run in accordance with the Lake Hawthorn Operating Rules (Appendix 1). Under these rules, releases from Lake Hawthorn to the Murray River are allowed to occur under the following conditions:

- Murray River flow exceeds 15,000 ML/d at Mildura;
- Murray River salinity at Merbein is below 420 EC;
- The increment in Murray River salinity, downstream of the Murray-Darling junction, caused by releases from Lake Hawthorn does not exceed 20 EC;
- No adverse effect is caused to the operation of Lake Victoria (SKM 2003).

The *Management Plan for the Improvement of Urban Stormwater Quality for Mildura Rural City Council* was compiled in 2001 by SKM. This plan involves both Lake Hawthorn and Ranfurly, along with other sites, and identifies the values of these sites and the threats to them from stormwater.

The Sunraysia Drainage Coordination Group developed the *Draft Opportunities for Environmental, Social and Economic Benefits through Management of Lake Hawthorn, Lake Ranfurly and Bob Corbould Wetland* in 2005. This document was developed to identify opportunities to progress corporate and regional goals through management of the lakes (Sunraysia Drainage Co-ordination Group, 2005).

The *Lake Hawthorn Habitat Management Plan (*Lloyd Environmental 2007) aimed to identify and address current and potential threats to Murray Hardyhead and other flora and fauna and to inform future management and operations at Lake Hawthorn.

Lake Hawthorn is one of a number of sites in the Mallee region to undergo a *Preliminary Salinity Impact Assessment* (CDM Smith 2015) to ascertain the likely downstream impacts of environmental watering. The Basin Salinity Management Strategy records and tracks salinity credits and debits, defined as significant if the average EC at Morgan is altered by 0.1 EC or more within 30 years.

Additional information on regional agreements, policies, plans and activities can be found in the *Context Document for Environmental Water Management Plans, Mallee CMA Region* (Sunraysia Environmental 2014).

Figure 9. A picnic area on the north western shore of Lake Hawthorn.

3.0 Hydrology and System Operations

3.1 Lake Morphology

Lake Hawthorn has a shallow saucer shape where the majority of the bed lies near 33 m AHD, with the lowest point measured at 32.7 m AHD (Figure 10). The edges rise relatively steeply to 35.5 m AHD, particularly on the western side. Higher levels cause flooding of property adjoining the lake (SKM 2013). At 35.5 m AHD the volume of the lake is 4,802 ML and the surface area is 224 ha (SKM 2013).

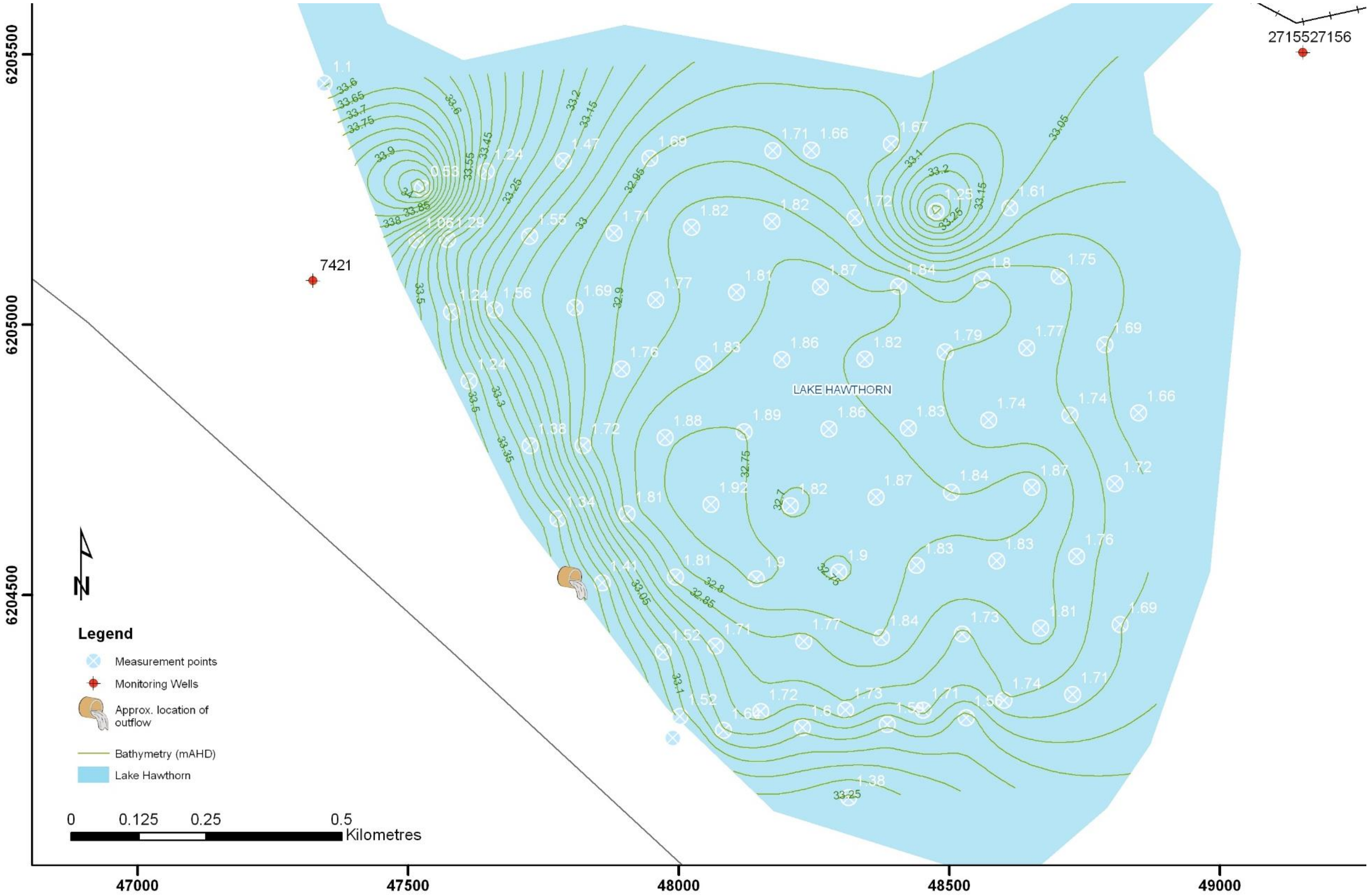


Figure 10. Lake Hawthorn Bathymetry (January 2007) (Lloyd 2007, p.12)

3.2 Water management and delivery

Wetland hydrology is a key influence on 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 (DEPI 2005). A wetland's hydrology is determined by 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 and rivers.

3.2.1 Pre-regulation (Natural Conditions)

Prior to river regulation and levee bank construction, Lake Hawthorn and Lake Ranfurly were inundated under Murray River flows above approximately 50,000 ML/day (Ecological Associates 2015, p.3), and would have retained water for a period of time after river levels fell, and potentially also experienced drying phases. Natural flows were strongly seasonal with daily discharges highest in spring and lowest in autumn (Figure 11) (Ecological Associates 2007b).

3.2.2 Post-regulation

In this part of the Murray River, the frequency, duration and magnitude of all but the largest floods have been reduced due to effects of major storages in the Murray River and its tributaries (Thoms et al, 2000, p 106). Although Euston Weir is a significant distance upstream from Hawthorn/Ranfurly there are no major tributaries or losses from the River Murray in the study area and the hydrology for this reach of the Murray River can be broadly described in terms of the flow passing Euston Weir (Ecological Associates 2007b).

Regulation of the Murray River has decreased the volume of water flowing through Euston Weir. The construction of levees at Hawthorn/Ranfurly has increased the commence to flow (CTF) rate at Lake Hawthorn to an estimated 86,000 (ML/day) (Gippel, cited in Ecological Associates 2015, p.3). Lake Hawthorn now primarily receives inflows from stormwater and irrigation drainage however all sources of inflow are impacted by extended dry conditions. Figure 13 (page 27) provides an indication of the level of various hydrological components at Lake Hawthorn, highlighting the increased flow needed to connect via the Murray River.

A spells analysis undertaken by Gippel (2014) was consulted to better understand the frequency of flood inundation of Lake Hawthorn under post-regulation conditions (Figure 12). The percentage of years with the threshold event 50,000 ML/d pre-regulation to 90,000 ML/day post-regulation (baseline) have significantly reduced (from 75 per cent to 12 per cent of years). The interval between events has also increased (almost fourfold). This is shown in Table 3.

The seasonal distribution of flows in this section of the Murray River show that, despite a reduction in discharge, the river retains the same annual pattern of higher flows in Winter and Spring with lower flows in Summer and Autumn (Figure 11).

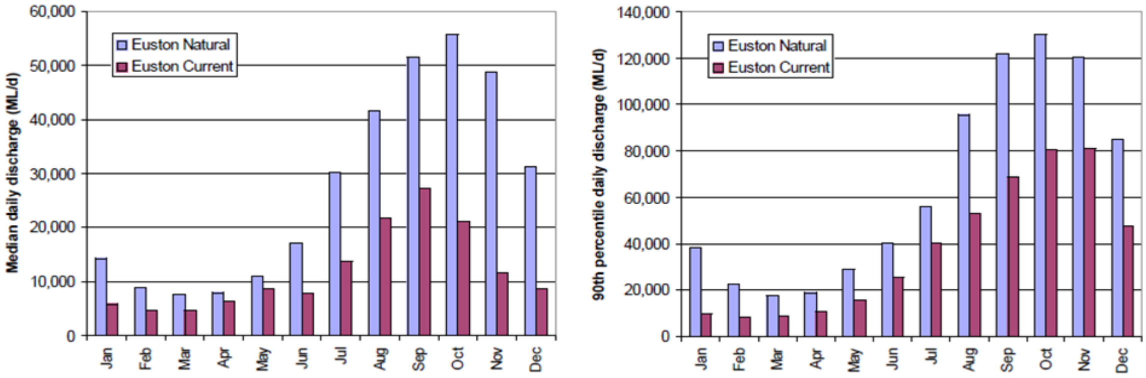
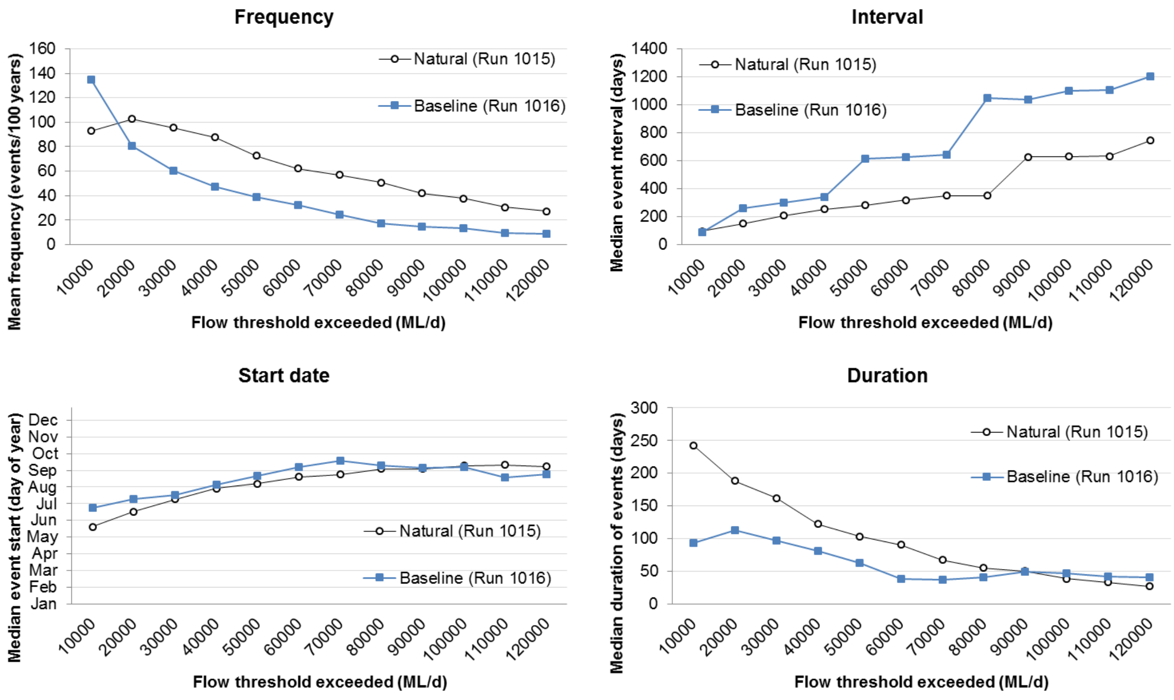


Figure 11. Distribution of median flows and 90th percentile flows for each month in the River Murray at Euston for natural and current (benchmark) conditions. Source: derived from MDBC MSM-Bigmod 109-year data (Ecological Associates, 2007b)



3.2.3

Figure 12. Comparison of Natural and Baseline Modelled Flow Scenarios for Euston Downstream (Gippel, 2014)

Table 3. Modelled natural and baseline flows for flow thresholds of 50,000 to 90,000 ML/d downstream of Euston

Natural (N)/ Baseline (B)	Threshold ML/d	Frequency Mean (/10yrs)	Median Interval (50% of events are less than)	Median Duration (50% of events are shorter than)	Median Event Start date	Percentage of years with Event
N	50,000	7.28	283	103	12th Aug	75%
B	50,000	6.86	612	62	26th Aug	37%
N	90,000	4.21.	626	50	8th Sept	38%
B	90,000	1.49	1039	50	10th Sept	12%

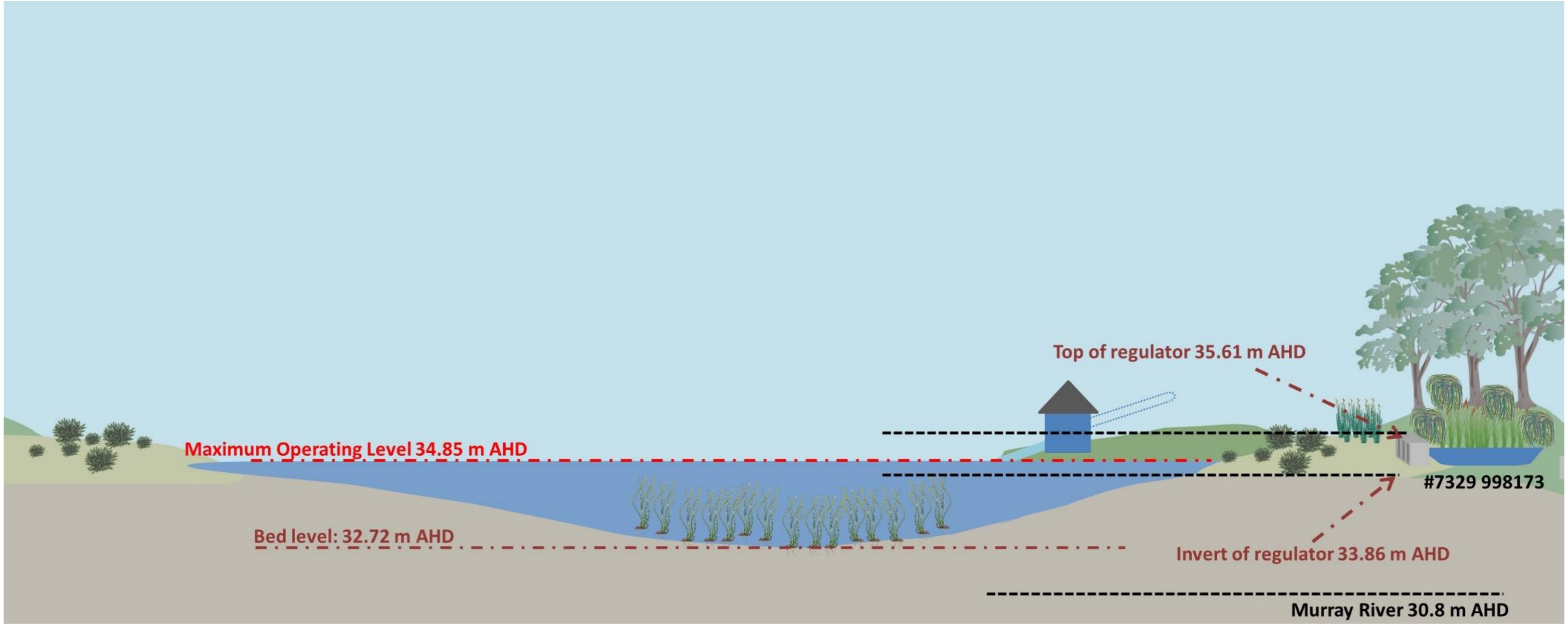


Figure 13. Height datum for relevant components at Lake Hawthorn (not to scale)

3.2.4 Irrigation and drainage impact on hydrology within the target area

Levee banks now restrict flooding from the Murray River to Lake Hawthorn; however, Lake Hawthorn can receive inflows from other sources (described below), and can connect with Lake Ranfurly at high water levels (Ecological Associates 2007b). There are regulators in place under the railway line between Lake Hawthorn and Lake Ranfurly and on the channel that connects Lake Hawthorn and wetland #7329 998173 to the Murray River.

Commissioned in 1968, Goulburn Murray Water has pumps in place at Lake Hawthorn to enable pumping to Wargan Basins when the lake levels reach 34.85 m AHD as part of the Lake Hawthorn Drainage Diversion Scheme (Lloyd Environmental 2007).

As this environmental watering proposal is not inundating Lake Hawthorn to a level above 34.85 m AHD subsequently triggering Goulburn-Murray Water to pump excess water to the Wargan Basins, this proposal would not be accountable under the operating rules (Appendix 1).

Lloyd Environmental (2007) states that Lake Hawthorn receives water (and salt) from:

- Irrigation subsurface drainage water from the Merbein, Mildura and Irymple districts as part of Lower Murray Water's sub-surface drainage scheme;
- Irrigation drainage water directly from individual irrigated properties;
- Runoff from surrounding urban areas;
- Inflows from the Murray River under high flows;
- Rainfall; and
- Groundwater inflows from regional and perched watertables.

Historically, Lake Hawthorn received inflows from Lake Ranfurly through a regulator, however Lake Ranfurly is hypersaline, and this option is no longer used. Water has been allowed to flow from Lake Hawthorn into Lake Ranfurly to provide temporary storage of drainage water during periods of elevated water levels (Lloyd Environmental 2007).

Water outflows from Lake Hawthorn include:

- Pumping to Wargan Evaporation Basin;
- Evaporation;
- Controlled release to the Murray River under high river flows (>15,000 ML/d);
- Seepage to groundwater.

Figure 14 shows the flow relationships of the irrigation and stormwater drainage systems affecting Hawthorn/Ranfurly.

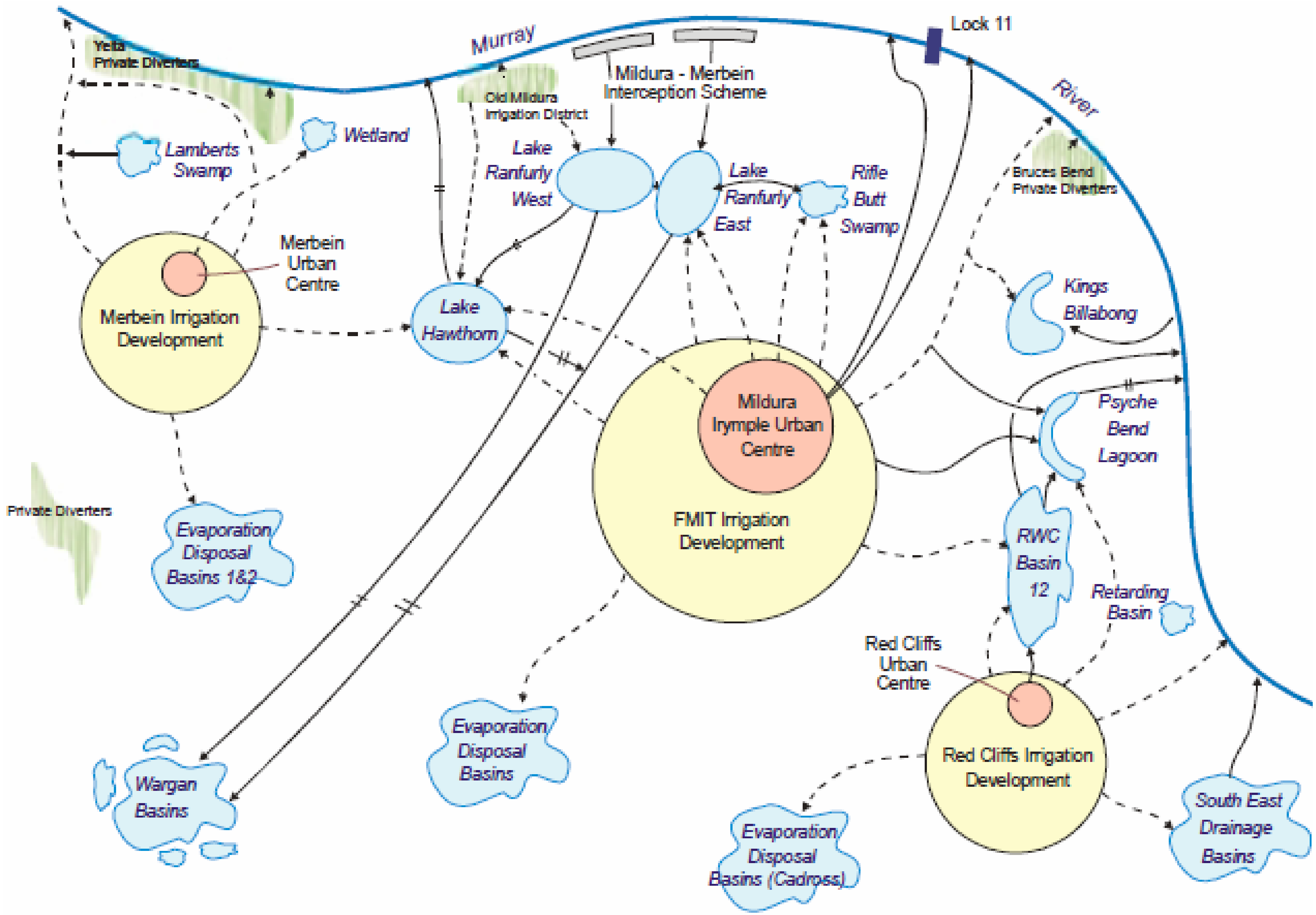


Figure 14. Schematic of the irrigation drainage system (SKM 2002)

Since the 1940's, water levels in Lake Hawthorn have been managed, and fluctuations of over 1 m annually are known to occur (from 34.36 to 35.8 m AHD) (Lloyd 2007). However, water levels have tended to be more stable since 2000, remaining between 34.5 and 35 m AHD. This is in part due to reduced irrigation drainage to the lake as irrigation techniques have improved. It is estimated that irrigation drainage volumes received by Lake Hawthorn have reduced from approximately 10,140 ML/year in 1988 to approximately 2,640 ML/year or less (Lumb 2015, p.10). Additionally, the millennium drought affected water levels from all inflow sources to Lake Hawthorn and the lake was essentially dry from 2008 to 2010 (Ellis 2013). A significant rise in salinity levels coincided with the reduced water levels in the lake, with a maximum salinity reading of 68,000 EC recorded in March 2008 (AWE 2014). Prior to that the EC levels averaged 4,400 EC between 1998 and 2000.

Areas surrounding the Mildura township have been developed in recent years, expanding the road network and residential housing zone. Stormwater from several newly developed areas is diverted to the Mildura South stormwater drainage wetlands, which in turn outfalls to Lake Hawthorn. The residential stormwater catchment area currently totals 618 ha (Lumb 2015, p.10).

3.2.5 Environmental watering

Lake Hawthorn received an initial delivery of 350 ML of environmental water in 2005 covering an approximate surface area of 200 ha. This environmental allocation was focused on sustaining the Murray Hardyhead population in the lake. Some of the population was translocated from Lake Hawthorn to Lake Koorlong as salinity levels could not be maintained within the tolerable range for Murray Hardyhead at Lake Hawthorn. Subsequent drying of Lake Hawthorn in 2008 resulted in the extirpation of all resident fish including Murray Hardyhead (Ellis 2013).

Since that time water delivery has recommenced in 2016 and continued almost annually to support habitat for a wide range of migratory shorebirds, waders and other waterbird species that are frequently observed at the lake. A citizen science bird monitoring program has now been established at the site to better capture this data throughout the year.

Table 3a - A summary of environmental watering at Lake Hawthorn

Water year	Time of inflow	Environmental Water Source	Total volume (ML)	Area (ha) inundated
2005	Summer-Autumn	Unknown	350	200
10-11	Spring	Natural flows	n/a	n/a
2016	Autumn-Winter	VEWH	460	148
16-17	Spring	Natural flows	n/a	n/a
2018	Autumn-Winter	VEWH	800	n/a
18-19	Spring-Autumn	VEWH	1498	148
19-20	Spring-Autumn	VEWH	tbc	148

4.0 Water Dependent Values

4.1 Environmental Values

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

4.1.1 Listings and Significance

Fauna

A list of native species recorded in the area was obtained by a recent search of the Victorian Biodiversity Atlas, Appendix 2. This list was supplemented by records collected over 16 years of bird surveys conducted by a dedicated local Citizen Scientist. Of special interest and responsibility are the water dependent species listed in legislation, agreements or conventions shown in Table 4 (over page). Lake Ranfurly has been the subject of many surveys. Listed species recorded at Lake Ranfurly are shown in Table 5. These species may also find suitable habitat at Lake Hawthorn.

These species are considered water-dependent because they forage or nest in or over water, or require flooding to trigger breeding and fledging. The list also includes the Carpet Python (*Morelia spilota metcalfei*), Dwarf Burrowing Skink (*Lerista timida)* and the Hooded Scaly-foot (*Pygopus schraderi)* that are indirectly dependent on water as they live within floodplain woodlands and benefit from vegetation cover and fallen timber.

Table 4. Listed fauna recorded at Lake Hawthorn

Common Name	Scientific Name	Type	International Agreements	EPBC Status	FFG Status	DEPI Status	Records
Australasian Shoveler	*Anas rhynchotis*	F	NL	NL	NL	V	42
Intermediate Egret	*Ardea intermedia*	B	NL	NL	L	EN	1
Eastern Great Egret	*Ardea modesta*	B	C, J	NL	L	V	13
Hardhead	*Aythya australis*	B	NL	NL	NL	V	25
Musk Duck	*Biziura lobata*	B	NL	NL	NL	V	1
Red-necked Stint	*Calidris ruficollis*	B	C, J	NL	NL	NL	50
Whiskered Tern	*Chlidonias hybridus javanicus*	B	NL	NL	NL	NL	12
Murray Hardyhead	*Craterocephalus fluviatilis*	F	NL	L	L	CR	4
Unspecked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	F	NL	NL	L	NL	1
Little Egret	*Egretta garzetta nigripes*	B	NL	NL	L	EN	6
Flat-headed Galaxias	*Galaxias rostratus*	F	NL	NL	L	V	2
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	C	NL	L	V	3
Caspian Tern	*Hydroprogne caspia*	B	C, J	NL	L	NT	48
Dwarf Burrowing Skink*	*Lerista timida*	R	NL	NL	L	EN	3
Golden Perch	*Macquaria ambigua*	F	NL	NL	L	NT	9
Carpet Python*	*Morelia spilota metcalfei*	R	NL	NL	L	EN	5
Rufous Night Heron	*Nycticorax caledonicus*	B	NL	NL	NL	NT	1
Pied Cormorant	*Phalacrocorax varius*	B	NL	NL	NL	NT	7
Royal Spoonbill	*Platalea regia*	B	NL	NL	NL	V	2
Glossy Ibis	*Plegadis falcinellus*	B	Bo	NL	NL	NT	1
Baillon's Crake	*Porzana pusilla palustris*	B	NL	NL	L	V	2
Freshwater Catfish	*Tandanus tandanus*	F	NL	NL	L	EN	
Common Greenshank	*Tringa nebularia*	B	C, J, R, Bo	NL	NL	V	8

Legend
Type: Reptile, Bird, Fish
EPBC status: Listed, Not Listed
International Bird Agreements: China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement, Bonn Convention, Not Listed
FFG status: Listed as threatened, Not Listed
DELWP status: CRitically Endangered, ENdangered, Vulnerable, Near Threatened, Not Listed

Table 5. Listed fauna recorded at Lake Ranfurly

Common Name	Scientific Name	Type	International Agreements	EPBC Status	FFG Status	DELWP Status	Records
Common Sandpiper	*Actitis hypoleucos*	B	C, J, R, Bo	NL	NL	V	1
Australasian Shoveler	*Anas rhynchotis*	B	NL	NL	NL	V	42
Eastern Great Egret	*Ardea modesta*	B	C, J	NL	L	V	13
Ruddy Turnstone	*Arenaria interpres*	B	C, J, R, Bo	NL	NL	V	6
Hardhead	*Aythya australis*	B	NL	NL	NL	V	25
Red Knot	*Calidris canutus*	B	C, J, R, Bo	NL	NL	EN	1
Sharp-tailed Sandpiper	*Calidris acuminata*	B	C, J, R, Bo	NL	NL	NL	
Curlew Sandpiper	*Calidris ferruginea*	B	C, J, R, Bo	L	NL	EN	8
Great Knot	*Calidris tenuirostris*	B	C, J, R, Bo	NL	L	EN	3
Whiskered Tern	*Chlidonias hybridus javanicus*	B	NL	NL	NL	NT	12
Little Egret	*Egretta garzetta nigripes*	B	NL	NL	L	EN	6
Gull-billed Tern	*Gelochelidon nilotica macrotarsa*	B	NL	NL	NL	EN	3
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	C	NL	L	V	3
Caspian Tern	*Hydropogne caspia*	B	C, J	NL	L	NT	48
Bar-tailed Godwit	*Limosa lapponica*	B	C, J, R, Bo	NL	NL	NL	2
Black-tailed Godwit	*Limosa limosa*	B	C, J, R, Bo	NL	NL	V	2
Carpet Python	*Morelia spilota metcalfei*	R	NL	NL	L	EN	5
Blue-billed Duck	*Oxyura australis*	B	NL	NL	L	EN	3
Pied Cormorant	*Phalacrocorax varius*	B	NL	NL	NL	NT	7
Royal Spoonbill	*Platalea regia*	B	NL	NL	NL	NT	2
Glossy Ibis	*Plegadis falcinellus*	B	C, Bo	NL	NL	NT	2
Baillon's Crake	*Porzana pusilla palustris*	B	NL	NL	L	V	2
Hooded Scaly Foot*	*Pygopus schraderi*	R	NL	NL	L	CR	
Caspian Tern	*Sterna caspia*	B	NL	NL	L	NT	48
Freckled Duck	*Stictonetta naevosa*	B	NL	NL	L	EN	3
Marsh Sandpiper	*Tringa stagnatilis*	B	C, J, R, Bo	NL	NL	V	17
Long-toed Stint	*Calidris subminuta*	B	C, J, R, Bo	L	NL	NT	
Pacific Golden Plover	*Pluvialis fulva*	B	C, J, R, Bo	L	NL	V	

Legend
Type: Reptile, Bird, Fish
EPBC status: Listed, Not Listed
International Bird Agreements: China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement, Bonn Convention, Not Listed

mallee catchment management authority

FFG status: Listed as threatened, Not Listed
DELWP status: CRitically Endangered, ENdangered, Vulnerable, Near Threatened, Not Listed

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

Migratory shorebirds

Australia provides coastal and freshwater wetland habitat for shorebirds that migrate annually from their northern hemisphere breeding grounds to non-breeding grounds in the southern hemisphere (Department of the Environment 2015). During the non-breeding season (August – April) migratory shorebirds rest and feed, building their body mass by up to 70% to enable the northward breeding migration, via the East-Asian-Australian Flyway. Northern hemisphere breeding grounds include Siberia, Russia and Alaska (Department of the Environment 2015). For some species, such as the Sharp-tailed Sandpiper (*Calidris acuminata*) and the Bar-tailed Godwit (*Limosa lapponica*), up to 88% of the global population spends the non-breeding season in Australia.

Lake Hawthorn and Lake Ranfurly are well known for their ability to support a large range of waterbirds. Of particular significance are EPBC listed migratory species recorded. In addition to the Red-necked Stint (Figure 15), ten other EPBC listed, northern hemisphere breeding migratory birds have been recorded at Hawthorn and Ranfurly. These species are among 35 species included in the *Wildlife Conservation Plan for Migratory Shorebirds* (Department of the Environment 2015).

As detailed in Table 6, this series of waders prefer the specific foraging and loafing habitat that is found at Lake Hawthorn and Lake Ranfurly. Furthermore, many of these species are known to flock together (Department of the Environment 2016) and 'beater' species, which stir up the substrate during foraging, and enhance prey opportunity, can encourage 'follower' species to also visit an area (Whelan, Wenny & Marquis, 2008).

(photo: Matthew Studebaker)

Red-necked Stint
(*Calidris ruficollis*)

Migration Cycle

The smallest migrating wader (Parker 2000), the Red-necked Stint breeds in north-eastern Siberia and western Alaska, arriving in Australia from late August and departing for the Artic once more in March-April (Birds in Backyards 2016). More than 80% of the global population of Red-necked Stint migrates to Australia in the non-breeding season. Some juveniles are known to overwinter within Australia (Department of the Environment 2016)

Habitat

The Red-necked Stint forages on bare wet mudflats and very shallow water. It will forage on samphire and have been known to feed among algal mats (Department of the Environment 2016). An omnivorous wader, it is known to feed on small vertebrates, insects, molluscs, gastropods, crustaceans, seeds and saltmarsh plants. This waterbird feeds by jabbing and probing its bill on mudflats, and by gleaning from vegetation growing in saltmarsh and water. The Red-necked Stint is known to roost on sheltered beaches, among saltmarsh.

Threats

Loss of important habitat including foraging and roosting sites such as is found within Hawthorn/Ranfurly can impact the bird's capacity to build up energy stores for the northern migration and breeding season.

Drought and reduced inundation extent and frequency at Lake Hawthorn may severely impact this species through reducing available forage sites and/or reducing the potential of overwintering for juveniles at this site.

Figure 15. The Red-necked Stint

Wetlands like Lake Hawthorn provide links in the flyways of these internationally important species. Juveniles of many of these species are known to overwinter within Australia, and this site may provide an important inland habitat niche. The Red-necked Stint (*Calidris ruficollis*) and vulnerable Common Greenshank (*Tringa nebularia*) are listed species recorded in the Victorian Biodiversity Atlas for Lake Hawthorn (Table 5). A citizen scientist has provided an extensive dataset of bird sightings spanning sixteen years of observations at Lake Hawthorn. Additional species recorded at Lake Hawthorn by this observer include the Sharp-tailed Sandpiper (*Calidris acuminata*), Bar-tailed Godwit (*Limosa lapponica*), and the vulnerable Marsh Sandpiper (*Tringa stagnatilis*). The remaining species, including the critically endangered Curlew Sandpiper (*Calidris ferruginea*) have been recorded at Ranfurly, and may opportunistically utilise habitat at Lake Hawthorn.

Table 6 Migratory Species recorded at Lake Hawthorn & Lake Ranfurly

Species Name	Common Name	Image	Food Resource	Foraging Habitat	Migration Pattern	
					Southward (Arrival in Australia)	Northward (Departure from Australia)
Common Sandpiper	*Actitis hypoleucos*		Insects, crustaceans, molluscs	0-1 cm: Shallow water, bare soft mud	July-November	Feb-May
Ruddy Turnstone	*Arenaria interpres*		Insects, worms, crustaceans, molluscs, and spiders	0-2 cm: Mudflats, saltmarsh, water depth to 3 cm	August	March-April
Sharp-tailed Sandpiper	*Calidris acuminata*		Worms, crustaceans, molluscs, insects, seeds of *Ruppia* spp.	0-12 cm: Shallow water, bare wet mud & sand, inundated vegetation	August	March-April
Red Knot	*Calidris canutus*		Worms, bivalves, gastropods, crustaceans and echinoderms, occasionally vegetation	0-12 cm: Shallow water, mud flats, sand flats	Late August	March-April
Curlew Sandpiper	*Calidris ferruginea*		Worms, molluscs, crustaceans, insects, *Ruppia* spp. seeds	0-3 cm: In water near the shore, bare wet mud	Late August	March-April
Great Knot	*Calidris tenuirostris*		Bivalve molluscs, snails, worms, crustaceans	0-12 cm: Shallow water, mud flats, sand flats	Late August	March-April
Bar-tailed Godwit#	*Limosa lapponica*		Worms, molluscs, crustaceans, insects, plant material	0-7 cm: Shallow water, exposed sand, soft mud, beds of seagrass	Late August	Feb-April
Black-tailed Godwit#	*Limosa limosa*		Annelids, crustaceans, arachnids, fish eggs and spawn and tadpoles of frogs, occasionally seeds	5-10 cm: Shallow water, open soft muddy areas	Late August	March-April
Common Greenshank	*Tringa nebularia*		Molluscs, crustaceans, insects, occasionally fish and frogs	1-7 cm: Shallow water, wetland edge, soft mud	August	March-April

Marsh Sandpiper	*Tringa stagnatilis*		Insects, molluscs, crustaceans	1-7 cm: Shallow water	September	March-April

(Department of the Environment 2016) Images Source: Birdlife Australia 2016 #Images Source: Trepte 2014
Foraging depths: Ntiamoa-Baidu et al 1998; Helmers cited in Plauny 2000)

Other Waterbirds

Australia's waterbirds are often nomadic and take advantage of highly variable, and often temporary, aquatic resources. The distribution of temporary habitat patches throughout the landscape may facilitate movement and exploitation of available resources for waterbirds (Roshier et al. 2001). The provision of environmental water to wetlands is one method of creating such habitat patches for waterbirds, allowing them to move between suitable habitat to survive and reproduce (MDBA 2009).

In total, sixty species of waterbirds are recorded on the species list at Hawthorn/Ranfurly (Appendix 2), many of which are listed in various Acts and Conventions (Table 4 & Table 5). Whilst outside, the target area it should be noted that Lake Ranfurly is listed in the Directory of Important Wetlands in Australia due to the high number and diversity of waterbirds recorded (Department of the Environment 2010). Both Lakes have supported high numbers and a diverse range of species in the past, with Bluml (1992) stating that Lake Ranfurly regularly supported 10,000 – 15,000 waterbirds at a time. All of the listed water dependent species that have been recorded at Ranfurly (Table 5), but for which no records exist at Hawthorn, are birds. Thus, it is very likely that these species would readily move to Lake Hawthorn should water be delivered to Hawthorn only. One recorded example is the Red-necked Avocet (*Recurvirostra novaehollandiae*), which is a resident nomadic wader, known to visit, forage and feed at inland saltwater lakes (Atlas of Living Australia, n.d.). This is one of two species for which Lake Ranfurly was noted as an Area of International and National Importance for Shorebirds (Watkins 1993). It has been recorded regularly at both Lake Ranfurly and Lake Hawthorn, supporting the hypothesis that the waders guild will value the shallow water habitat provided by environmental water delivery to Lake Hawthorn.

The woodland habitat surrounding wetland #7329 998173 contains diverse vegetation and is likely to provide suitable habitat for a range of bird species (ECOS 2001, cited in SKM 2001). The vegetation in this area includes extensive Lignum Swampy Woodland which may provide important breeding habitat for many waterbirds species including the Musk Duck, Freckled Duck, Blue-billed Duck and Hardhead (Rogers and Ralph 2011).

Hooded Scaly-foot

The Hooded Scaly-foot, is a legless lizard that is critically endangered in Victoria (DSE 2013). The population of this species found at Lake Ranfurly is one of only six known populations in Victoria. Little is known about the ecology, habitat requirements or home range of this species although it appears to depend upon the burrows of large invertebrates for shelter and feeds on spiders and scorpions (Robertson & Canessa 2012). The number of Hooded Scaly-foot individuals recorded at Lake Ranfurly during monitoring efforts has declined significantly from 15 in 2002/2003, to five individuals recorded between 2006 and 2008 (Robertson & Sluiter 2010), and only one in surveys of 2012-2013 (Robertson 2013). Although this species is not directly dependent on water, it does require vegetation cover and woody debris (MCMA 2011A), making it indirectly dependent on water. As it is a species of high conservation significance and the Lake Ranfurly population appears to be in decline, it should be considered as part of any works, including environmental watering, at Hawthorn/Ranfurly.

Vegetation Communities

Within the bed of Lake Hawthorn, the Ecological Vegetation Class (EVC) mapped is Lake Bed Herbland (Figure 16). For a full list of EVCs present at Hawthorn/Ranfurly and details on each see Appendix 3.

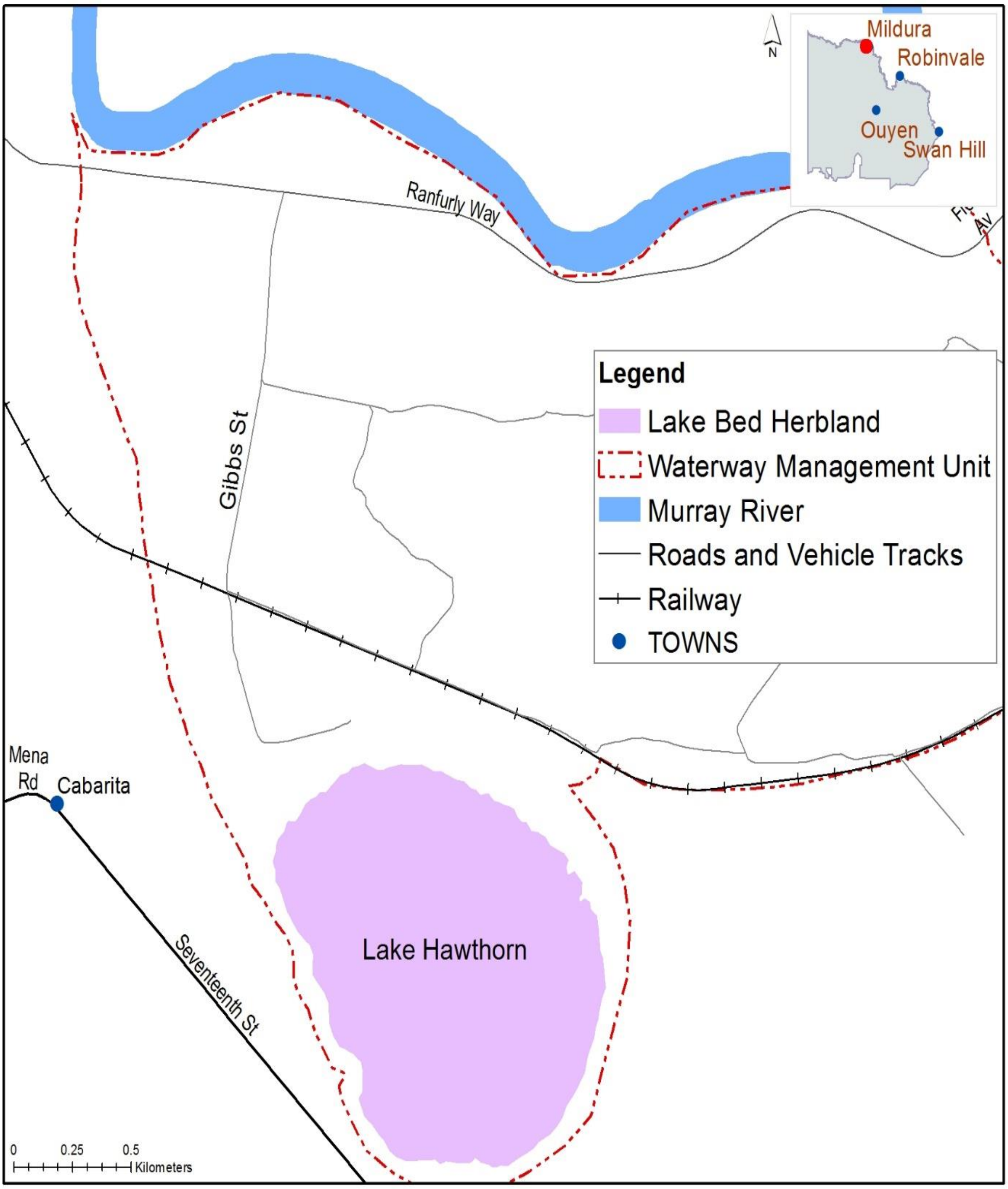


Figure 16. Ecological Vegetation Classes (EVCs) at Hawthorn/Ranfurly

Lake Bed Herbland is mapped across the wetland bed of Lake Hawthorn, with approximately 148 ha of this EVC within the target area. This EVC is considered to be vulnerable in the Murray Scroll Belt Bioregion and is defined as herbland dominated by species which are adapted to drying mud. This EVC is usually found in less saline lakes of the north-west of Victoria (DSE 2009). Lake Hawthorn supports a modified, saline Lake Bed Herbland community. Lake Bed Herbland prefers a variable flooding regime with a critical interval of 2-5 years (also variable) between events and ponding of 6-36 months (VEAC 2008a).

The bed of Lake Hawthorn has in the past supported benthic herblands. These herblands consist of beds of aquatic plants, in particular at Lake Hawthorn, *Ruppia* spp., and benefit from constant inundation with fluctuations in water level, preferably an increase in level in August/September, and lower level in December/January (Ellis 2013). Lake Hawthorn has exhibited the capacity for these herblands to become re-established after drying (Ellis 2013).

Lignum Swampy Woodland surrounds wetland # 7329 998173 and is found in patches around Lake Hawthorn and Ranfurly. This EVC is considered to be depleted in the Murray Scroll Belt Bioregion. Lignum dominates this EVC but it also supports Eucalypt or Acacia woodland with River Red Gum and Black Box being the dominant trees species. Black Box woodlands provide strong habitat links from the riverine corridor to the surrounding Mallee landscape in this region. 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 can tolerate a range of conditions from wet to dry and saline to fresh (Roberts & Marston 2011).

Tangled Lignum (*Muehlenbeckia florulenta)*, is considered to be the most significant floodplain shrub in mainland Australia due to its extensive distribution, local dominance and value as habitat (Roberts & Marston 2011). It has particular ecological value as a waterbird breeding habitat (Rogers & Ralph 2011) making it significant around wetland # 7329 998173 because of its close proximity to the lake environs. Wetland birds that breed over water, such as Egrets, use flooded Lignum shrublands (Ecological Associates 2007a) for resting and the Musk Duck, Freckled Duck, Blue-billed Duck and Hardhead all use Lignum for nesting (Rogers & Ralph 2011).

Riverine Chenopod Woodland surrounds part of wetland # 7329 998173 and Lake Hawthorn, generally on slightly higher elevations than the Lignum Swampy Woodland of the wetland bed. This eucalypt woodland is mostly found on riverine terraces and has a diverse shrubby-grassy understorey (DSE 2009). This EVC is considered to be depleted in the Murray Scroll Belt Bioregion and much of the Black Box vegetation characteristic of this vegetation class is degraded around the lakes.

The presence of aquatic macrophyte beds in the wetlands is important. Small native fish species recorded in the target area require aquatic vegetation for habitat and as a food source (Rogers & Ralph 2011). Similarly, many of the waterbirds species that occur at this site feed on and amongst aquatic vegetation. *Ruppia* spp. is an aquatic macrophyte that can tolerate fresh water but becomes dominant in brackish to saline water and is most productive in depths of less than 1 metre (Congdon & McComb 1979, p.123). This species is known to occur at Lake Hawthorn, even at recent elevated salinity levels (Ellis 2013), and may provide the aquatic habitat required by Murray Hardyhead and other small native fish at this site.

Flora

Water dependent flora species listed in the various acts and agreements which have been recorded in the areas of Lake Hawthorn and Lake Ranfurly are listed in Table 7, with records for each site marked individually, indicating similarities in the environments surrounding each lake. A full list of recorded flora at Hawthorn/Ranfurly is provided in Appendix 2.

Table 7. Listed water dependent flora species recorded at the site

Scientific Name	Common Name	EPBC Status	FFG Status	DELWP status	Lake Hawthorn	Lake Ranfurly
Atriplex lindleyi* subsp. *conduplicata	Baldoo	NL	NL	R	✓	
Atriplex limbata	Spreading Saltbush	NL	L	V		✓
Calandrinia volubilis	Twining Purslane	NL	NL	NL		✓
Eragrostis australasica	Cane Grass	NL	NL	V		✓
Eragrostis lacunaria	Purple Love-grass	NL	NL	V	✓	✓
Eragrostis setifolia	Bristly Love-grass	NL	NL	V		✓
Eremophila divaricata* subsp. *divaricata	Spreading Emu-bush	NL	NL	R		✓
Eremophila maculata* subsp. *maculata	Spotted Emu-bush	NL	NL	R	✓	
Frankenia serpyllifolia	Bristly Sea-heath	NL	NL	R	✓	✓
Frankenia sessilis	Small-leaf Sea-heath	NL	NL	R		
Malacocera tricornis	Goat Head	NL	NL	R	✓	✓
Phyllanthus lacunellus	Sandhill Spurge	NL	NL	R	✓	✓
Sarcozona praecox	Sarcozona	NL	NL	R	✓	✓
Sida ammophila	Sand Sida	NL	NL	V	✓	✓
Sida intricata	Twiggy Sida	NL	NL	V	✓	
Sida spodochroma	Limestone Sida	NL	L	V	✓	
Swainsona microphylla	Small-leaf Swainson-pea	NL	NL	R	✓	✓
Swainsona reticulata*	Kneed Swainson-pea	NL	L	V	✓	✓
Templetonia egena	Round Templetonia	NL	NL	V	✓	
Minuria cunninghamii	Bush Minuria	NL	NL	R		✓
Muehlenbeckia horrida* subsp. *horrida	Spiny Lignum	NL	NL	R		✓

Legend
EPBC status: Not Listed **FFG** status: Listed as threatened, Not Listed
DELWP status: Vulnerable, Rare

*Possibly water dependent, found around lakes and watercourses, and could potentially be found around wetlands.

A key wetland species known to re-establish at Lake Hawthorn if water persists (Ellis 2013) is *Ruppia* spp. This submerged macrophyte offers important wading, feeding and foraging habitat for waterbirds including the listed migratory species described in Table 6 (page 35). The *Ruppia* spp. present at Lake Hawthorn exist in the saline water and require constant inundation. A fluctuating shoreline, however, may open up vegetated forage habitat for shorebirds that feed on *Ruppia* seeds and forage on macroinvertebrates located in *Ruppia* beds.

Spiny Lignum, *Muehlenbeckia horrida* subsp. *horrida*, is considered rare in Victoria (DEPI 2014) and is found in the target area. This species occurs in the Lignum Swampy Woodland EVC close to the river, along with Tangled Lignum. It is also considered to be a species typical of the vulnerable Lake Bed Herbland EVC (DSE 2004) which dominates the wetland beds within Lake Hawthorn. The water regime for these EVCs and for Tangled Lignum may also be appropriate for Spiny Lignum given that they are found in the same habitats.

Two rare species of Sea-heath (*Frankenia* spp.) are recorded at Hawthorn/Ranfurly (Table 7). These species are restricted to saline environments (Royal Botanic Gardens 2015). Also recorded at Lake Hawthorn is the vulnerable Kneed Swainson-pea (*Swainsona reticulata*). This floodplain species is only known to occur at only eight sites in the Mallee (Mallee CMA 2011B).

4.1.2 Wetland Depletion and Rarity

Hawthorn/Ranfurly contains four wetlands, one of which (Lake Hawthorn) is in the target area. The lake has been classified using the Corrick-Norman wetland classification system as Semi-Permanent Saline. Deep Freshwater Marsh is one of the most significantly altered wetland types in Victoria and the Mallee CMA Region since 1788 (Mallee CMA 2006A) (Table 8).

Across the state, the greatest decreases in original wetland area have been in the freshwater meadow (43 per cent decrease), shallow freshwater marsh (60 per cent decrease) and deep freshwater marsh (70 per cent decrease) categories (DNRE 1997).

Table 8. Changes in area of the wetlands in the target area by Corrick classification

Category	No of Wetlands in target area	Total target area (ha)	Decrease in wetland area from 1788 to 1994		
			% Change in area in Victoria	% Change in area in Mallee CMA	% Change in Murray Scroll Belt
Semi-permanent Saline	1	148	-7	9	+100

Source: DEPI Biodiversity interactive maps, Mallee Wetland Strategy (Mallee CMA 2006A)

Semi-permanent Saline wetlands are generally less than 2 metres deep and are classified as exceeding salinity values greater than 3000mg/L, and have sub-categories defined as salt pan, salt meadow, salt flats, sea rush, hypersaline lake, Melaleuca and dead timber.

4.1.3 Ecosystem Functions

Wetland ecosystems support distinctive communities of plants and animals and provide numerous ecosystem services to the community (DEPI 2005). The target area comprises part of a large saline lake.

Lake Hawthorn has the potential to provide feeding, breeding and drought refuge sites for an array of flora and fauna, especially waterbirds and fish. The large expanse of shallow wading habitat available, combined with the potential for re-establishment of aquatic vegetation and small-bodied native fish can enhance wetland productivity. Offering shallow wading habitat and loafing sites in this saline environment offers an important habitat niche that is likely to facilitate visitation by migratory shorebirds. These birds in turn can help disperse seed and aquatic invertebrates (Whelan, Wenny & Marquis, 2008).

Altered water regimes in the target area due to levee construction and dry conditions have seen a decrease in the frequency of inundation in Lake Hawthorn and significantly reduced inflows. This has resulted in a decrease in the ability for the lake to perform these valuable ecosystem functions.

4.2 Social

4.2.1 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 the Mallee 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 Murray River 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 both concentration and diversity. They include large numbers of burial, midden and hunting sites.

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.

4.2.2 Cultural Heritage

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

Surveyed sites at Lake Hawthorn include middens, earth features, scarred trees, Aboriginal mounds and surface scatters. Surface scatters in this area may consist of chipped stone artefacts, animal bones, shell, charcoal, hearth stones, clay balls and ochre.

Aboriginal people continue to have a connection to this country. The recorded cultural heritage sites show the area was an important meeting place for Aboriginal people, with water and food sources making it possible to survive in this landscape. There is no native title claim over this area but the Latji Latji and Nyeri Nyeri people have a vested interest in this region. Appendix 4 outlines the actions necessary if Aboriginal cultural heritage values are unearthed during environmental water delivery activities.

European heritage reflects the pioneering history of the area. Significant European footprints include those of Americans George and William Chaffey, who came to develop irrigation infrastructure on an old sheep station arising in the settlement of Mildura in 1887. William Chaffey constructed the Mildara Winery just downstream of this sub-unit, in Merbein, in 1909 (Merbein n.d.).

4.2.3 Recreation

The lake is popular for bike riding, bird watching, nature photography and walking. The Lake Hawthorn area has historically maintained a high recreational value for birdwatchers. One such example is local citizen scientist Pauline Bartel, who has collected and maintained bird survey data over the past 16 years. Pauline's work has resulted in more than 13,000 birds counted at Lake Hawthorn, representing 160 species, 16 of which are listed. Waterbirds are likely to take advantage of delivery of environmental water at Lake Hawthorn, and enhance bird watching potential. A grant enabled the bird hide located on the foreshore (Figure 17) to be upgraded and new signage installed by committee members of the local Landcare Group, Cabarita Inc in 2016.

There are also existing bike trails around Lake Hawthorn (Sunraysia Drainage Coordination Group 2005) and walking trails were reinstated in 2016 (Cabarita Inc 2016) that link with the Murray River and offer walkers the capacity to link Council's planned Murray River Walking Trail. The former Lake Hawthorn Sailing Club building is also located at the site, and community events are held at Lake Hawthorn including the 'Make the Lake' Art Exhibition, which draws visitors from the wider community.

Three citizen scientists have been collecting bird data at Lake Hawthorn. Eight new species of birds have been surveyed by the scientists that were not previously listed in this plan. These species have been added to Appendix 1 and are registered with Birdlife Australia on their online database.

4.3 Economic

The economic benefits of Lake Hawthorn and Lake Ranfurly arise from the Lake Hawthorn Drainage Diversion Scheme, the Mildura-Merbein Salt Interception Scheme, irrigation and stormwater drainage usage, and the recreation and tourism opportunities the lakes provide (Sunraysia Drainage Coordination Group 2005).

Figure 17. The bird-hide at Lake Hawthorn

4.4 Significance

The environmental, social and economic values outlined above indicate the significance of this site. While these values do not constitute Lake Hawthorn and Lake Ranfurly being rare or pristine sites, the riparian and floodplain communities of the Murray River are important to the functioning of the river system and its sustainability. Water birds rely on a range of different wetland habitats. Saline wetlands are known to support significantly larger numbers of waterbirds than freshwater wetlands, although freshwater wetlands are needed for some species for breeding (Young, 2001).

Lake Hawthorn and Lake Ranfurly offer valuable shallow feeding, foraging and loafing habitat for waterbirds that is not often found on the floodplain. The target area at Lake Hawthorn represents a rare opportunity to provide habitat for internationally recognised, EPBC listed, migratory shorebird species. Additionally, resident waterbird populations are also a likely to benefit from permanent inundation of the lake and its close proximity to Lignum communities for breeding.

Lake Hawthorn dried out between 2008 and 2010, before refilling due to localised flooding and elevated Murray River flows in 2010-11. The refilling event resulted in the re-establishment of *Ruppia* beds throughout the lake, indicating the viability of seed banks within the wetland bed and its capacity to perform important ecosystem services. There is great potential for re-establishing a shallow wading environment for shorebirds at Lake Hawthorn.

The historic waterbird records for this area are abundant and diverse, with extensive areas of Lignum Shrublands providing roosting, nesting and feeding habitats. Particularly, the large number of EPBC listed migratory species among the wader guild emphasise the target area's potential to support, and perhaps encourage, a diversity of species.

The values contained within Hawthorn/Ranfurly, and specifically the target area for this plan, makes this area a priority for protection and enhancement through environmental water management.

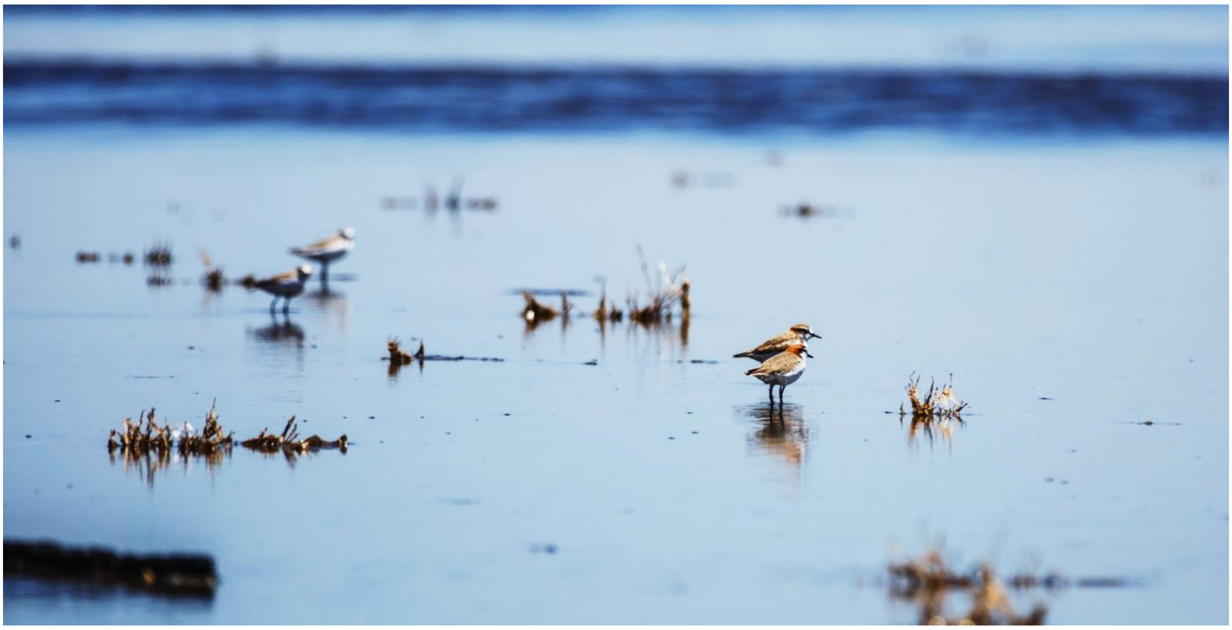


Figure 18. Small wader guilds are likely to take advantage of the shallow wading habitat offered by delivery of environmental water to Lake Hawthorn.

5.0 Ecological Condition and Threats

The Mallee River Health Strategy (MCMA 2006) lists threats in this area including changed flow regime, pest plants and animals, loss of wetland connectivity. The *Mallee Waterway Strategy 2014-22* (MCMA 2014) includes changed water regime, reduced wetland area, altered wetland form, degraded water quality and invasive species as threats within the Merbein Waterway Management Unit.

5.1 Current Condition

One method for assessing the current condition of a wetland is the Index of Wetland Condition (IWC) developed by DELWP. 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. Further information on the IWC scoring is provided in the *Mallee CMA Regional Context Document* (Sunraysia Environmental 2014).

Lake Hawthorn has not been assessed using the IWC criteria. However, the lake has completely dried out twice in the past ten years. Some of the land surrounding Lake Hawthorn is degraded by elevated salinity (Bluml 1992). At Lake Ranfurly this degradation is particularly evident with areas of bare, salt-affected land and only very salt tolerant species able to survive (Ecological Associates 2007a). Similarly, at Lake Hawthorn the original Black Box – Chenopod vegetation can no longer survive close to the lake due to the exclusion of flooding and elevated groundwater levels. Black Box occurs in the riparian zone, however closer to the lake only salt tolerant species such as Austral Seablite, Ruby Saltbush and the invasive African Boxthorn now survive (Bluml 1992). A modified Lake Bed Herbland community appears to be in a relatively steady state offering an important habitat niche for many species.

Initiated in 1993, Waterwatch Victoria monitors waterways in their catchment to raise knowledge in the community about issues with water and encourage monitoring groups to undertake action. There are currently three inactive water quality monitoring sites around Lake Hawthorn last monitored during 2007 and two active and two inactive sites located around Lake Ranfurly which were last monitored during February 2014.

Since the commencement of almost annual water deliveries in 2016 there have been regular reports of wide varieties of waterbirds at Lake Hawthorn (Figure 19a). Optimal water levels of 33.0-33.3mAHD have been largely maintained by the program, however, due to constraints in delivery infrastructure and competition for water availability salinity levels have continued to rise to a level >70,000 EC.

Figure 19a. Waterbirds observed at Lake Hawthorn (January 2019).

5.2 Condition Trajectory

Without management intervention in the form of environmental water delivery, condition within the target area is expected to further decline. The lack of inflows to Lake Hawthorn resulted in the extirpation of all resident fish, including one of only five known populations of the nationally endangered Murray hardyhead (*Craterocephalus fluviatilis*), as the lake dried out from late 2008 to mid-2010 (Ellis 2013), and dried out again in 2016. A translocation of Murray hardyhead was trialled at Lake Hawthorn in 2018, however subsequent fish surveys have failed to detect any individuals of the species. It is suspected that the high salinity level in the lake is a barrier to successful recruitment and that the translocated population is likely to become extinct.

Dry conditions will continue to impact. If the modified Lake Bed Herbland vegetation community and the extensive beds of *Ruppia* spp. are continued to be lost, the potentially significant communities of migratory shorebirds will not be able to be sustained. This may lead to reduced ecosystem services provided by both the wetland and waterbirds as the abundance and diversity of waterbirds that visit the lake will decline. Maintenance of the water level at Lake Hawthorn suitable for shorebirds and waders that has been in place since 2016 however, is likely to continue to render the site as favourable habitat for these and other waterbird guilds (Figure 19b).

Figure 20b. Red-necked avocets observed at Lake Hawthorn (November 2019).

5.2.1 Water Related Threats

The current altered water regime and complete drying of the lakebed is considered the biggest threat for the target area and is the primary factor behind the development of this environmental water management plan.

Some of the threats which impact on the values at Hawthorn/Ranfurly include:

- Altered water regime;
- Loss or reduction of wetland connectivity;
- Water quality;
- Introduction/increase of exotic flora and fauna;
- Increased salinity;
- Degraded habitats;
- Altered physical form of wetland.

Changed water regime

The regulation of the Murray River has seen the water regime through Hawthorn/Ranfurly altered. Flow events of the magnitude required to allow flows into the lake are less frequent and of shorter duration. Levees have increased the flow threshold to further reduce the frequency of natural inundation at Lake Hawthorn. This, combined with dry conditions over the last decade resulting in reduced runoff, and reduced drainage and urban stormwater inflows affects the capacity of the wetland to provide habitat and vegetation that is part of a functioning floodplain ecosystem.

Loss of wetland connectivity

Reduced connectivity to the Murray River and reduced frequency of natural flooding events has led to less frequent freshwater inflows and restricted movement of aquatic fauna.

Acid sulfate soils

Sulfidic sediments (potential acid sulfate soils) can be an issue in freshwater wetlands impacted by secondary salinization (Baldwin 2008). Wetlands used as drainage or disposal basins, such as Lake Hawthorn and Ranfurly, can be exposed to sulfates through saline irrigation discharge and groundwater salinity. Evaporation and lack of flushing in these basins can result in further elevations in salinity (CSIRO 2004). Waterlogged and anaerobic conditions can encourage sulfidic sediment formation. When exposed to oxygen during a drying phase sulfuric acid can form and be released into surrounding waters when subsequently flooded, with dire environmental consequences (MCMA 2012). Baldwin (2008) found that although Lake Hawthorn had a large store of reduced sulfur in its sediments, there was little likelihood of the wetland turning acidic during a drying event due to the large neutralizing, or buffering, capacity of the lake sediments.

Introduced Flora and Fauna

Introduced fish species Common Carp (*Cyprinus carpio*), and Mosquito fish (*Gambusia holbrooki*), pose a serious threat to the ecology of Lake Hawthorn. Ho et al (2004) found both these species to be present during aquatic vertebrate surveys, although complete dry down has resulted in extirpation of all fish species in the lake. Carp have been found to contribute to the loss of aquatic vegetation and increased turbidity, resulting in loss of habitat for waterfowl (Purdey & Loyn 2008). This species also competes with native fish for habitat and food as well as having a detrimental effect on water quality (MCMA 2003).

Agricultural and other weeds are an ongoing threat and management issue along the Murray River floodplain. These may pose a threat when water is applied. Spiny rush (*Juncus acutus* subsp. *Acutus*) has extensively colonised shrubland around Lake Hawthorn (Lloyd Environmental 2007) and African Boxthorn (*Lycium ferocissimum*) is found around both lakes (Bluml 1992).

6.0 Management Objectives

6.1 Management Goal

The goal for the Hawthorn/Ranfurly EWMP is:

> *To provide a flow regime to the target area that provides permanent shallow wading habitat for internationally important migratory shorebirds and a diverse population of resident native waterbirds.*

The overall goal proposed for the Hawthorn/Ranfurly target area has been developed through consultation with stakeholders. This goal considers the values the wetlands support and the potential threats that need to be managed. This includes consideration of the values the wetlands have historically supported and the likely values they could support into the future.

The Mallee CMA acknowledges that the primary use of Lake Hawthorn will continue to be as an irrigation drainage and urban stormwater disposal basin. Any ecological and hydrological objectives recommended in this EWMP are secondary to the site's primary use. However, opportunities to protect the environmental values and improve conditions may be provided through environmental watering at this site.

6.2 Ecological Objectives

Ecological objectives represent the desired ecological outcomes of the site based on the management goal above, as well as the key values outlined in the Water Dependent Values section. The ecological objectives are expressed as the target condition or functionality for each key value.

As with any healthy wetland ecosystem, ecological outcomes are interrelated. The objectives outlined in Table 9, if achieved, contribute to wetland productivity and improve the overall health of the system. Reinstating the shallow wading habitat at Lake Hawthorn is expected to increase visitation by migratory shorebirds and re-establish benthic herblands.

Attainment of the ecological objectives is anticipated to have wider benefits for the target area and is expected to result in:

- Improving wetland productivity;
- Re-instatement of aquatic vegetation communities;
- Improvement of fringing emergent vegetation;
- An increase in habitat and foraging grounds for other aquatic and semi-aquatic species.

Table 9. Ecological objectives for Lake Hawthorn

Ecological objective	Justification (value based)
Reintroduce saline marsh habitat, particularly benthic herblands including *Ruppia* beds.	The saline marsh environment at Lake Hawthorn requires inundation to maintain water dependent *Ruppia* spp., which is known to re-establish at this site, if water persists. *Ruppia* spp. can provide habitat for small-bodied fish and feeding habitat for waterbirds including waders.
Provide suitable wading, feeding, foraging and loafing habitat for shorebirds	Australia's waterbirds are often nomadic, requiring habitat patches throughout the landscape to facilitate movement. Similarly, internationally important migratory species depend on suitable wetland feeding grounds to store energy for migration to their northern hemisphere breeding grounds. Lake Hawthorn can offer shallows and mudflats, and feeding, foraging, wading and loafing sites for a range of waterbirds. This habitat may be particularly suited to migratory waders including the Red-necked Stint and the vulnerable Common Greenshank.

6.3 Hydrological Objectives

Hydrological objectives describe the components of the water regime required to achieve the ecological objectives for the target area. The hydrological requirements to achieve the objectives are presented in Table 10.

The hydrological objectives for Lake Hawthorn are centred on establishing a permanent shallow wading environment to support waterbirds, particularly nationally and internationally significant migratory shorebirds. Providing a shallow wading environment between spring and autumn each year is important, as migratory shorebirds typically arrive in Australia in late winter or early spring and depart in autumn. However, some juveniles may overwinter in Australia so it is important to for water to remain ponded in Lake Hawthorn on a permanent basis. Maintaining a minimum water level within the lake, may also promote re-establishment of aquatic vegetation, an important habitat requirement of many species of waterbird.

Seasonal variation in water levels is beneficial for *Ruppia* spp. to establish thick beds (Ellis 2013). These aquatic species may persist in wetlands that are frequently flooded but if complete drying of the wetland occurs over summer they will die off and be replaced by lake bed herbs (Ecological Associates 2007b). Seeds and turions can germinate on re-wetting, however inundation over the longer term will help provide extensive *Ruppia* beds. Roberts & Marston (2011) states a slow drawdown of water is required to prevent collapse of plants. Ellis (2013) supports this, suggesting a gradual but partial drawdown phase, to provide a fluctuation in water levels is essential for *Ruppia* establishment. Following natural seasonality is encouraged: increasing water levels in spring, and lowering in summer is likely to be beneficial to *Ruppia* multiplication (Ellis 2013).

Delivery of environmental water to Lake Hawthorn to a maximum level of 33.3 m AHD will provide a maximum depth in the lake of 0.58 m for *Ruppia* spp. establishment. Because the majority of the lake bed lies at or below 33.3 m AHD, and the bed increases in depth gradually (Figure 10, page 23), inundating to this level will also provide extensive shallow wading habitat of less than 10 cm depth for migratory shorebirds.

Partial drawdown of Lake Hawthorn from 33.3 m AHD to a minimum of 33.0 m AHD (Figure 21) is proposed to occur naturally through evaporation. Allowing levels to fall below 33.0 m AHD will expose a greater area to drying and will reduce the capacity of *Ruppia* beds to firmly re-establish. At 33.0 m AHD fifty per cent of the lake bed area is inundated, representing 114 ha. It is expected that managing the wetland for the elements above will also support the presence of other native water dependent species.

In summer evaporation would lead to rapid drying of the lake (Lumb 2015). Using an estimated annual evaporation rate of 2,000 mm/year (Lumb 2015), top up volumes will be required, particularly in spring and summer, if stormwater and drainage inflows are insufficient. Inflows are not currently measured, but are estimated to be 2,640 ML/year or less from irrigation drainage (Lumb 2015). It will be necessary to monitor lake levels and manage environmental water delivery in response to increased inflows or evaporation rates.

These water requirements have been used as a guide to develop the hydrological objectives for Lake Hawthorn.

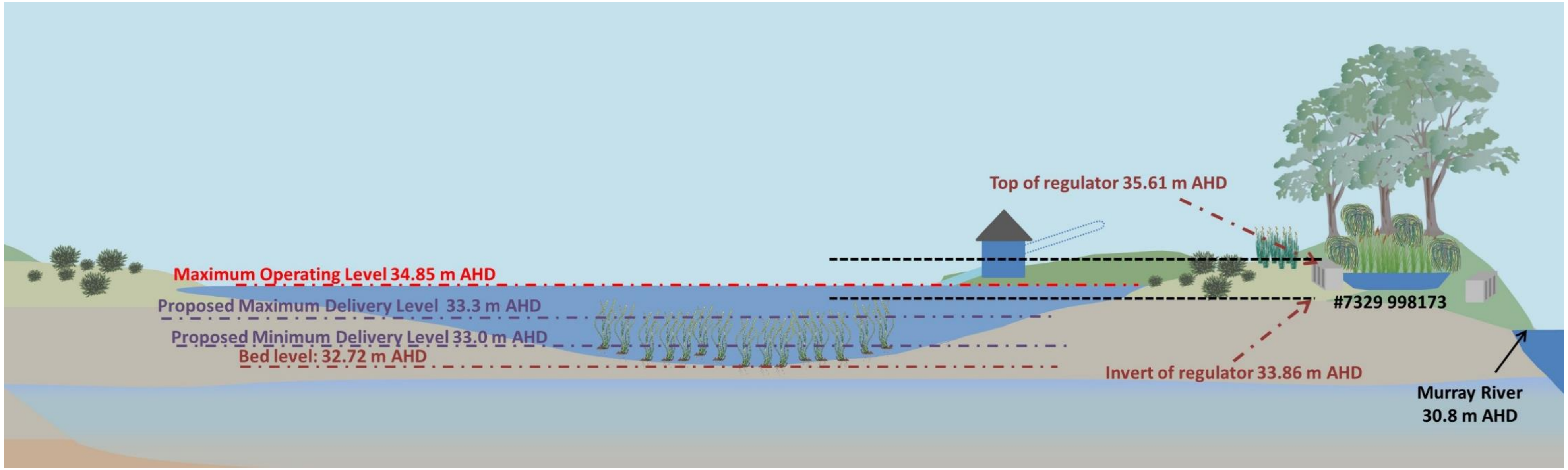


Figure 21. Height datum for relevant components at Lake Hawthorn (not to scale), including proposed environmental water delivery regime.

Table 10. Hydrological objectives for Lake Hawthorn

Ecological objective	Water management area	Hydrological Objectives												
		Mean frequency of events (Number per 10 years)			Tolerable interval between events (years)		Duration of ponding (months)			Preferred timing of inflows[#]	Target supply level (TSL) (m AHD)	Volume to fill to TSL[1] (ML)	Volume to maintain at TSL[2] (ML)	Total volume per event[3] (ML)
		Min	Opt	Max	Min	Max	Min	Opt	Max					
Reintroduce saline marsh habitat, particularly benthic herblands including *Ruppia* beds. **Provide** suitable wading, feeding, foraging and loafing habitat for shorebirds	**Wetland Bed inundated at 33.0 to 33.3 m AHD**	10	10	10	0	1	12	12	12	Spring/ Summer to achieve permanent ponding	33.3	400	200	1,000

[#] Timing of inflows is dependent on system demand and ability to deliver during low irrigation demand, which will coincide with lower irrigation drainage inflows. Environmental water delivery would only be required in years where irrigation and urban stormwater drainage inflows are insufficient to maintain a suitable water depth.

[1] Estimate based on filling from empty to the target supply level (TSL)

[2] Estimate based on maintaining at target supply level (TSL) for optimum duration of ponding, based on maximum drawdown level of 33.0 m AHD

[3] Delivery plus three top up events

6.3.1 Water Management Regime

The wetland watering regime has been derived from the ecological and hydrological objectives. To allow for adaptive and integrated management, the water management regime is framed using the seasonally adaptive approach. This means that a regime is identified for optimal conditions, however flexibility is encouraged in accordance with the minimum, maximum and optimal hydrological objectives in Table 10.

The optimal watering regime for Lake Hawthorn is described in the following pages. The extent of the target area inundated is presented in Figure 23. Due to the inter-annual variability of these estimates (particularly the climatic conditions and inflows), determination of the predicted volume requirements in any given year will need to be undertaken by the environmental water manager when watering is planned.

Water level data collected at Lake Hawthorn over the past decade is presented in Figure 22, combined with annual rainfall data to indicate the extent to which Lake Hawthorn may be reliant on rainfall now that it experiences regular flooding inundation less frequently than prior to river regulation and levee construction. Environmental watering of Lake Hawthorn may not be required during median or wet years.

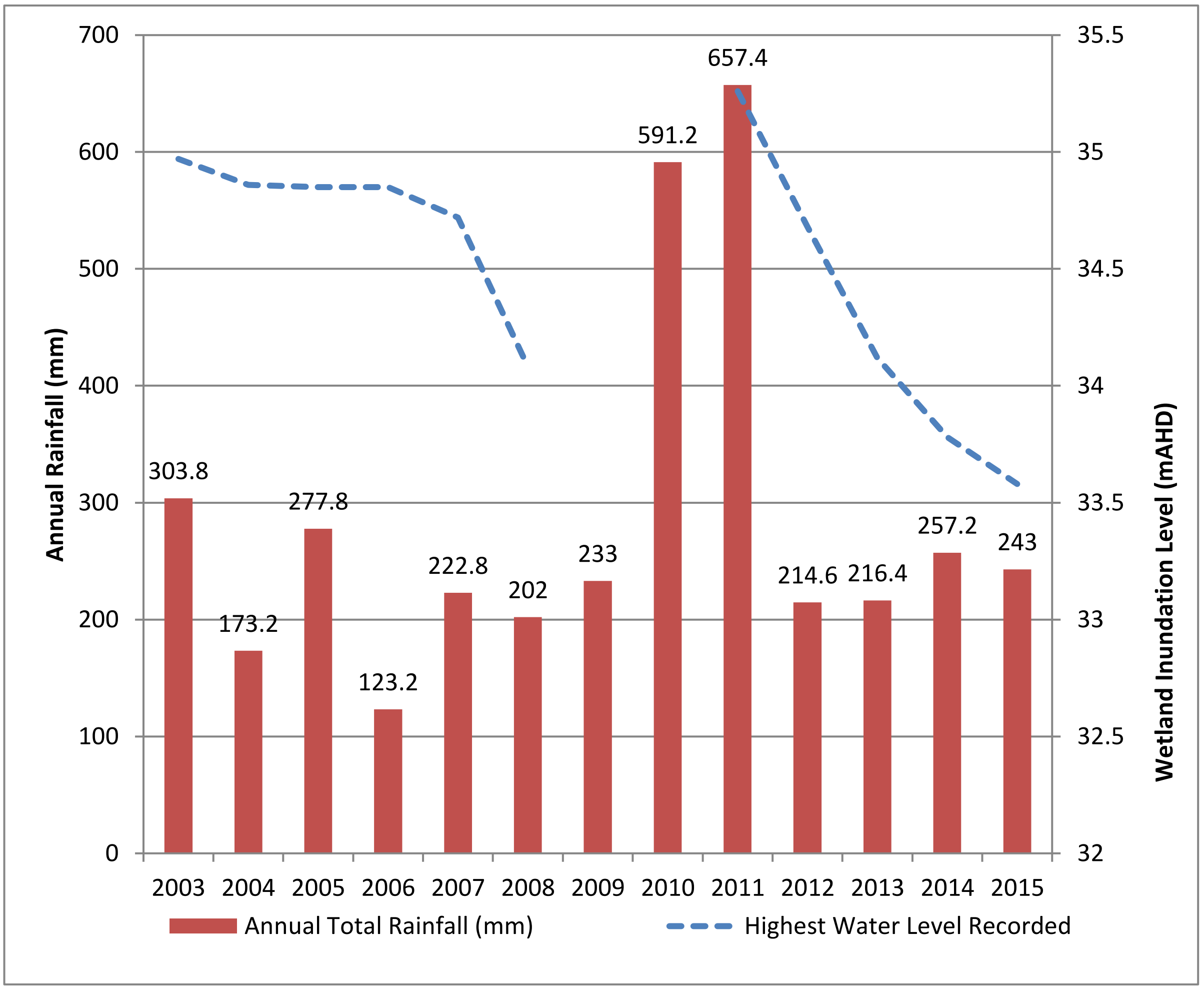


Figure 22. Comparison of annual rainfall data (Mildura Airport) and water levels recorded for Lake Hawthorn 2003-2015.

Water level monitoring will be required to maintain a minimum water level of 33.0 mAHD, and a target of 33.3 mAHD at Lake Hawthorn. Delivery of environmental water may be required at various times during the year to maintain a minimum level, however the frequency, extent and timing of delivery will be dependent on:

- Availability of environmental water;
- Urban stormwater and irrgiation drainage inflows; and
- Irrigation demand in the delivery system.

Water levels could be allowed to decrease marginally through summer to expose wetland sediments and fringing vegetation whilst also maintaining aquatic macrophyte beds within the wetland (Ellis 2013). Subsequent increases in water level should be high enough to inundate exposed sediments to promote a rise in primary production.

The proposed water regime is provided below. A 'dry' year and a 'wet' year for the purposes of this regime are defined as 20% below and 20% above average annual rainfall respectively. These definitions are likely to require refinement in the future. For the purposes of planning delivery, a rolling 12 month total may be suitable to apply in conjunction with water level trends.

Predicted Annual Rainfall Value*	**Water Regime – Lake Hawthorn**
Dry Year (e.g. <225 mm)	Provide environmental water via irrigation infrastructure to permanently inundate the target area and achieve a water level of 33.3 m AHD to encourage germination of *Ruppia* spp. and visitation by shorebirds. Allow natural recession of a maximum of 0.3 m (to 33.0 m AHD) before delivering a top-up volume as necessary to return the lake to 33.3 m AHD.
Average Year (e.g. ~290 mm)	Provide environmental water via irrigation infrastructure to permanently inundate the target area and to maintain a water level of 33.3 m AHD to encourage germination of *Ruppia* spp. and visitation by shorebirds. Allow natural recession of a maximum of 0.3 m (to 33.0 m AHD) to expose mudflats for foraging shorebirds and to promote *Ruppia* spp. germination, before delivering a top-up volume as necessary to return the lake to 33.3 m AHD.
Above Average Year (e.g. >350 mm)	Monitor water level. Deliver environmental water if necessary, to sustain a water level of 33.3 m AHD to maintain *Ruppia* spp. beds. Allow natural recession of a maximum of 0.3 m (to 33.0 m AHD) before delivering a top-up volume as necessary to return the lake to 33.3 m AHD.

*Consideration should also be given to rainfall data from preceding years, and trends in below (or above) average rainfall totals.

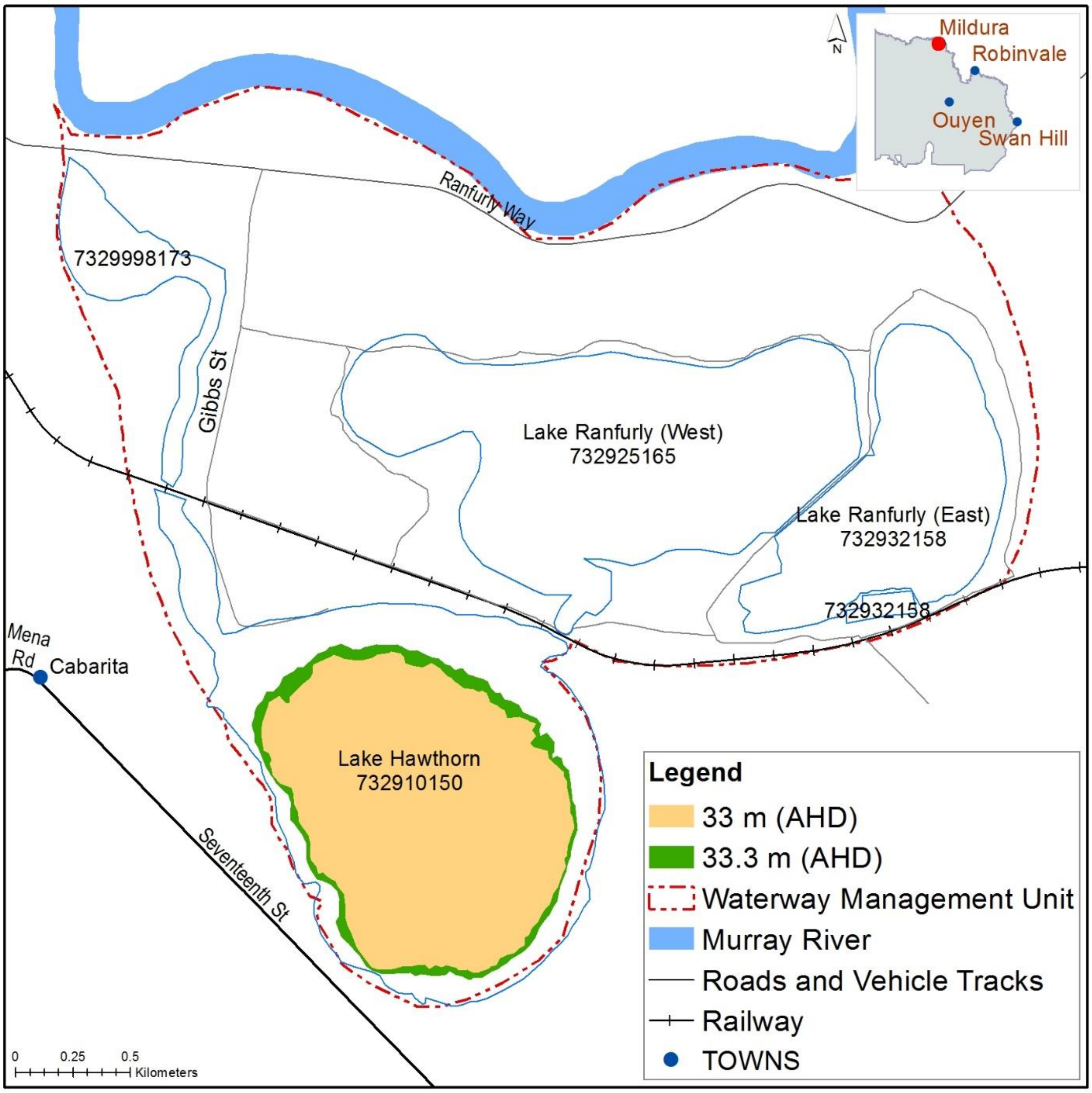


Figure 23. Proposed inundation extent at Lake Hawthorn

7.0 Managing Risks to Achieve Objectives

Delivery Plans will be developed for all wetland sites allocated environmental water. A broad risk assessment has been undertaken for the system to identify any major risks which would require mitigation measures; these are outlined in Table 12. The Risk Rating matrix in Table 11 has been used to rate the risks in Table 12. Prior to delivering environmental water in any given season, these risks will be further refined as part of the Seasonal Watering Proposal and Environmental Water Delivery Plan process. These documents will provide a greater level of risk analysis and mitigation measures according to conditions observed closer to the proposed delivery (i.e. operational risks). The documents will also include detailed consideration of the impact of proposed mitigation measures on the likelihood and consequence of the risk occurring (residual risk) as this may change according to catchment conditions closer to the proposed delivery. They will clearly outline roles and responsibilities regarding risk management.

Table 11. Risk Rating

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Extreme 5
Likelihood	Almost Certain 5	Medium 5	Medium 10	High 15	High 20	High 25
	Likely 4	Low 4	Medium 8	Medium 12	High 16	High 20
	Possible 3	Low 3	Medium 6	Medium 9	Medium 12	High 15
	Unlikely 2	Low 2	Low 4	Medium 6	Medium 8	Medium 10
	Rare 1	Low 1	Low 2	Low 3	Low 4	Medium 5

Table 12: Environmental Water Delivery Risk Assessment

Risk Category	Risk #	Risk Type	Without Mitigation			Mitigation	Residual Risk		
			Likelihood	Consequence	Rating		Likelihood	Consequence	Rating
Supply	1.0	Supply is limited to the irrigation season (see section 8.0)	Possible	Moderate	Medium	• Ensure Delivery Plan adheres to delivery constraints with regard to timing	Rare	Moderate	Low
Timing	2.0	Timing of delivery incompatible with objectives (see section 8.0)	Likely	Moderate	Medium	• Investigate installation of infrastructure options to facilitate longer term management of the site • Monitor the ecological response of the wetland to inundation • Add or drawdown water where appropriate or practical	Rare	Moderate	Low
Salinity	3.0	Increased salinity impact	Unlikely	Moderate	Medium	• Maintain delivery within proposed inundation level (33.3 m AHD maximum) to reduce risk of achieving direct pathway via surface water to Murray River • Continue to review water quality data to identify trends • Adhere to current best management practices in terms of assessing risk of transmission via groundwater to Murray River. Adjust management to reflect new knowledge as it arises	Rare	Minor	Low
Pest Animals	4.0	Improved conditions for non-native fish (e.g. Common Carp, Eastern Gambusia)	Possible	Minor	Medium	• Monitor for presence of pest fish if connection with a naturally occurring population occurs: ○ Consider eradication or control activities to reduce pest fish population levels ○ Regular aquatic surveys	Rare	Moderate	Low
Social	5.0	Complete dry down causes community concern over odour/loss of amenity	Likely	Moderate	Medium	• Investigate installation of infrastructure options to facilitate longer term management of the site to avoid complete drawdown and to achieve ecological objectives • Monitor the ecological response of the wetland to inundation	Rare	Moderate	Low

Risk Category	Risk #	Risk Type	Without Mitigation			Mitigation	Residual Risk		
			Likelihood	Consequence	Rating		Likelihood	Consequence	Rating
Flood Mitigation	6.0	Delivery reduces headspace for stormwater disposal in extreme rainfall event	Rare	Major	Low	• Monitor long term weather forecasts, adjust delivery accordingly • Liaise with relevant stakeholders to ensure pumping infrastructure is operational	Rare	Moderate	Low
Reputation	7.0	Unable to provide evidence in meeting ecological objective	Possible	Moderate	Medium	• Ensure ecological objectives are communicated to wider community • Ensure monitoring activities are undertaken • Establish monitoring framework	Rare	Moderate	Low
	7.1	Key stakeholders not supportive of environmental water release, view it as use of an irrigation source	Possible	Moderate	Medium	• Continue to engage with stakeholders and undertake communications around environmental water sources, ecological objectives and benefits of environmental water delivery	Rare	Moderate	Low

8.0 Environmental Water Management Infrastructure

8.1 Constraints

8.1.1 Salinity risk management

Mallee CMA commissioned a *Preliminary Salinity Impact Assessment* (CDM Smith 2015) to investigate the likely downstream impacts of environmental watering events at Hawthorn/Ranfurly in accordance with the Murray Darling Basin Authority's Basin Salinity Management Strategy. This study tested potential watering regimes for Lake Hawthorn and wetland #7329 98173, focussing on surface water salinity processes and groundwater salinity processes, and estimated the salinity impact of these regimes in terms of their EC impact at Morgan.

The salinity impact assessment included three target areas and stage levels, with minimum, optimal and maximum regimes:

- an initial inundation of wetland #7329 998173 to a height of 35.7 mAHD and draw down to 34.9 mAHD;
- inundation of Lake Hawthorn to between 34.3 and 34.8 mAHD; and
- permanent inundation of Lake Hawthorn to 33.3 mAHD (the option proposed in this EWMP).

The preliminary assessment estimates that by maintaining a shallow level in Lake Hawthorn between 33.0 and 33.3 mAHD the total impact at Morgan could be 0.02 EC for the proposed inundation of Lake Hawthorn (Table 13). The other target areas are not proposed in this EWMP.

Table 13. Estimated EC impacts at Morgan for watering options at Lake Hawthorn

Option	Target area (ha)	Stage level (m AHD)	Target watering frequency		Estimated EC impact at Morgan: Groundwater pathway	Surface water pathway	Total
Wetland #7329998173	**44**	**35.7, drawn down to 34.9**	**Min**	1 year in every 10	0.01	negligible	0.02
			Opt & Max	2 years in every 10	0.03	negligible	0.03
Lake Hawthorn	**225**	**34.3 - 34.8**	**Min**	1 year in every 10	0.01	n.a.	0.01
			Opt & Max	2 years in every 10	0.03	n.a.	0.03
Proposed Regime: Lake Hawthorn	**148**	**33.3**	**Optimal**	10 years in every 10	0.02	n.a.	0.02

(CDM Smith 2015)

As the salinity impacts of the proposed watering actions at Lake Hawthorn do not exceed 0.1 EC at Morgan they are not considered an accountable action under the BSMS. Furthermore, it is not proposed to return environmental water to the Murray River from Lake Hawthorn, thus no surface water pathway for salinity will occur as a result of the proposed regime.

8.2 Infrastructure Recommendations

Environmental water will be delivered to Lake Hawthorn via existing irrigation supply infrastructure which outfalls to the south eastern shoreline of the lake. A key constraint to the delivery of environmental water to Lake Hawthorn is the time and rate at which water can be delivered. Increased horticultural demand is placed on the irrigation supply system during the spring and summer each year, which corresponds with the peak growing season and lower seasonal rainfall.

To achieve the ecological objectives, specifically, to provide wading habitat for migratory shorebirds, the lake must experience an inundation phase between spring and autumn. Supply pressure in peak irrigation season may limit the delivery of environmental water to the lake. It is strongly recommended that investigations are undertaken to determine a means of delivering suitable volumes of environmental water to Lake Hawthorn during spring and summer to maintain the shallow wading habitat.

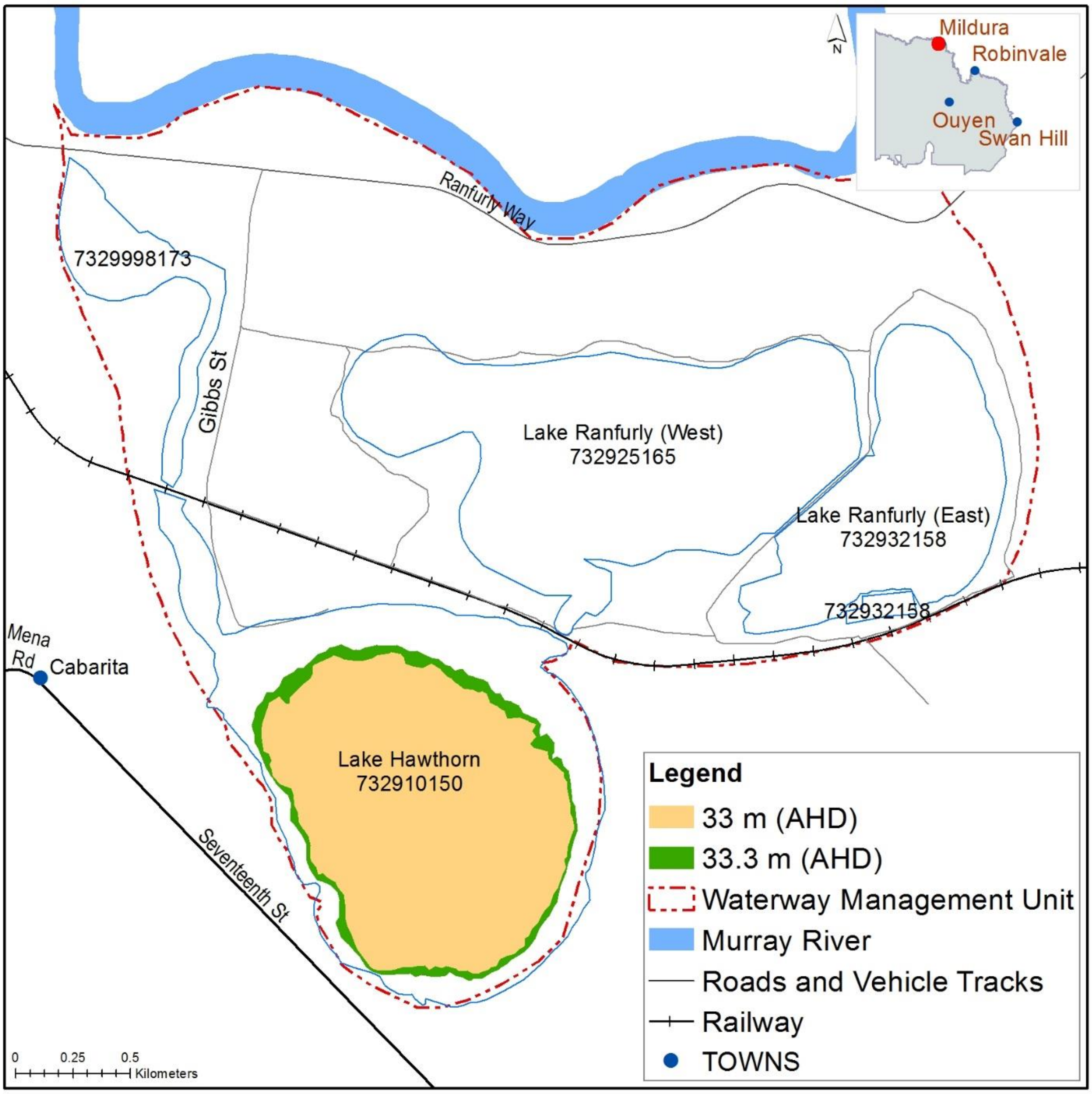


Figure 24. Proposed inundation extent of Lake Hawthorn

Connectivity of Lake Hawthorn via wetland #7329 998173 could be enhanced with the construction of a two-way regulator along Ranfurly Way (**Error! Reference source not found.**) and an upgrade to the regulator between wetland #7329 998173 and Lake Hawthorn at the railway line (**Error! Reference source not found.**). This would facilitate freshwater inflows during natural flood events, and may enable return of water to the Murray River under the operating rules for Lake Hawthorn (Appendix 1).

Figure 25. Regulator structure located at wetland # 7329 998173 along Ranfurly Way

Figure 26. Regulator located at railway line between wetland # 7329 998173 and Lake Hawthorn,

9.0 Demonstrating Outcomes

9.1 Monitoring Priorities at the Site

Ecological monitoring is required to demonstrate the effectiveness of environmental watering in achieving ecological objectives, to help manage environmental risks and to identify opportunities to improve the efficiency and effectiveness of the program. Monitoring of the impact of water management events is proposed as outlined in Table 14. The monitoring events should include baseline and event-based monitoring.

Table 14. Proposed Monitoring for Lake Hawthorn

Objective	Hypotheses	Indicator(s)	Frequency
Provide wading habitat for waterbirds	Delivery of environmental water as per plan will provide and maintain shallow wading habitat that will encourage visitation by migratory shorebirds and other species of waterbird	Bird Surveys, making use of existing survey programs and data collection	Seasonally each year
Improve delivery estimation requirements	Stormwater inflows are insufficient to inundate the lake bed permanently in most years	Monitor water levels and response to inflow	Ongoing

Furthermore, photo point monitoring will be conducted before and after water management events at Lake Hawthorn to measure the success of environmental watering and wetting and drying phases in improving wetland and littoral zone vegetation communities.

Detailed monitoring of water management at Lake Hawthorn would be dependent on funding from the State or Commonwealth governments.

10.0 Consultation

This Plan was developed in collaboration with the key stakeholders outlined in Table 15.

Table 15. Consultation Process for development of the Lake Hawthorn& Ranfurly Environmental Water Management Plan

Meeting date	Stakeholders	Details
May 2016	Local Residents	A poster explaining the EWMP was put up at the Lake Hawthorn display board.
Ongoing throughout plan development	Mildura Rural City Council	Initial discussion to introduce concept of plan and presentation, discussion of proposed regime and review of draft plan
August 2016	Goulburn-Murray Water	Initial discussion to introduce concept of plan and presentation. Factsheet delivered.
Ongoing throughout plan development	Lower Murray Water	Initial discussion to introduce concept of plan and presentation, discussion of proposed regime and review of draft plan
August 2016	Parks Victoria	Initial discussion to introduce concept of plan
August 2016	Department of Environment, Land, Water & Planning	Consultation on environmental management and project development
May 2016	Cabarita Inc	Initial discussion to introduce concept of plan and intent of environmental water delivery. Factsheet delivered.
August 2016	Indigenous Groups	Face-to-face discussions/on-Country visits
June 2016	Mallee CMA – Land and Water Advisory Committee	Preparation for environmental watering event
June 2016	Sunraysia Bird Observers Club	Initial discussion to introduce concept of plan. Factsheet delivered. Consultation on timing of waterbird surveys

11.0 Knowledge Gaps and Recommendations

This plan is based on best information at the time of writing. Further investigation and information collection will continue and the results of this work will continue to build a better understanding of the site and add rigor to future planning. Some areas where further knowledge could enhance planning and delivery capacity are outlined in Table 17.

Table 17. Knowledge gaps and recommendations for the target area

Knowledge and data gaps	Action recommended	Priority level	Responsibility
Conceptual and detailed designs for the proposed water delivery infrastructure	Engage consultant(s) to carry out investigations and designs	1	Implementation of any of these recommendations would be dependent on investment from Victorian and Australian Government funding sources as projects managed through the Mallee CMA
Determine significance of floodplain and wetland #7329 998173 for resident waterbird breeding habitat	Data collection and monitoring	2	
IWC for Lake Hawthorn	IWC assessment undertaken to establish baseline condition and as the basis for ongoing monitoring of improvement over time	3	

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Appendix 1: Lake Hawthorn operating rules

The following rules are used by Goulburn- Murray Water as the construction authority for the MDBC. Operating rules for Lake Hawthorn were first devised in 1968 upon scheme inception. A review of the rules in 1992 (Gato & Budahazy) noted that some minor changes to the rules had occurred over time. The current operating rules are specified below (SKM, 1998d).

Releases from Lake Hawthorn to the River Murray occur when all of the following conditions are satisfied:

i. The flow in the River Murray at Mildura exceeds 15,000 ML/d; and
ii. The salinity at Merbein is below 420 EC; and
iii. The increment in salinity downstream of the junction of the Murray and Darling Rivers caused by releases from Lake Hawthorn does not exceed 20 EC and
iv. No adverse effect is caused on the operation of Lake Victoria.

If these conditions are met then water is preferentially disposed to the river rather than being pumped to Wargan Basins.

Operating rules stress that these regulations for releasing water from Lake Hawthorn cannot be considered in isolation from the overall state of the river at the time of release. Consideration should also be given to the expected length of surplus River Murray flows, the time of year and the diversion pattern expected downstream. Communication protocols must also be followed, as specified below.

The pumping station from Lake Hawthorn to Wargan Basins is operated with the following guidelines in mind:

i. Off-peak power is used as much as possible to minimise pumping costs;
ii. The level of the lake is held below 34.85 m AHD for as long as possible, by the use of one or more pumps during off-peak hours;
iii. When the level exceeds 35.00 m AHD, times of pumping are extended as required to control the maximum level to 35.25 m AHD. The minimum drawdown level is 34.25 m AHD;
iv. Subject to seasonal conditions and time of year, discretion can be exercised in pump usage. Pumping may be suspended or moderated in anticipation of high River Murray flows which will permit gravity releases or for periods when drainage inflows will be low and it can be expected that the lake level will be reduced by evaporation; and
v. The outfall channel to the Wargan Basins has a capacity of approximately 34 ML/d. Consequently, only two of the Lake Hawthorn pumps can be operated simultaneously.

The operational range for Lake Hawthorn represents a compromise between the lake's use as a pondage for salinity control and its recreational and aesthetic value to the local community. The adoption of this operational range has not been a constraint on the effective operation of the scheme.

Wargan Basins are filled in the sequence 2, 3, 4 and 5 to 49.19 m AHD.

Basin 1 is only used in an emergency situation and can accept water from all three Lake Hawthorn pumps for a period not exceeding 8 days. This practice could however cause overtopping of the channel and damage to adjoining private land.

Following reviews of the scheme, several changes to operating rules have been proposed viz: During January to October:

- Set point for 8 hour pumping 34.60 m AHD
- Set point for 18 hour pumping 35.10 m AHD During November and December:
- Set point for 8 hour pumping 34.65 m AHD
- Set point for 24 hour pumping 35.15 m AHD

Appendix 2: Flora and fauna species list

Flora – Native

Scientific Name	Common Name	Victorian Advisory List	Records
Abutilon otocarpum	Desert Lantern	Vulnerable	1
Acacia ligulata	Small Cooba		1
Acacia loderi	Nealie	Vulnerable	1
Acacia melvillei	Yarran	Vulnerable	1
Acacia oswaldii	Umbrella Wattle	Vulnerable	4
Acacia stenophylla	Eumong		2
Acacia victoriae subsp. *victoriae*	Bramble Wattle	Rare	2
Actinobole uliginosum	Flannel Cudweed		1
Amaranthus grandiflorus	Large-flower Amaranth	Vulnerable	1
Amyema linophylla subsp. *orientale*	Buloke Mistletoe	Vulnerable	1
Amyema miquelii	Box Mistletoe		1
Amyema miraculosa subsp. *boormanii*	Fleshy Mistletoe		1
Atriplex eardleyae	Small Saltbush		1
Atriplex leptocarpa	Slender-fruit Saltbush		3
Atriplex lindleyi	Flat-top Saltbush		4
Atriplex lindleyi subsp. *conduplicata*	Baldoo	Rare	1
Atriplex lindleyi subsp. *inflata*	Corky Saltbush		9
Atriplex nummularia	Old-man Saltbush		2
Atriplex nummularia subsp. *omissa*	Dwarf Old-man Saltbush	Rare	1
Atriplex pseudocampanulata	Mealy Saltbush	Rare	1
Atriplex pumilio	Mat Saltbush		2
Atriplex rhagodioides	Silver Saltbush	Vulnerable	3
Atriplex spp.	Saltbush		2
Atriplex vesicaria	Bladder Saltbush		7
Atriplex vesicaria subsp. *minor*	Bladder Saltbush	Poorly known	2
Atriplex vesicaria subsp. *variabilis*	Bladder Saltbush		1
Austrostipa elegantissima	Feather Spear-grass		3
Austrostipa nitida	Balcarra Spear-Grass		1
Austrostipa scabra subsp. *falcata*	Rough Spear-grass		2
Austrostipa scabra/nitida/nodosa spp. agg.	Variable Spear-grass		1
Bolboschoenus medianus	Marsh Club-sedge		1
Brachyscome ciliaris	Variable Daisy		1
Brachyscome lineariloba	Hard-head Daisy		5
Brachyscome spp.	Daisy		1

Scientific Name	Common Name	Victorian Advisory List	Records
***Bromus* spp.**	Brome		1
Bulbine semibarbata	Leek Lily		3
Calandrinia eremaea	Small Purslane		1
Calandrinia volubilis	Twining Purslane	Rare	1
Callitris gracilis	Slender Cypress-pine		1
Calocephalus sonderi	Pale Beauty-heads		1
Calostemma luteum	Yellow Garland-lily	Vulnerable	1
Calotis cuneifolia	Blue Burr-daisy	Rare	1
Calotis hispidula	Hairy Burr-daisy		5
***Calotis* spp.**	Burr Daisy		1
Casuarina pauper	Belah		2
Centipeda cunninghamii	Common Sneezeweed		1
***Chenopodioideae* spp.**	Chenopod		1
Chenopodium curvispicatum	Cottony Saltbush		1
Chenopodium nitrariaceum	Nitre Goosefoot		3
***Chenopodium* spp.**	Goosefoot		1
Crassula colorata	Dense Crassula		3
***Crassula sieberiana* s.l.**	Sieber Crassula		1
***Crassula* spp.**	Crassula		1
Cressa australis	Rosinweed		1
Cynoglossum australe	Australian Hound's-tongue		1
Daucus glochidiatus	Australian Carrot		1
Disphyma crassifolium* subsp. *clavellatum	Rounded Noon-flower		13
Dissocarpus biflorus* var. *biflorus	Twin-flower Saltbush	Rare	4
Dissocarpus paradoxus	Hard-head Saltbush		6
Dodonaea viscosa* subsp. *angustifolia	Giant Hop-bush	Rare	1
Dodonaea viscosa* subsp. *angustissima	Slender Hop-bush		4
Duma florulenta	Tangled Lignum		4
Duma horrida subsp. horrida	Spiny Lignum	Rare	1
Einadia nutans	Nodding Saltbush		5
Enchylaena tomentosa* var. *tomentosa	Ruby Saltbush		12
***Enchylaena tomentosa* var. *tomentosa* (shrubby form)**	Ruby Saltbush (shrubby inland form)		1
Enneapogon avenaceus	Common Bottle-washers		1
Enteropogon acicularis	Spider Grass		2

Scientific Name	Common Name	Victorian Advisory List	Records
Eragrostis australasica	Cane Grass	Vulnerable	1
Eragrostis dielsii	Mallee Love-grass		2
Eremophila polyclada	Twiggy Emu-bush	Vulnerable	5
Erodium crinitum	Blue Heron's-bill		1
Eucalyptus camaldulensis	River Red-gum		1
Eucalyptus dumosa	Dumosa Mallee		1
Eucalyptus largiflorens	Black Box		8
Euphorbia drummondii spp. agg.	Flat Spurge		1
Exocarpos aphyllus	Leafless Ballart		3
Goodenia fascicularis	Silky Goodenia		1
Goodenia pinnatifida	Cut-leaf Goodenia		3
Goodenia pusilliflora	Small-flower Goodenia		1
Harmsiodoxa blennodioides	May Smocks		1
Hyalosperma semisterile	Orange Sunray		1
Hydrilla verticillata	Hydrilla	Rare	1
Isoetopsis graminifolia	Grass Cushion		3
Lawrencia squamata	Thorny Lawrencia		1
Leiocarpa panaetioides	Woolly Buttons		1
Leiocarpa websteri	Stalked Plover-daisy		1
Liliaceae spp. *(sensu lato)*	Lily		1
Lycium australe	Australian Box-thorn		2
Lysiana exocarpi	Harlequin Mistletoe		1
Maireana aphylla	Leafless Bluebush	Poorly known	1
Maireana appressa	Grey Bluebush		5
Maireana brevifolia	Short-leaf Bluebush		7
Maireana pentagona	Hairy Bluebush		1
Maireana pyramidata	Sago Bush		10
Maireana sedifolia	Pearl Bluebush	Rare	2
Maireana spp.	Bluebush		1
Maireana turbinata	Satiny Bluebush		2
Malacocera tricornis	Goat Head	Rare	2
Marsilea costulifera	Narrow-leaf Nardoo		1
Marsilea drummondii	Common Nardoo		2
Melaleuca lanceolata	Moonah		3
Minuria cunninghamii	Bush Minuria	Rare	4
Myoporum parvifolium	Creeping Myoporum		1
Myoporum platycarpum	Sugarwood		2

Scientific Name	Common Name	Victorian Advisory List	Records
Myosurus australis	Mousetail		1
Myriocephalus rhizocephalus	Woolly-heads		2
Myriophyllum verrucosum	Red Water-milfoil		1
Nicotiana spp.	Tobacco		1
Nicotiana velutina	Velvet Tobacco		1
Nitraria billardierei	Nitre-bush		11
Olearia pimeleoides	Pimelea Daisy-bush		1
Osteocarpum acropterum var. *deminutum*	Babbagia		7
Osteocarpum salsuginosum	Bonefruit		1
Phyllanthus lacunellus	Sandhill Spurge	Rare	1
Pimelea microcephala subsp. *microcephala*	Mallee Rice-flower		2
Pimelea spp.	Rice Flower		1
Pittosporum angustifolium	Weeping Pittosporum		1
Plagiobothrys elachanthus	Hairy Forget-me-not		2
Plantago cunninghamii	Clay Plantain		3
Pogonolepis muelleriana	Stiff Cup-flower		3
Polycalymma stuartii	Poached-eggs Daisy		2
Ptilotus nobilis subsp. *nobilis*	Pink Mulla-mulla		4
Ptilotus spathulatus	Pussy Tails		1
Ranunculus pentandrus var. *platycarpus*	Inland Buttercup		1
Ranunculus spp.	Buttercup		1
Rhagodia spinescens	Hedge Saltbush		12
Rhodanthe corymbiflora	Paper Sunray		3
Rhodanthe pygmaea	Pygmy Sunray		2
Rhodanthe stuartiana	Clay Sunray		1
Rumex brownii	Slender Dock		2
Rytidosperma caespitosum	Common Wallaby-grass		3
Rytidosperma spp.	Wallaby Grass		1
Salsola tragus	Prickly Saltwort		5
Salsola tragus subsp. *tragus*	Prickly Saltwort		1
Sarcozona praecox	Sarcozona	Rare	5
Sclerochlamys brachyptera	Short-wing Saltbush		6
Sclerolaena decurrens	Green Copperburr	Vulnerable	1
Sclerolaena diacantha	Grey Copperburr		4

Scientific Name	Common Name	Victorian Advisory List	Records
Sclerolaena muricata	Black Roly-poly		1
Sclerolaena obliquicuspis	Limestone Copperburr		3
Sclerolaena tricuspis	Streaked Copperburr		7
Senecio glossanthus s.l.	Slender Groundsel		6
Senecio glossanthus s.s.	Slender Groundsel		2
Senna form taxon 'coriacea'	Broad-leaf Desert Cassia		1
Senna form taxon 'petiolaris'	Woody Cassia		1
Sida ammophila	Sand Sida	Vulnerable	1
Sida intricata	Twiggy Sida	Vulnerable	1
Sida trichopoda	Narrow-leaf Sida		1
Solanum opacum	Green-berry Nightshade		2
Swainsona reticulata	Kneed Swainson-pea	Vulnerable	2
Tecticornia pergranulata	Blackseed Glasswort		7
Tecticornia pruinosa	Bluish Glasswort		5
Tecticornia tenuis	Slender Glasswort		2
Tecticornia triandra	Desert Glasswort	Rare	5
Tetragonia eremaea s.l.	Desert Spinach		3
Tetragonia tetragonioides	New Zealand Spinach		1
Triptilodiscus pygmaeus	Common Sunray		1
Vittadinia dissecta s.l.	Dissected New Holland Daisy		1
Vittadinia dissecta var. *hirta*	Dissected New Holland Daisy		1
Vittadinia pterochaeta	Winged New Holland Daisy	Vulnerable	1
Wahlenbergia gracilenta s.l.	Annual Bluebell		1
Zygophyllum apiculatum	Pointed Twin-leaf		1
Zygophyllum aurantiacum subsp. *aurantiacum*	Shrubby Twin-leaf		1
Zygophyllum glaucum	Pale Twin-leaf		1
Zygophyllum spp.	Twin-leaf		1

Flora – Exotic

Scientific Name	Common Name
Alhagi maurorum	Camel Thorn
Asphodelus fistulosus	Onion Weed
Avena spp.	Oat
Brassica tournefortii	Mediterranean Turnip
Bromus rubens	Red Brome
Carduus tenuiflorus	Winged Slender-thistle
Carrichtera annua	Ward's Weed
Carthamus lanatus	Saffron Thistle
Centaurea melitensis	Malta Thistle
Centaurea spp.	Knapweed
Cirsium vulgare	Spear Thistle
Citrullus lanatus	Camel Melon
Conyza bonariensis	Flaxleaf Fleabane
Cotula bipinnata	Ferny Cotula
Hordeum glaucum	Northern Barley-grass
Hypochaeris glabra	Smooth Cat's-ear
Juncus acutus subsp. *acutus*	Spiny Rush
Lactuca serriola	Prickly Lettuce
Lamarckia aurea	Golden-top
Lepidium didymum	Lesser Swine-cress
Lepidium draba	Hoary Cress
Limonium lobatum	Winged Sea-lavender
Lycium ferocissimum	African Box-thorn
Marrubium vulgare	Horehound
Medicago minima	Little Medic
Mesembryanthemum nodiflorum	Small Ice-plant
Nicotiana glauca	Tree Tobacco
Opuntia spp.	Prickly pear
Polycarpon tetraphyllum	Four-leaved Allseed
Psilocaulon granulicaule	Wiry Noon-flower
Reichardia tingitana	False Sow-thistle
Schismus barbatus	Arabian Grass
Sisymbrium erysimoides	Smooth Mustard
Solanum nigrum s.l.	Black Nightshade
Solanum nigrum s.s.	Black Nightshade
Sonchus oleraceus	Common Sow-thistle
Spergularia diandra	Lesser Sand-spurrey
Spergularia rubra s.l.	Red Sand-spurrey
Urtica urens	Small Nettle
Vulpia bromoides	Squirrel-tail Fescue

Fauna – Native

Scientific Name	Common Name	Victorian Advisory List
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	
Acanthiza nana	Yellow Thornbill	
Acanthiza uropygialis	Chestnut-rumped Thornbill	
Accipiter fasciatus	Brown Goshawk	
Acrocephalus stentoreus	Clamorous Reed Warbler	
Actitis hypoleucos	Common Sandpiper	Vulnerable
Alcedo azurea	Azure Kingfisher	Near threatened
Anas gracilis	Grey Teal	
Anas rhynchotis	Australasian Shoveler	Vulnerable
Anas superciliosa	Pacific Black Duck	
Anhinga novaehollandiae	Darter	
Anthochaera carunculata	Red Wattlebird	
Anthus novaeseelandiae	Australasian Pipit	
Aphelocephala leucopsis	Southern Whiteface	
Aquila audax	Wedge-tailed Eagle	
Ardea ibis	Cattle Egret	
Ardea modesta	Eastern Great Egret	Vulnerable
Ardea pacifica	White-necked Heron	
Artamus cinereus	Black-faced Woodswallow	
Artamus cyanopterus	Dusky Woodswallow	
Artamus leucorynchus	White-breasted Woodswallow	
Artamus personatus	Masked Woodswallow	
Artamus superciliosus	White-browed Woodswallow	
Aythya australis	Hardhead	Vulnerable
Barnardius zonarius barnardi	Mallee Ringneck	
Barnardius zonarius zonarius	Australian Ringneck	
Biziura lobata	Musk Duck	Vulnerable
Burhinus grallarius	Bush Stone-curlew	Endangered
Cacatua sanguinea	Little Corella	
Calidris canutus	Red Knot	Endangered
Carduelis carduelis	European Goldfinch	
Certhionyx variegatus	Pied Honeyeater	
Charadrius ruficapillus	Red-capped Plover	
Chenonetta jubata	Australian Wood Duck	

Scientific Name	Common Name	Victorian Advisory List
Cheramoeca leucosternus	White-backed Swallow	
Chroicocephalus novaehollandiae	Silver Gull	
Cincloramphus mathewsi	Rufous Songlark	
Circus approximans	Swamp Harrier	
Circus assimilis	Spotted Harrier	Near threatened
Climacteris picumnus victoriae	Brown Treecreeper (south-eastern ssp.)	Near threatened
Colluricincla harmonica	Grey Shrike-thrush	
Coracina novaehollandiae	Black-faced Cuckoo-shrike	
Corcorax melanorhamphos	White-winged Chough	
Corvus coronoides	Australian Raven	
Corvus mellori	Little Raven	
Cracticus nigrogularis	Pied Butcherbird	
Cracticus torquatus	Grey Butcherbird	
Cygnus atratus	Black Swan	
Dacelo novaeguineae	Laughing Kookaburra	
Dicaeum hirundinaceum	Mistletoebird	
Diplodactylus damaeus	Beaded Gecko	
Diplodactylus tessellatus	Tessellated Gecko	
Dromaius novaehollandiae	Emu	Near threatened
Egretta garzetta nigripes	Little Egret	Endangered
Egretta novaehollandiae	White-faced Heron	
Elseyornis melanops	Black-fronted Dotterel	
Emydura macquarii	Murray River Turtle	Vulnerable
Entomyzon cyanotis	Blue-faced Honeyeater	
Eolophus roseicapilla	Galah	
Epthianura albifrons	White-fronted Chat	
Epthianura aurifrons	Orange Chat	
Epthianura tricolor	Crimson Chat	
Erythrogonys cinctus	Red-kneed Dotterel	
Falco cenchroides	Nankeen Kestrel	
Falcunculus frontatus	Crested Shrike-tit	
Fulica atra	Eurasian Coot	
Gallinago hardwickii	Latham's Snipe	Near threatened
Gallinula tenebrosa	Dusky Moorhen	
Gallinula ventralis	Black-tailed Native-hen	

Scientific Name	Common Name	Victorian Advisory List
Gehyra variegata	Tree Dtella	
Geopelia striata	Peaceful Dove	
Grallina cyanoleuca	Magpie-lark	
Gymnorhina tibicen	Australian Magpie	
Haliaeetus leucogaster	White-bellied Sea-Eagle	Vulnerable
Haliastur sphenurus	Whistling Kite	
Heteronotia binoei	Bynoe's Gecko	
Hieraaetus morphnoides	Little Eagle	
Himantopus himantopus	Black-winged Stilt	
Hydroprogne caspia	Caspian Tern	Near threatened
Lichenostomus cratitius	Purple-gaped Honeyeater	Vulnerable
Lichenostomus ornatus	Yellow-plumed Honeyeater	
Lichenostomus penicillatus	White-plumed Honeyeater	
Lichenostomus virescens	Singing Honeyeater	
Litoria peronii	Peron's Tree Frog	
Lophocroa leadbeateri	Major Mitchell's Cockatoo	Vulnerable
Malacorhynchus membranaceus	Pink-eared Duck	
Malurus cyaneus	Superb Fairy-wren	
Malurus lamberti	Variegated Fairy-wren	
Malurus leucopterus	White-winged Fairy-wren	
Malurus splendens	Splendid Fairy-wren	
Manorina flavigula	Yellow-throated Miner	
Manorina melanocephala	Noisy Miner	
Merops ornatus	Rainbow Bee-eater	
Microcarbo melanoleucos	Little Pied Cormorant	
Milvus migrans	Black Kite	
Morelia spilota metcalfei	Carpet Python	Endangered
Myiagra inquieta	Restless Flycatcher	
Neophema chrysostoma	Blue-winged Parrot	
Ninox novaeseelandiae	Southern Boobook	
Northiella haematogaster	Blue Bonnet	
Nymphicus hollandicus	Cockatiel	
Ocyphaps lophotes	Crested Pigeon	
Oxyura australis	Blue-billed Duck	Endangered
Pachycephala rufiventris	Rufous Whistler	
Pardalotus striatus	Striated Pardalote	

Scientific Name	Common Name	Victorian Advisory List
Pelecanus conspicillatus	Australian Pelican	
Petrochelidon neoxena	Welcome Swallow	
Petrochelidon nigricans	Tree Martin	
Petroica goodenovii	Red-capped Robin	
Phalacrocorax carbo	Great Cormorant	
Phalacrocorax sulcirostris	Little Black Cormorant	
Phalacrocorax varius	Pied Cormorant	Near threatened
Phaps chalcoptera	Common Bronzewing	
Philemon citreogularis	Little Friarbird	
Platalea flavipes	Yellow-billed Spoonbill	
Platalea regia	Royal Spoonbill	Near threatened
Platycercus elegans	Crimson Rosella	
Platycercus elegans flaveolus	Yellow Rosella	
Plectorhyncha lanceolata	Striped Honeyeater	
Pluvialis squatarola	Grey Plover	Endangered
Podargus strigoides	Tawny Frogmouth	
Polytelis anthopeplus monarchoides	Regent Parrot	Vulnerable
Pomatostomus ruficeps	Chestnut-crowned Babbler	
Pomatostomus superciliosus	White-browed Babbler	
Porzana pusilla palustris	Baillon's Crake	Vulnerable
Porzana tabuensis	Spotless Crake	
Psephotus haematonotus	Red-rumped Parrot	
Psephotus varius	Mulga Parrot	
Pygopus schraderi	Hooded Scaly-foot	Critically endangered
Recurvirostra novaehollandiae	Red-necked Avocet	
Rhipidura albiscarpa	Grey Fantail	
Rhipidura leucophrys	Willie Wagtail	
Rhynchoedura ornata	Beaked Gecko	Critically endangered
Smicrornis brevirostris	Weebill	
Sminthopsis crassicaudata	Fat-tailed Dunnart	Near threatened
Struthidea cinerea	Apostlebird	
Suta suta	Curl Snake	
Tachybaptus novaehollandiae	Australasian Grebe	
Tadorna tadornoides	Australian Shelduck	

Scientific Name	Common Name	Victorian Advisory List
Taeniopygia guttata	Zebra Finch	
Threskiornis molucca	Australian White Ibis	
Threskiornis spinicollis	Straw-necked Ibis	
Tiliqua rugosa	Stumpy-tailed Lizard	
Todiramphus sanctus	Sacred Kingfisher	
Underwoodisaurus milii	Thick-tailed Barking Gecko	
Vanellus miles	Masked Lapwing	
Vanellus tricolor	Banded Lapwing	
Acrocehalus australis	Australian reed warbler	
Gelochelidon macrotarsa	Australian tern	
Calidris subminuta	Long-toed stint	
Himantopus leucocephalus	Pied stint	
Hirundo neoxena	Welcome sparrow	
Pluvialis fulva	Pacific golden plover	
Ptilotual penicillate	White-plumed honeyeater	
Spatula rhynchotis	Australasian shoveler	

Fauna – Exotic

Scientific Name	Common Name
Columba livia	Rock Dove
Oryctolagus cuniculus	European Rabbit
Passer domesticus	House Sparrow
Sturnus vulgaris	Common Starling
Turdus merula	Common Blackbird
Vulpes vulpes	Red Fox

Appendix 3: Ecological vegetation classes

Description of each EVC in the Hawthorn/Ranfurly sub-unit

EVC no.	EVC name	Bioregional Conservation Status Murray Scroll Belt	Description
97	Semi-arid Woodland	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.
98	Semi-arid Chenopod Woodland	Depleted (Terrestrial BCS)	Sparse, low non-eucalypt woodland to 12 m tall of the arid zone with a tall open chenopod shrub-dominated understorey to a treeless, tall chenopod shrubland to 3 m tall. This EVC may occur as either a woodland (typically with a very open structure but tree cover >10%) or a shrubland (tree cover <10%) with trees as an occasional emergent.
103	Riverine Chenopod Woodland	Depleted	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	Herbland or shurbland 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'.
823	Lignum Swampy Woodland	Depleted	Understorey dominated by Lignum, typically of robust character and relatively dense (at least in patches), in association with a low 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: Cultural heritage contingency plan

In the event that Aboriginal cultural heritage is found during the conduct of the activity, contingency measures are set out below. The contingency measures set out the sponsor's requirements in the event that Aboriginal cultural heritage is identified during the conduct of the activity.

Management of Aboriginal Cultural Heritage found during the Activity

In the event that new Aboriginal cultural heritage is found during the conduct of the activity, then the following must occur:

- The person who discovers Aboriginal cultural heritage during the activity will immediately notify the person in charge of the activity;
- The person in charge of the activity must then suspend any relevant works at the location of the discovery and within 5m of the relevant place extent;
- In order to prevent any further disturbance, the location will be isolated by safety webbing or an equivalent barrier and works may recommence outside the area of exclusion;
- The person in charge of the activity must contact the and the **Mallee CMA Indigenous Facilitator;**
- Within a period not exceeding 1 working days a decision/ recommendation will be made by the **Mallee CMA Indigenous Facilitator** and the **Aboriginal stakeholder,** as to the process to be followed to manage the Aboriginal cultural heritage in a culturally appropriate manner, and how to proceed with the works;
- A separate contingency plan has been developed in the event that suspected human remains are discovered during the conduct of the activity.

Notification of the Discovery of Skeletal Remains during the carrying out of the Activity

1. Discovery:

- If suspected human remains are discovered, all activity in the vicinity must ***stop*** to ensure minimal damage is caused to the remains, and,
- The remains must be left in place, and protected from harm or damage.

2. Notification:

- Once suspected human skeletal remains have been found, Victoria Police (use the local number) and the Coroner's Office (1300 309 519) must be notified immediately;
- If there is reasonable grounds to believe that the remains could be Aboriginal, the DSE Emergency Co-ordination Centre must be immediately notified on 1300 888 544; and
- All details of the location and nature of the human remains must be provided to the relevant authorities.
- If it is confirmed by these authorities that the discovered remains are Aboriginal skeletal remains, the person responsible for the activity must report the existence of the human remains to the Secretary, DPCD in accordance with s.17 of the Act.

3. Impact Mitigation or Salvage:

- The Secretary, after taking reasonable steps to consult with any Aboriginal person or body with an interest in the Aboriginal human remains, will determine the appropriate course of action as required by s.18(2)(b) of the Act.
- An appropriate impact mitigation or salvage strategy as determined by the Secretary must be implemented.

4. Curation and Further Analysis:

- The treatment of salvaged Aboriginal human remains must be in accordance with the direction of the Secretary.

5. Reburial:

- Any reburial site(s) must be fully documented by an experienced and qualified archaeologist, clearly marked and all details provide to AAV;
- Appropriate management measures must be implemented to ensure that the remains **are not disturbed in the future**