Lake Elizabeth Environmental Water Management Plan

Final Draft

North Central Catchment Management Authority

Connecting Rivers, Landscapes, People

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

State Government Victoria

Department of Environment and Primary Industries

Acknowledgement of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

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Executive summary

This Environmental Water Management Plan (EWMP) investigates and documents existing knowledge about Lake Elizabeth. It aims to assist in the development of an environmental watering proposal for the consideration of Environmental Water Holders. It is not a holistic management plan for the site, but is focused on specific environmental water management at Lake Elizabeth.

The following information is provided in the Plan to facilitate appropriate environmental water management at Lake Elizabeth into the future.

Lake Elizabeth is a 94 hectare deep permanent saline lake located within the Wandella Creek sub-catchment of the Loddon River basin. The wetland is considered bioregionally important and is part of a State Wildlife Reserve managed by Parks Victoria. The reserve currently provides a variety of ecological functions including habitat for a diverse range of native flora and fauna species, and supports an important salt tolerant aquatic plant community, Sea Tassel (*Ruppia megacarpa*).

In 2010 an Environmental Watering Plan (EWP) was commissioned by Goulburn-Murray Water's Connections Project (formerly the Northern Victoria Irrigation Renewal Project) to mitigate the potential impacts of modernising the irrigation network at Lake Elizabeth. The EWP prescribed a three year watering cycle that aligned with the ecological objectives determined at the time. Murray Hardyhead (*Craterocephalus fluviatilis*) an *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* listed fish species that was declared extinct in Lake Elizabeth in the early 2000s, was therefore not considered in the EWP. However prior to the wetland almost completely drying in 2007, environmental water was regularly allocated to maintain the wetland permanently for Murray Hardyhead.

In response to the declining number of known stable Murray Hardyhead sites in the Kerang region, the Department of Environment and Primary Industries (DEPI) and Arthur Rylah Institute (ARI) undertook a series of translocation site surveys in the 2011-12 season as part of the Murray Hardyhead Recovery Plan. The investigation revealed that Lake Elizabeth still had the appropriate salt tolerant vegetation, with adequate infrastructure for environmental water delivery and a history of the species being present in the wetland. DEPI commissioned the North Central CMA to further investigate the suitability of Lake Elizabeth being managed as a Murray Hardyhead translocation site through the development of this EWMP.

Investigations undertaken as part of this EWMP revealed that Lake Elizabeth is a through-flow system that is impacted directly by groundwater. This is confirmed by historical groundwater bore data which shows that the groundwater level is at all times above the level of the wetland bed (71.01m AHD) preventing the wetland from completely drying out. This EWMP therefore further investigates the implications of this inability to dry, and refines the ecological objectives and management goal developed in the EWP.

EWMPs are a requirement under the *Water Act 1989*, with the aim of providing a tool for consistent, transparent and informed management of environmental water. The EWMP will support environmental water delivery priority setting processes by the North Central CMA's and Victorian Environmental Water Holder's (VEWH) and also assist the Murray Hardyhead Recovery Plan. This EWMP prescribes both a short and long term management goal and water regime targeting salt tolerant vegetation. The long term goal investigates the potential for Murray Hardyhead translocation into Lake Elizabeth.

Background information, the EWP and local technical input was used to determine the below environmental water management goals and watering regime for Lake Elizabeth:

Short term (next one to three years) environmental water management goal for Lake Elizabeth

To provide an appropriate water regime that maintains Lake Elizabeth as a permanent, saline wetland that supports Saline Aquatic Meadow (EVC 842) vegetation, particularly Large-fruit Sea Tassel, Long-fruit Water-mat and Stonewort.

Long term (future) environmental water management goal for Lake Elizabeth

To provide an appropriate water regime that maintains Lake Elizabeth as a permanent, saline wetland whilst providing habitat for reintroduction of the critically endangered Murray Hardyhead through maintenance of appropriate water quality and the provision of Saline Aquatic Meadow (EVC 842) vegetation, particularly Large-fruit Sea Tassel, Long-fruit Water-mat and Stonewort.

Please note: *the potential to achieve the above long term management goal should be trialled using a rigorous field based monitoring program. This program will monitor the response of the wetland to environmental water delivery and test the assumptions underpinning the salt and water balance model. The results of the trial will reveal the feasibility of achieving conditions appropriate for Murray Hardyhead translocation in the future.*

Optimal watering regime

Provide environmental water to maintain a permanent regime.

Fresh inflows to be delivered annually to regulate salinity levels between 25,000-40,000 EC. Inflows preferably delivered in spring to freshen the system and coincide with the germination period of aquatic macrophytes and the peak breeding season of Murray Hardyhead (should translocation occur). Allow the wetland to recede naturally in winter. Water level of 73.2m AHD should not be exceeded.

Please note: *management under this regime is dictated by salinity targets for the purpose of Murray Hardyhead. See Figure 8 for preferred timing of inflows.*

A salt and water balance model was developed to investigate the interaction between the surface and groundwater at Lake Elizabeth. The model predicts that salinity of 40,000 EC (or below) can be achieved within approximately 12 to 18 months if the wetland is constantly refilled to a level between 73 and 73.5m AHD. If conditions progress as predicted, translocation should only occur if salinity can be managed to mimic the natural seasonality required by Murray Hardyhead.

A risk identification process was also undertaken to investigate potential risks associated with environmental water delivery and associated wetland management at Lake Elizabeth. Detailed risk assessments will be undertaken prior to delivering environmental water to the wetland in any given season. This will be detailed in the Seasonal Watering Proposal for the wetland which is undertaken on an annual basis.

Knowledge gaps and recommendations are provided which will assist in improving knowledge about environmental water management and ecological outcomes for Lake Elizabeth. Investment in these recommendations is highly suggested to ensure that appropriate monitoring is undertaken in the short term to promote appropriate conditions for the long term objective of translocating Murray Hardyhead.

Contents

Figures

Tables

Acknowledgements

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- Andrea Keleher, Paulo Lay and Bruce Mathers (Department of Environment and Primary Industries)
- Chris Solum (Goulburn-Murray Water Connections Project)
- Ross Stanton (Goulburn-Murray Water)
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- Neil Hampton (Landholder).

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Abbreviations

ARI	Arthur Rylah Institute for Research
BE	Bulk Entitlement
Bonn	The Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention or CMS)
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
DEPI	Department of Environment and Primary Industries
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
EWP	Environmental Watering Plan
FSL	Full Supply Level
GL	Gigalitre (one billion litres)
G-MW	Goulburn-Murray Water
IWC	Index of Wetland Condition
JAMBA	Japan-Australia Migratory Bird Agreement
MDBA	Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC)
ML	Megalitre (one million litres)
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
TSL	Targeted Supply Level
VEWH	Victorian Environmental Water Holder

1. Introduction

1.1. Background

Environmental water management in Victoria is entering a new phase as ongoing water recovery means significant volumes of water are being returned to the environment. This has provided new opportunities to protect, restore and reinstate high value aquatic ecosystems throughout northern Victoria. The spatial coverage of environmental watering has expanded considerably in recent years and this trend is likely to continue into the future.

Environmental watering in Victoria has historically been supported by management plans that document key information such as the watering requirements for a site, predicted ecological responses and any water delivery arrangements. State and Commonwealth environmental watering programs now have the potential to extend watering beyond those sites that have been traditionally watered in the past. It is important that there is a consistency in planning for environmental watering across both jurisdictions and therefore, new plans are required which will reflect this.

Environmental Watering Management Plans (EWMP or Plans) are currently being developed by Victorian Catchment Management Authorities for all current and future environmental watering sites throughout northern Victoria. It is intended that the Plans will provide a tool for consistent, transparent and informed management of environmental water across all sites.

1.2. Purpose

The purpose of this Plan is to investigate and document all relevant existing knowledge about Lake Elizabeth to facilitate the development of proposals for environmental watering for consideration by the Victorian and/or Commonwealth Environmental Water Holders.

Critical information provided within the Plan for each site will include:

- management responsibilities
- environmental, social and economic values
- existing water delivery arrangements including recent delivery records and any identified issues
- environmental condition and threats
- environmental objectives
- recommended water regimes to meet objectives under a range of climatic conditions
- any potential risks relating to environmental watering
- delivery system constraints and any opportunities to improve delivery with infrastructure changes
- identification of any knowledge gaps and recommendations to resolve.

This document is the EWMP for Lake Elizabeth in the North Central Catchment Management Authority (North Central CMA) region. The Plan is not a holistic management plan for the site, but rather is focused on specific environmental water management at the site.

1.3. Site location

The North Central CMA region is approximately three million hectares in size, bordered by the Murray River to the north, and the Central Highlands to the south. The region includes the Campaspe, Loddon, Avoca and Avon-Richardson Rivers and a number of significant wetland complexes, including Gunbower Forest, Kerang Lakes, Avoca Marshes and the Boort Wetlands (refer to Figure 1).

Lake Elizabeth is a bioregionally significant 94 hectare wetland situated approximately ten kilometres north-west of Kerang (Figure 3). It is located within the Wandella Creek sub-catchment of the Loddon river basin and was historically associated with the Loddon River system (including Wandella and Venables creeks) receiving floodwaters during large flood events. Since the development of the Torrumbarry Irrigation System and river regulation, Lake Elizabeth has become isolated from its natural floodplain. It now receives fresh water through channel deliveries and is a terminal wetland which becomes saline through groundwater interactions (North Central CMA, 2010).

Figure 1: North Central CMA region

1.4. Consultation

The original Lake Elizabeth EWP (North Central CMA, 2010) incorporated a targeted community and agency engagement process, which included the following representatives: Goulburn-Murray Connections Project (G-MW CP, formerly NVIRP) Technical Advisory Committee (TAC), agency stakeholders, interested groups and adjoining landholders. Appendix 1 summarises the information sourced from this process.

This EWMP builds on the foundations set by the Lake Elizabeth EWP. Initial consultation in the development of this plan was undertaken through landholder interviews on 15 August 2013 and 19 September 2013 and a stakeholder teleconference on 14 August 2013. A follow up community and stakeholder meeting was held on the 27 November 2013 to advise on the outcomes of the EWMP process. In December 2013, stakeholders were also invited to comment on the draft EWMP before a third community meeting was held on the 8 January 2014 to summarise the final EWMP recommendations (on site meeting). Participants involved in the EWMP process include: Neil Hampton, Glenice Ficken, Dennis Carmichael, Ernie Moore, Chris Gitsham, Colin Gitsham and Geoff Gitsham (community representatives), Andrea Keleher, Bruce Mathers, Paulo Lay (DEPI), Mark Tscharke, Peter Foster (Parks Victoria), Chris Solum (Goulburn-Murray Water Connections Project), Ross Stanton (Goulburn-Murray Water) Bridie Velik-Lord, Tori Perrin (VEWH), Tim Shanahan, Phil Dyson, Amy Russell and Bree Bisset (North Central CMA). Outcomes and discussion points from the community consultation phase are presented in Appendix 2.

1.5. Information sources

Information used in the development of this Plan has been compiled from various sources including scientific reports, management plans (i.e. Lake Elizabeth EWP (North Central CMA, 2010)), Geographic Information System (GIS) layers, salt and water balance modelling and stakeholder and community knowledge. A full list of information sources used can be found in the reference section of this Plan.

1.6. Limitations

The information sources used in the development of this Plan have some limitations. In particular, the management plans and reports relied upon vary in age and therefore the degree to which they reflect the current situation. Further to this a number of assumptions that underpin the salt and water balance model have not been tested in the field. Although every effort has been made to use the best available information in the development of this Plan, it is acknowledged that there is an ongoing intention to update the Plan as new information and knowledge become available.

2. Site overview

2.1. Catchment setting

Lake Elizabeth is a 94 hectare terminal wetland situated approximately ten kilometres north-west of Kerang within the Wandella Creek sub-catchment (refer to Figure 2). Lake Elizabeth sits in an area that is rich in large sized wetlands, many of which are part of the Kerang Wetlands Ramsar site. Lake Elizabeth is classified as a permanent saline lake and is considered bioregionally significant, supporting high water fowl numbers and an important salt tolerant submerged aquatic plant assemblage (DSE, 2006 cited in North Central CMA, 2010). Up until the early 2000s the wetland also supported the critically endangered fish species Murray Hardyhead (*Craterocephalus fluviatilis*) (NLWRA, cited in North Central CMA, 2010).

The area encompassing Lake Elizabeth (the Kerang Lakes area) has undergone dramatic change since the construction of the Torrumbarry Irrigation Supply System in the 1920s. Lake Elizabeth was once classified as a permanent open freshwater lake; however regulation as part of the irrigation supply system has resulted in its classification shifting to a permanent saline lake (Kelly, 1996). The wetland now receives environmental water via the Torrumbarry 28/2 Channel (North Central CMA, 2010).

Land use in the catchment (approximately 1,304 hectares) surrounding Lake Elizabeth is agricultural-based, with areas supporting grazing, irrigated horticulture, dairying and cropping (SKM, 2004). The average rainfall in the Kerang region is 375mm/ year, with May to October being significantly wetter than November to April (Macumber, 2002). Maximum average temperatures range from 31.6°C in January to 14.6°C in July, with the minimum rarely dropping below zero degrees (BOM, 2013).

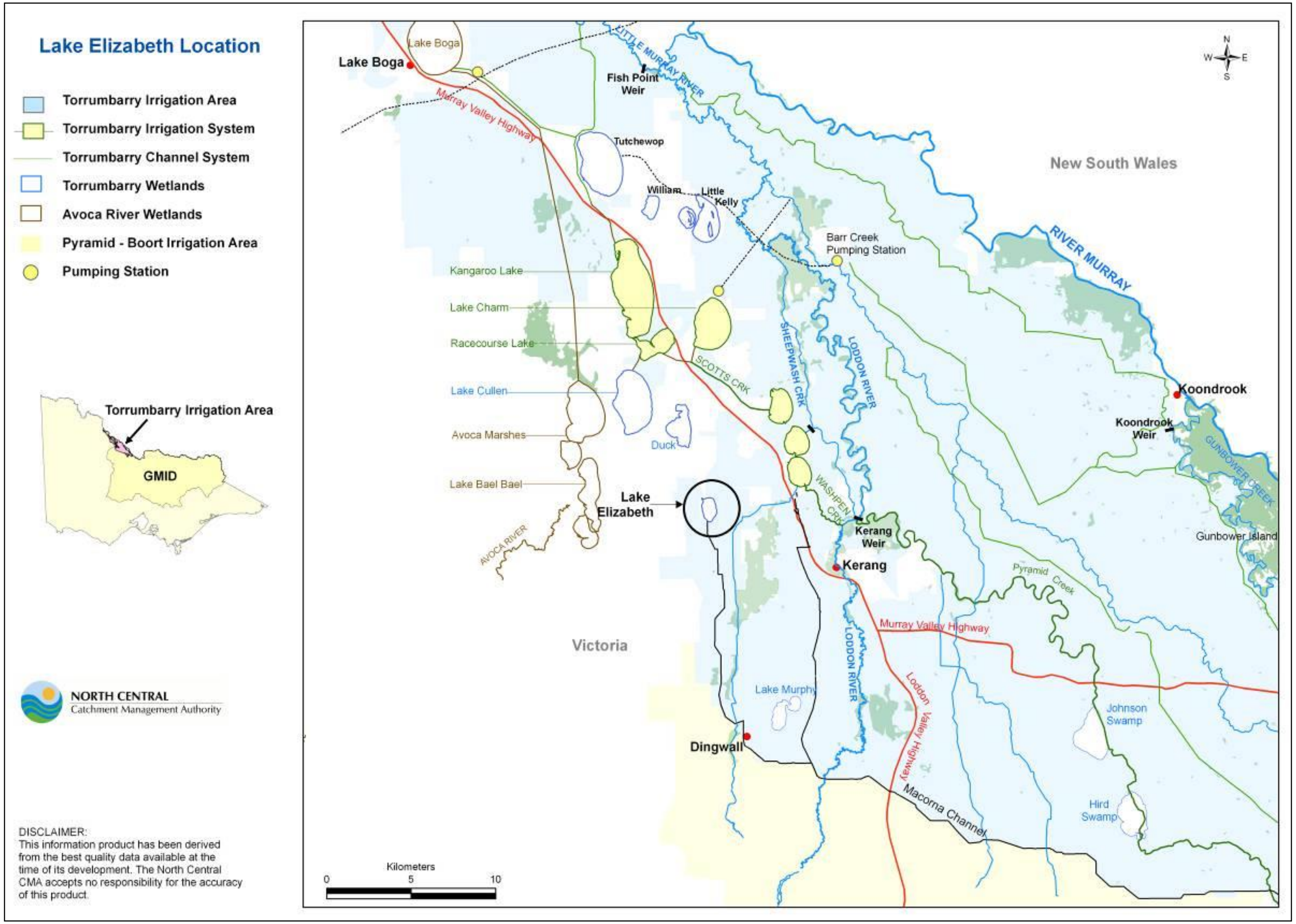


Figure 2: Lake Elizabeth location

2.2. Land status and management

Lake Elizabeth is a State Wildlife Reserve under the *Crown Land (Reserves) Act 1978* and is managed by Parks Victoria under the *Wildlife Act 1975* (VEAC, 2008). In 2009, VEAC recommended that Lake Elizabeth remain as a Wildlife Area (State Game Reserve), with management focusing on conserving and protecting species, communities and or habitats of indigenous animals and plants while permitting recreational (including hunting in season as specified by the land manager) and educational uses (DSE, 2009a and VEAC, 2008).

The local water corporation that manages the Torrumbarry Irrigation System is Goulburn-Murray Water (G-MW) and the regional environmental water manager is the North Central CMA. Table 1 describes the key stakeholders with possible involvement in the management of Lake Elizabeth.

Table 1: Agencies and stakeholder groups with a responsibility or interest in the environmental water management of Lake Elizabeth

Agency / Stakeholder Group	Responsibility / Interest
Commonwealth Environmental Water Holder (CEWH)	Management of Commonwealth environmental water entitlements.
Department of Environment & Primary Industries (DEPI)	Provision of financial, policy and strategic support for the management of public and private land (including wetlands). Policy and regulatory oversight of the VEWH. Management of hunting licensing on public land including Lake Elizabeth. Provision of technical and extension support for the sustainable management of agriculture surrounding Lake Elizabeth. Approval of EWMPs. Legislative responsibilities for the management of flora and fauna.
Field and Game Australia	A voluntary organisation formed by hunters to promote responsible firearm ownership and ethical hunting.
Gannawarra Shire Council	Local council for area including Lake Elizabeth. Responsible for regulation of local development through planning schemes and on-ground works.
Goulburn-Murray Water (G-MW)	Rural water corporation responsible for the management of water-related services in the irrigation area of northern Victoria. Resource manager responsible for making seasonal allocations in the region.
Local community	Recreational users of Lake Elizabeth, including passive recreational pursuits (walking, bird watching), hunting.
Local landholders	Management of private land surrounding Lake Elizabeth.
Murray-Darling Basin Authority (MDBA)	Responsible for preparing, implementing and enforcing the Murray-Darling Basin Plan. Responsible for planning integrated management of water resources across the Murray-Darling Basin.
North Central CMA	Coordination and monitoring of natural resource management programs in north central Victoria. Local operational management of the Environmental Water Reserve to rivers and wetlands including Lake Elizabeth.
Parks Victoria	Custodian and land manager of Lake Elizabeth
Victorian Environmental Water Holder (VEWH)	Management of Victorian environmental water holdings since July 1 2011.
Wemba Wemba (Wamba- alternative spelling) Traditional Owners	The recognised Native Title Group of Lake Elizabeth is the Wamba Barapa Wadi Peoples NT Claimants.

2.3. Wetland characteristics

Wetlands in Victoria are currently classified using a system developed by Corrick and Norman which includes information on water depth, permanency and salinity (Corrick & Norman, 1980 in DSE, 2007) (refer to Appendix 3 for further information about the wetland categories). Wetlands through Victoria were mapped and classified between 1975 and 1994 and developed into spatial GIS layers. These layers represent the wetland characteristics at the time of mapping (referred to as Wetlands 1994 layer), as well as a categorisation of the wetland characteristics prior to European settlement (referred to as Wetlands 1788 layer) (DSE, 2007).

DEPI predicted that Lake Elizabeth was a permanent open freshwater lake prior to European settlement (DEPI, 2013a). A change to the hydrology, most notably the development of the Torrumbarry Irrigation System in the 1920s, followed by cessation of diversions in the 1970s, caused the wetland to be held permanently full with little physical flushing. As a consequence saline groundwater levels began to increase and the wetland became saline. The wetland is now classified as a permanent saline lake (DEPI, 2013b). Table 2 describes the wetland characteristics of Lake Elizabeth.

Table 2: Summary of Lake Elizabeth characteristics

Characteristics	Description
Name	Lake Elizabeth
Mapping ID (Wetland 1994 layer)	7626 551457
Area	94 hectares
Bioregion	Victorian Riverina
Conservation status	Bioregionally Important Wetland
Land status	State Wildlife Reserve
Land manager	Parks Victoria
Surrounding land use	Broadacre dryland cropping
Water supply	Natural: Wandella & Venables Creeks Current: Terminal Wetland, Channel outfall (28/2) • 300EC • Capacity of 15ML/day (due to culvert restrictions)
1788 wetland category	Permanent Open Freshwater (wet; can have dry periods), >1.0m)
1994 wetland category and sub-category	Permanent Saline (>4,400EC)
Current classification	Permanent Saline lake
Wetland capacity	Maximum level 74.6 m AHD (1,599 ML*) (Price Merrett, 2013) Previously managed at 73.5 (FSL)- 74.0m AHD (1,165-1,389 ML*) *Not including wetting up losses, e.g. seepage
Wetland depth at target capacity	Depth of Wetland (Range): 0-3.6 metres

2.4.Environmental water

Environmental water available for use at Lake Elizabeth can come from a number of sources, as detailed in Table 3 and expanded in Appendix 4.

Table 3: Environmental water that may be used at Lake Elizabeth

Water entitlement	Environmental water management agency
Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999 (incl. Amendments Orders and Notices 2005, 2006, 2007 and 2009)	Environment Minister / Victorian Environmental Water Holder
River Murray Unregulated Flows	Environment Minister / Victorian Environmental Water Holder
Environmental Entitlement (Murray System- NVIRP Stage 1) 2012	Victorian Environmental Water Holder
Commonwealth Environmental Water Holdings	Commonwealth Environmental Water Holder

Water available from all of these water sources will vary from season to season, accordingly to climatic conditions, volumes held in storage and carryover entitlements.

2.5. Legislative and policy framework

There are a range of international treaties, conventions and initiatives, as well as National and Victorian State Acts, policies and strategies that direct management of wetlands within Northern Victoria. Those which may have particular relevance to Lake Elizabeth and the management of its environmental and cultural values are listed below. For the functions and major elements of each refer to Appendix 5.

International treaties, conventions and initiatives:

- Convention on Wetlands (Ramsar) 1971
- China Australia Migratory Birds Agreement (CAMBA) 1986
- Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) 2002
- Japan Australia Migratory Birds Agreement (JAMBA) 1974
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979

Commonwealth legislation and policy:

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Part IIA)
- *Australian Heritage Commission Act 1975* (Register of the National Estate)
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- *Native Title Act 1993*
- *Water Act 2007*
- Wetlands Policy of the Commonwealth Government of Australia 1997
- A Framework for Determining Commonwealth Environmental Watering Actions 2009
- Revised National Recovery Plan for the Murray Hardyhead (*Craterocephalus fluviatilis*) 2013

Victorian legislation:

- *Aboriginal Heritage Act 2006*
- *Catchment and Land Protection Act 1994*
- *Water Act 1989*
- *Wildlife Act 1975*
- *Flora and Fauna Guarantee Act 1988* (FFG Act)

- State Environment Protection Policy (Waters of Victoria) 2003
- State Environment Protection Policy (Groundwater of Victoria) 1997

Victorian policy, codes of practice, charters and strategies:

- North Central Regional Catchment Strategy (North Central CMA, 2003)
- Northern Region Sustainable Water Strategy (DSE, 2009a)
- Our Water Our Future (DSE, 2004)
- Victorian threatened flora and fauna species (advisory list)
- Victorian Waterway Management Strategy (DEPI, 2013)

2.6. Related plans and activities

Lake Elizabeth Environmental Water Management Plan (EWP)

In 2010 the Lake Elizabeth Environmental Watering Plan (EWP) was commissioned by Goulburn-Murray Water Connections Project (G-MW CP, formerly the Northern Victoria Irrigation Renewal Project) to mitigate the potential impacts of rationalising the irrigation network. The EWP prescribed the following water regime:

Frequency of wetting:	Minimum: one (1.5) in five years
	Optimum: one (1.5) in three years
	Maximum: permanent
Duration:	18 months
Timing:	Autumn or spring filling
Extent and depth:	Approximately 1.5 metres (top-ups may be required to maintain level)
Variability	moderate

The water regime for Lake Elizabeth was based primarily on providing conditions appropriate to support the salt tolerant aquatic plant assemblages typical of an intermittent brackish/ saline lake and to provide waterbird feeding and breeding opportunities as well as restoring invertebrate diversity and abundance. The optimum and minimum regimes involved drawdown and drying phases creating mudflat habitat and restoring the littoral zone (North Central CMA, 2010).

Although extensive, the Lake Elizabeth EWP only took into consideration those values present at the wetland at the time of writing. One species that was historically present in the wetland (up until the early 2000s) but was not considered in the EWP was the *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999* listed fish species Murray Hardyhead. As the species was considered locally extinct in the wetland, the potential to re-support the critically endangered fish species was not considered a priority management objective in the EWP.

Based on the information presented in the EWP, an annual mitigation water commitment of 267 ML was tagged for Lake Elizabeth. This volume was calculated from a baseline year (2004-05 with 401ML recorded outfall) and the desired water regime which specified 18 months of wetting in three year (North Central CMA, 2010). The annual mitigation water commitment was incorporated into the *Environmental Entitlement (Murray Systems- NVIRP Stage 1) 2012* and is available annually for use at Lake Elizabeth to support the wetland's water dependent ecological values.

Murray Hardyhead Recovery Plan

The National Recovery Plan for the Murray Hardyhead (Recovery Plan) is a long term management strategy for Victoria that has the overall objective of minimising the probability of species extinction in the wild whilst increasing the chances of important population becoming self-sustaining for the future (Stoessel *et al.* 2013, Backhouse, *et al.* 2008a and Backhouse, *et al.* 2008b).

To date extensive intervention in the form of environmental water delivery and captive breeding has prevented the overall extinction of the species, however fewer populations exist now then what existed when the Recovery Plan was original prepared in 2007. As a result the EPBC listing for Murray Hardyhead was elevated from Vulnerable to Endangered in 2012 (DEPI, 2013d). Further to this insufficient funding resulted in a downscale of Murray Hardyhead monitoring as well as the conclusion of the captive breeding program in 2012-13.

Currently a draft Revised Recovery Plan for Murray Hardyhead (Revised Recovery Plan) is being developed to supersede the Recovery Plan. The overall objective is to improve the conservation status of the species, with the ultimate long-term goal of removing the species from threatened species schedules. Specifically the goal for Victoria over the next five years is:

1. Maintaining existing populations to ensure no wild populations become extinct, and
2. Establishing at least one extra population in each district (Kerang and Mildura) (DEPI, 2013d and Stoessel *et al.* 2013).

In an effort to investigate the feasibility of establishing new populations in the Kerang area, a survey was conducted in May 2012 by DEPI and Arthur Rylah Institute (ARI) to identify potential sites for Murray Hardyhead translocation. Twenty sites were assessed for water delivery infrastructure (presence of or ability to construct in the future), salinity (sites <1,000 EC excluded), ability to control alien fish species via salinity management and suitable habitat (i.e. aquatic vegetation and water quality). A total of three sites were assessed as suitable, Lake Elizabeth, Golf Course Lake and Lake Wandella. Lake Elizabeth was identified to be the most suitable, having supported Murray Hardyhead in the recent past, being connected to the irrigation network and containing suitable aquatic habitat (Stoessel & Dedini, 2013).

The information and investigations detailed within this EWMP aim to further investigate the feasibility of Lake Elizabeth as a translocation site for Murray Hardyhead. A number of complimentary surveys including vegetation and salt and water balance modelling were conducted as part of the EWMP process.

Complimentary Works

Lake Elizabeth is included in the North Central CMAs 'Protecting and Enhancing Priority Wetlands' project. The project, which runs from July 2012 to June 2015, aims to maintain and improve the ecological condition of wetlands of international, national or state significance within the North Central CMA region.

The four year project will deliver intensive on ground works, including invasive animal and plant reduction works, native revegetation, improvement in habitat condition through fencing of remnant vegetation and conduit maintenance to assist with the delivery of environmental water. To date the project has identified and mapped all invasive plant and animal species and revegetation and fencing opportunities for Lake Elizabeth. The project has commenced a spring weeds program and rabbit baiting program in 2013. During the implementation, the North Central CMA will work with neighbouring landholders and community groups to identify areas of concern and encourage participation through an incentives scheme.

The project will consolidate existing works that have been undertaken on priority wetlands which are contained in the Torrumbarry Irrigation area, such as the provision of environmental water and the delivering on-ground land management activities to neighbouring wetlands.

The project will also contribute to meeting obligations highlighted in various Federal and State legislation (e.g. the *Environment Protection and Biodiversity Conservation Act 1999*), as well as requirements under various international treaties and agreements (e.g. the Ramsar Convention on Wetlands). It will address the current gap in investment that exists beyond the long-term provision of environmental water by contributing funds to undertake on-ground and complementary works.

3. Water Dependent Values

3.1. Environmental

3.1.1. Listings and significance

Lake Elizabeth is a regionally significant wetland that supports a range of important flora and fauna species as well as a significant submerged salt tolerant plant community (North Central CMA, 2010). Currently, the wetland is utilised by a diversity of native waterbird species, however in the past the wetland also provided refuge for Murray Hardyhead a nationally listed native fish species.

Table 4 details the legislation, agreements, conventions and listings that are relevant to Lake Elizabeth. Species recorded at Lake Elizabeth (including historical records) fall under four international listings, one national listing and two state listings. A full species list is provided in Appendix 6.

Table 4: Legislation, agreements, convention and listings relevant to the site, or species recorded at Lake Elizabeth

Legislation, Agreement or Convention	Jurisdiction	Listed
Ramsar Convention on Wetlands	International	✗
Japan Australia Migratory Birds Agreement (JAMBA)	International	✓
China Australia Migratory Birds Agreement (CAMBA)	International	✓
Korea Australia Migratory Birds Agreement (ROKAMBA)	International	✓
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	International	✓
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	National	✓
Flora and Fauna Guarantee Act 1988 (FFG Act)	State	✓
DSE advisory lists	State	✓

3.1.2. Fauna

Prior to the 1920s Lake Elizabeth supported an assemblage of freshwater flora and fauna species including the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* listed Murray Cod (*Maccullochella peelii peelii*) (DEPI, 2013b). When diversions ceased shortly thereafter and salinity began to increase locals reported a significant drop in fish life (including the loss of Murray Cod), whilst bird life rose dramatically (anecdotal accounts in Hydrotechnology, 1995).

In total 84 bird species have been formally recorded at Lake Elizabeth, 18 of which are considered significant (DEPI, 2013b; Australian Ecosystems, 2012; BirdLife Australia 2013; Rakali Consulting, 2013). Seven of the significant species are protected under migratory agreements (international agreements), including two, the Eastern Great Egret (*Ardea modesta*) and White-bellied Sea-Eagle (*Haliaeetus leucogaster*) which are also listed under the *Flora and Fauna Guarantee (FFG) Act 1988*. An additional two species, the Freckled Duck (*Stictonetta naevosa*) and Intermediate Egret (*Ardea intermedia*) are also listed under the FFG Act.

One of the critical determinants of the capacity for Lake Elizabeth to support high waterbird numbers and diversity is the abundance of the salt tolerant aquatic plant Sea Tassel (*Ruppia* spp.) particularly Large-fruit Sea Tassel. This plant also provided habitat for Murray Hardyhead which was first documented in Lake Elizabeth in 1971. Murray Hardyhead is a small, threatened native fish species endemic to the lowland floodplains of the Murray River and the lower Murrumbidgee River systems (Plate 1) (Ellis, 2005). The species is now considered extinct in eleven out of the thirteen historical locations (Stoessel & Dedini, 2013).

Plate 1: Murray Hardyhead

From 2002 up to 2006-07, Lake Elizabeth was managed as a permanent wetland through environmental water delivery to maintain conditions for Murray Hardyhead. This included maintaining salinity between 25,000 and 40,000 EC which excludes the exotic fish species Gambusia (*Gambusia hollbrooki*) the primary predator of Murray Hardyhead (Stoessel, 2010).

After three years of consecutive Murray Hardyhead surveys failed to confirm the presence of the species (2004, 2005 and 2006), it was declared locally extinct in Lake Elizabeth (DSE, 2006). Increased pressure from drought, reduced outfall and limited environmental water availability saw an overall reduction in the number of Murray Hardyhead populations in Victoria. It is understood that at best only four viable populations now exist in Victoria, two of which are historic, one established and one discovered following the floods (Stoessel & Dedini, 2013). Lake Elizabeth is now considered the highest priority in the Kerang area, for Murray Hardyhead translocation (Stoessel, 2012). Table 5 shows the listed fauna species that have been recorded at Lake Elizabeth.

Table 5: Significant fauna species recorded at the site

Common name	Scientific name	Type	Last record	International agreement	EPBC status	FFG status	Vic status
Australasian Shoveler	*Anas rhynchotis*	B	2013				VU
Black Falcon	*Falco subniger*	B	1999				VU
Blue-billed Duck	*Oxyura australis*	B	2004			L	EN
Brolga	*Grus rubicunda*	B	2009			L	VU
Common Greenshank	*Tringa nebularia*	B	1992	J/C	M		
Curlew Sandpiper	*Calidris ferruginea*	B	1989	J/C/R	M		EN
Eastern Great Egret	*Ardea modesta*	B	2001	J/C	M	L	VU
Freckled Duck	*Stictonetta naevosa*	B	2013			L	EN
Hardhead	*Aythya australis*	B	2013				VU
Intermediate Egret	*Ardea intermedia*	B	1990			L	EN
Marsh Sandpiper	*Tringa stagnatilis*	B	1991	J/C/R	M		

Murray Cod[1]	*Maccullochella peelii peelii*	F	~1920		VU	L	VU
Murray Hardyhead[2]	*Craterocephalus fluviatilis*	F	2002		EN	L	CR
Musk Duck	*Biziura lobata*	B	2013				VU
Pacific Gull	*Larus pacificus*	B	1991				NT
Pied Cormorant	*Phalacrocorax varius*	B	1988				NT
Red-necked Stint	*Calidris ruficollis*	B	1989	J/C/R	M		
Royal Spoonbill	*Platalea regia*	B	1995				NT
Sharp-tailed Sandpiper	*Calidris acuminata*	B	1992	J/C/R	M		
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	B	2006	C	M	L	VU

Legend
Type: Invertebrate, Fish, Amphibian, Reptile, Bird, Mammal
International: Camba, Jamba, Rokamba, Bonn (as per Section 2.3.1)
EPBC status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Migratory
EPBC presence: Known to occur, Likely to occur, May occur
FFG status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing
DSE status: presumed EXtinct, Regionally Extinct, Extinct in the Wild, CRitically endangered, ENdangered, Vulnerable, Rare, Near Threatened, Data Deficient, Poorly Known
[1]Ancedotal accounts of species being present in the 1920s (documented in Hydrotechnology, 1995 and during community consultation phase for development of this EWMP)
[2]Species declared locally extinct in 2006

3.1.3. Flora

Vegetation communities

Lake Elizabeth is located in the Victorian Riverina Bioregion which is characterised by a flat to undulating landscape on recent unconsolidated sediments with evidence of former stream channels and wide floodplain areas associated with major river systems and prior streams (DEPI, 2013c).

According to pre-1750 Ecological Vegetation Class (EVC) mapping, Lake Elizabeth supported a saline lake mosaic surrounded by chenopod woodland vegetation prior to European settlement (DEPI, 2013e). More recent mapping at Lake Elizabeth identified five EVCs including the vulnerable Riverine Chenopod Woodland (Rakali, 2013). Their conservation status in the Victorian Riverina Bioregion is presented in Table 6 and described in more detail in Appendix 7 (where available for Victorian Bioregion).

The current EVCs characteristic of Lake Elizabeth include:

- Low halophytic shrubland of drier inland areas, dominated by succulent-stemmed chenopods (samphires) (Samphire Shrubland) (DEPI, 2013c)
- Eucalypt woodland (Black Box –*Eucalyptus largiflorens*) occurring on elevated terraces (Riverine Chenopod Woodland) (DEPI, 2013c)
- Low Herbland of salt-tolerant species developing on drying lake beds (Brackish Lake Bed Herbland) (DSE, 2012)
- Eucalypt woodland with rhizomatous sedgy- turf grass understorey, with developed dominated by flood-stimulated species in association with flora tolerant of inundation (intermittent Swampy Woodland) (DSE, 2012)
- Submerged herbland of thin grass-like plants, occurring within brackish to saline waterbodies. The vegetation is characteristically extremely species-poor, comprising one or more species of *Lepilaena* spp. and/or *Ruppia* spp. (Saline Aquatic Meadow) (DSE, 2012).

Table 6: Ecological vegetation classes recorded at the site (Rakali, 2013)

EVC no.	EVC name	Source	Bioregional Conservation Status (Victorian Riverina Bioregion)
101	Samphire Shrubland	2013	Depleted
103	Riverine Chenopod Woodland	2013	Vulnerable
539	Brackish Lake Bed Herbland	2013	Vulnerable
813	Intermittent Swampy Woodland	2013	Vulnerable
842	Saline Aquatic Meadow	2013	Rare
Note: Bioregional Conservation Status' based on revised BCS compiled by D. Frood.			

An Index of Wetland Condition (IWC) assessment was undertaken in 2013 by Rakali (2013), where the majority of this wetland was assessed as Saline Aquatic Meadow (EVC 842) (as mapped in Appendix 7). This EVC is considered artificial at Lake Elizabeth being the product of salinisation, and comprises of extensive submerged beds of Large-fruit Sea Tassel, Long-fruit Water-mat and Stoneworts (including *Lamprothamneum macropogon* and *Nitella* spp.). It is believed that prior to salinisation this zone would have been occupied by Aquatic Herbland (EVC 653) and/ or Submerged Aquatic Herbland (EVC 918).

At the time of the assessment, the wetland was at approximately 30 per cent capacity and had a large area of exposed mudflats at the margins (M. Carter *pers comm.* August 2013). This mudflat zone was mapped as Brackish Lake Bed Herbland (EVC 539) and consisted mainly of bare mud or mats of dead Large-fruit Sea Tassel, with some living individuals of Lesser Sea-spurrey (*Spergularia marina*), Smooth Heliotrope (*Heliotropium curassavicum*), Creeping Monkey-flower (*Mimulus repens*) and Glaucous Goosefoot (*Chenopodium glaucum*). This zone would have supported Lake Bed Herbland (EVC 107) prior to salinisation (Rakali, 2013).

Fringing the Saline Aquatic Meadow (EVC 842) and Brackish Lake Bed Herbland (EVC 539) is Samphire Shrubland (EVC 101) followed by Intermittent Swampy Woodland (EVC 813) on the higher terraces. Both of these EVCs were separated into two distinct zones with Zone 1 generally supported a diversity of indigenous plants whilst Zone 2 contained a higher density of exotic weeds (Rakali, 2013). Riverine Chenopod Woodland (EVC 103) was also present at the high elevations of the western boundary of the wetland. Appendix 7 shows the EVC mapping undertaken at Lake Elizabeth in 2013 (Rakali, 2013).

Flora species

The flora of Lake Elizabeth has been altered dramatically in response to the changes in salinity levels in the past 100 years. Salt sensitive species have died out from the toxic effects of excess ions in their cells or by water deficiencies due to their inability to extract water from the surrounding soil. These species have been replaced with salt tolerant species (halophytes) such as Spiny Rush (*Juncus acutus*) and Water Button (*Cotula coronopifolia*) as well as aquatic salt tolerant species such as Large-fruit Sea Tassel, Long-fruit Water-mat and Stoneworts (Greenway & Munns, 1980 in Kelly, 1996).

A total of 107 species of vascular plant were observed in a survey conducted by Australian Ecosystems in 2012. Seventy of these species were indigenous with five listed as significant including FFG listed Buloke (*Allocasuarina luehmannii)* and Salt Paperbark (*Melaleuca halmaturorum* subsp. *halmaturorum*). A third FFG listed species Weeping Myall (*Acacia pendula*) has also been recorded, however this species is considered beyond its natural geographical distribution. Table 7 summarises the significant flora species recorded at Lake Elizabeth.

Table 7: Significant flora species recorded at Lake Elizabeth

Common name	Scientific name	Last record	EPBC status	FFG status	Vic status
Blackseed Glasswort	*Halosarcia pergranulata spp. Pergranulata*	2012			v
Buloke	*Allocasuarina luehmannii*	2012		L	
Cane Grass	*Eragrostis australasica*	1990			v
Deane's Wattle	*Acacia deanei*	2012			r
Salt Paperbark	*Melaleuca halmaturorum subsp. halmaturorum*	2012		L	v
Sea Tassel	*Ruppia maritima*	1990			k
Silver Mulga	*Acacia argyrophylla*	1990			x
Snow-wort	*Abrotanella nivigena*	1990			v
Weeping Myall#	*Acacia pendula*	2012		L	e

Legend
EPBC status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Not Listed
FFG status: Listed as threatened, Nominated, Delisted, Never Listed, Ineligible for listing
DSE status: presumed eXtinct, , endangered, vulnerable, rare, near threatened, data deficient, poorly known
Taxon which is both indigenous and naturalised and has extended beyond its original geographical distribution.

Although not listed three additional macrophyte species - Large-fruit Sea Tassel, Long-fruit Water-mat and Stonewort, are of particular importance at Lake Elizabeth (Figure 3). These species provide an important food source for a range of waterbirds, and historically would have provided shelter and a substrate for clutches of Murray Hardyhead eggs to attach to. Although sparse, Rakali (2013) identified all three species in the field and laboratory seed bank trials resulted in the germination of Stonewort and Large-fruit Tassel within eight weeks.

Figure 3: Left: Large-fruit Sea Tassel, Middle: Long-fruit Water-mat, Right: Stonewort (Rakali, 2013)

Large-fruit Sea Tassel was identified to be the most abundant species during the Rakali (2013) survey. The species is considered a relatively hardy aquatic plant species in Victoria and has a wide salinity tolerance. When conditions are favorable (including appropriate salinity, water temperature and turbidity) the species can form very dense mats, as was observed in the early 1990s (when Murray Hardyhead was present) at Lake Elizabeth (D. Cook *pers obs*. 2013). During the drought, when the wetland level dropped considerably, the community was reduced to a dead and/ or dying mat on the bed (NCCMA, 2010). Approximately 12 to 18 months post 2010-11 flooding, dense beds of Large-fruit Sea Tassel had again reestablished (Australian Ecosystems, 2012) suggesting that appropriate conditions will stimulate rapid reestablishment of the species.

3.1.4. Wetland depletion and rarity

Victoria's wetlands are currently mapped and are contained within a state wetland database, using an accepted statewide wetland classification system, developed by Andrew Corrick from the Arthur Rylah Institute (ARI). Mapping was undertaken from 1981 using 1:25,000 colour aerial photographs, along with field checking. This database is commonly known as the 1994 wetland layer and contains the following information (refer to Appendix 1):

- categories (primary) based on water regime
- subcategories based on dominant vegetation.

At the same time, an attempt was made to categorise and map wetland areas occupied prior to European settlement. This was largely interpretive work and uses only the primary category, based on water regime, referred to as the 1788 wetland layer.

It has been possible to determine the depletion of wetland types across the state using the primary category only, based on a comparison of wetland extent between the 1788 and 1994 wetland layers.

Comparison between the wetland layers has demonstrated the impact of European settlement and development on Victorian wetlands. This has been severe, with approximately one-third of the state's wetlands being lost since European settlement; many of those remaining are threatened by continuing degradation from salinity, drainage and agricultural practices (ANCA, 1996). Across the state, the greatest losses of original wetland area have been in the freshwater meadow (43 per cent), shallow freshwater marsh (60 per cent) and deep freshwater marsh (70 per cent) categories (NRE, 1997).

Under the mapping described above, Lake Elizabeth was originally classified as a permanent freshwater lake. This classification changed to permanent saline lake through salinisation as a result of its utilisation as permanent water storage in the Torrumbarry Irrigation system. This wetland type is the least depleted wetland category within Victoria and the area of permanent saline wetlands across Victoria is estimated to have decreased by two per cent since European settlement. Table 8 shows the current distribution of permanent saline lakes across the landscape and the proportion of the regional total that Lake Elizabeth contributes to.

Table 8: Current area of the site's classification in the region

Classification	Region			
	North Central CMA region	Goulburn-Murray Irrigation District	Victorian Riverina Bioregion	Victoria
Permanent saline lake (ha)	2,362	2,314	2,088	154,338
Lake Elizabeth (ha)	94	94	94	94
Lake Elizabeth as a proportion of the regional total	4%	4%	4.5%	0.06%

3.1.5. Ecosystem functions

Wetlands are considered ecologically important due to their role in maintaining biological diversity, promoting biochemical transformation and storage and decomposition of organic materials. They also provide crucial habitats for flora, invertebrates, fish, birds, reptiles, amphibians and mammals, improve water quality through filtration, control floods, regulate carbon levels and provide significant cultural and recreational values (DSE, 2007). Lake Elizabeth is known to provide all the ecosystem functions outlined above, as well as the following:

- Biodiversity- moderate to high diversity of waterbirds
- Threatened species and communities- supports a range of migratory and FFG listed waterbird species as well as significant flora species

- Priority wetland species and ecosystems- Lake Elizabeth once supported the critically endangered fish species Murray Hardyhead.

3.2. Social

3.2.1. Cultural heritage

The traditional owner group of the area including Lake Elizabeth is the Wemba Wemba (Wamba as an alternative spelling). To date Lake Elizabeth has not been surveyed for aboriginal sites, however it is within close proximity to other sites within the Kerang Lakes Area that are considered significant archaeological areas (e.g. Avoca Marshes) in Victoria.

3.2.2. Recreation

Lake Elizabeth is used for passive recreational pursuits including bird watching, recreational driving, picnicking and other nature based activities (Heron & Nieuwland, 1989). Prior to salinisation, the wetland was also a popular recreational fishing area (Kelly, 1996). When wet, the main recreational pursuit at the wetland is duck hunting (North Central CMA, 2010). The ability to provide these recreational values relies heavily on the wetland being in an appropriate ecological condition, through the provision of environmental water.

3.3. Economic

The economic value of a particular wetland to the regional economy can be quite difficult to measure. For the purpose of this Plan, a general discussion of the economic benefit of wetlands is provided, based on ACF (2010).

There are direct and indirect uses of wetlands which generate economic benefit on a local, regional and wider scale (ACF, 2010). Direct uses of Lake Elizabeth include the income generated from recreational pursuits and tourism, while indirect ‘uses’ include ecosystem services such as groundwater recharge, flood mitigation, nutrient treatment and carbon storage (DEWHA, 2010). In addition, other values can be placed on Lake Elizabeth, including its economic value to surrounding communities generated through duck hunting, camping and fishing.

4. Hydrology and system operations

Wetland hydrology is the most important determinant in the establishment and maintenance of wetland types and processes. It affects the chemical and physical aspects of the wetland which in turn affects the type of flora and fauna that the wetland supports (DSE, 2005). A wetland's hydrology is determined by surface and groundwater inflows and outflows in addition to precipitation and evapotranspiration (Mitsch & Gosselink, 2000)). Duration, frequency and seasonality (timing) are the main components of the hydrological regime for wetlands and rivers. Appendix 5 details the recent watering history of Lake Elizabeth.

4.1. Water management and delivery

4.1.1. Pre-regulation

Lake Elizabeth is a natural deflation basin characterised by a lunette at the east side which rises by up to ten metres above the wetland (Kelly, 1996). Naturally, water would have originated from the interconnecting Wandella and Venables creeks, which break away from the Loddon River approximately 30 kilometres upstream (south). The Wandella Creek, which flows parallel to the Loddon River, links a series of Black Box depressions, namely Leaghur Forest, Appin Forest and finally Wandella Forest which is situated only two kilometres to the west of Lake Elizabeth. During flood events, several break-away creeks would flow out from the Wandella Forest at varying flood levels. One of the main creeks would flow from a deep section named Flaxy's Swamp in the north-west corner of the forest. This creek would carry water northwards along the east side of Lake Elizabeth's lunette before circling around the northern end of the wetland entering in the north-west corner (see Figure 4) (Macumber, 2002 and R. O'Brien, DPI *pers. comm*. 2009 cited in North Central CMA, 2010).

The natural hydrological cycle of Lake Elizabeth would have followed a pattern of flooding in winter and spring with drawdown due to evaporation and groundwater recharge occurring over the summer months (SKM, 2004). This cycle would have resulted in a periodic flushing of the wetland and its salts, allowing it to be maintained as a permanent freshwater system (Kelly, 1996). This fluctuating water level would have supported a diversity of aquatic and terrestrial flora and fauna (R. O'Brien, DPI, *pers. comm*. 2009 cited in North Central CMA, 2010).

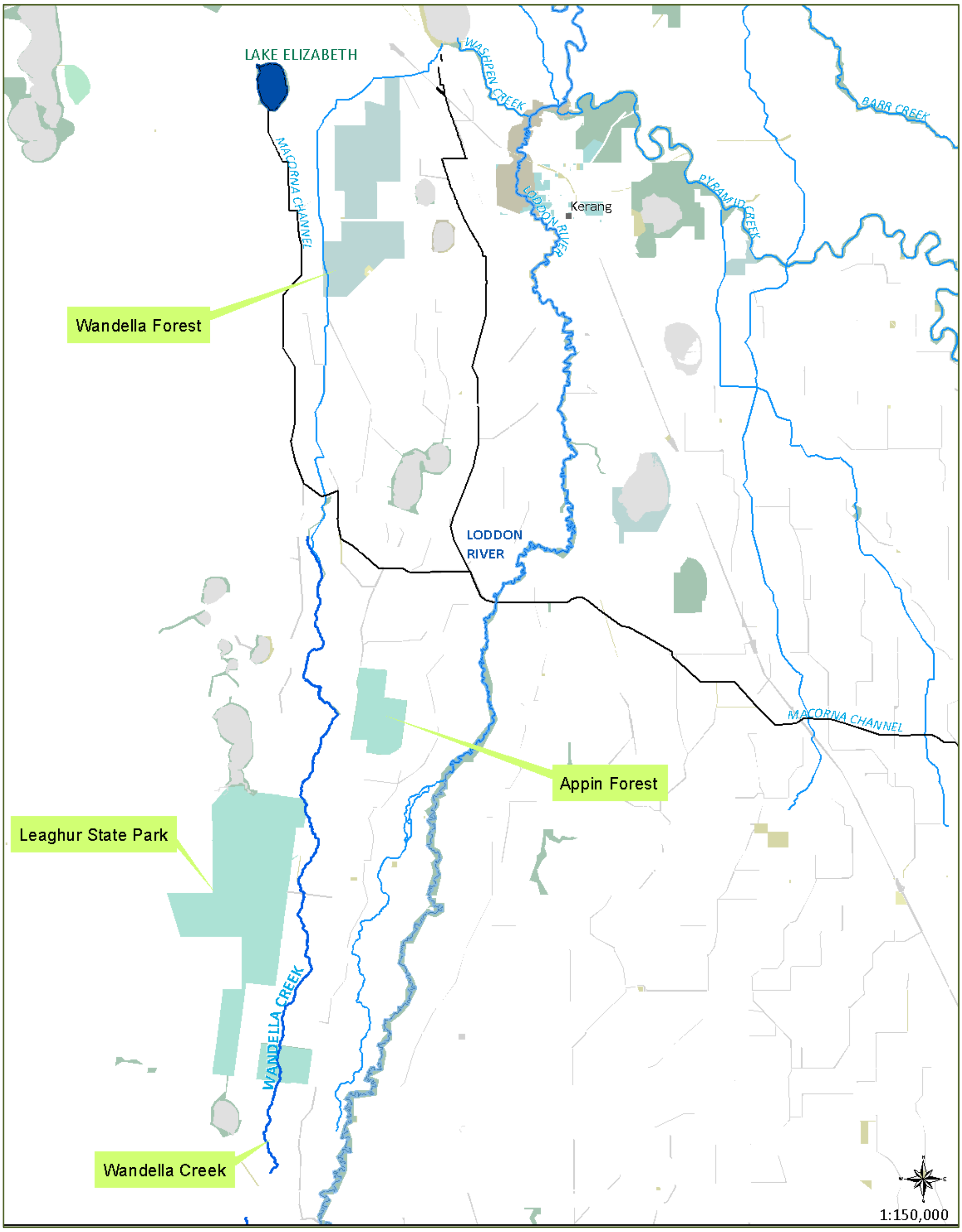


Figure 4: Natural hydrology of Lake Elizabeth

4.1.2. Post-regulation

The Kerang Times and Swan Hill Gazette (11 October, 1878 pp. 2) reported that widespread drought in the Loddon Catchment (thought to have began in 1877) caused Lake Elizabeth to dry during 1878. Regulation of the Loddon River began in earnest during the drought with the construction of a series of channels and weirs (Serpentine, Bridgewater, Kinypaniel, Lake Leaghur, Kerang Weir etc) (The *Australasian*, 8 April 1882 pp. 25). Shortly thereafter (thought to be the early 1880s) a channel was cut to allow water to be delivered directly to Lake Elizabeth (*Bendigo Advertiser*, 25 January 1884, pp. 2).

From the late 1880s to the 1980s Lake Elizabeth was used as a freshwater irrigation storage. Diversions flushed the wetland allowing it to remain relatively fresh, which is evidenced by Murray Cod records from the mid 1920s (DEPI, 2013b). However, reports indicate that the salinity began to rise from a relatively fresh state (approximately 650 EC) in the 1950s to levels of approximately 40,000 EC in the 1970s (Hydrotechnology, 1995). When farmers obtained water rights in the early 1970s, diversions ceased and the wetland effectively became a terminal system (Kelly, 1996). Salt began to accumulate and salt tolerant aquatics such as Sea Tassel established and thrived.

At around the same time as the cessation of diversions, Murray Hardyhead was discovered in Lake Elizabeth (first recorded by ARI in 1971). At the time a small number of sites in the Kerang and Swan Hill area had also been recorded containing Murray Hardyhead (Macumber, 2007).

Anecdotal evidence suggests that historically Lake Elizabeth rarely dried. Significant outfall water averaging 800 ML/yr in the 1990s from the No. 2 channel system assisting with maintain this level (R. O'Brien, DPI, *pers. comm.* 2009 cited in North Central CMA, 2010). However channel outfalls to the wetland decreased significantly over the following eight years due to a combination of increased channel efficiencies, lower water allocations, reduced rainfall and low catchment runoff (R. O'Brien *et al.,* 2009 cited in North Central CMA, 2010). Reduced inflows resulted in a lowering of the water level and subsequently a rise in salinity, with levels peaking in 1997-98 at nearly 60,000 EC (Lyon et al. 2002 cited in Macumber, 2002).

To counteract the potential impacts rising salinity levels would have on the Murray Hardyhead, environmental water from the *Bulk Entitlement (River Murray- Flora and Fauna) Conservation Order 1999* was regularly allocated (2002 onwards) to maintain salinity levels below 45,000 EC (DSE, 2006). Table 9 shows the watering history of Lake Elizabeth, which is also presented in further detail in Appendix 8.

Unfortunately in 2003 only a year after environmental water was first allocated to the wetland for Murray Hardyhead, a second peak salinity event of approximately 60,000 EC was experienced. Consecutive surveys for Murray Hardyhead in 2004, 2005 and 2006 failed to confirm the presence of the species and an environmental water allocation was not provided in 2007-08. It is now understood that adults can tolerate periods of elevated salinity, however juveniles and eggs are more sensitive (SKM, 2004). Further to this a significant algae bloom also occurred in the same year, and it is likely that both events caused irreversible damage to the population (B. Mathers *pers comms*. 2013).

A reduction in outfall volumes received by the wetland, dry climatic conditions and reduced environmental water availability meant that Lake Elizabeth began to drawdown in 2007. However a complete drawdown was counteracted for a number of years due to a period of considerable G-MW channel outfall entering the wetland. Records indicate that the wetland dropped to 71.5m AHD (40 cm of depth) in 2009 (Plate 1) before almost completely drying in 2010 (see Figure 5). This coincided with a period of lower than average groundwater levels (as can be seen in Figure 6).

No environmental water has been allocated to the wetland since 2007 and as at August 2013 the level was at approximately 72.3m AHD (Plate 2) (M. Carter *pers comm.,* 2013).

Table 9: Lake Elizabeth wetting/ drying calendar

Year	99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13[3]
Wetting / drying cycle[1]	w	w	w	w	w	w	w	w/d	w/d	w/d	w/d	w	w/d	w/d
Water Source[2]	TIS	TIS	TIS	E/ TIS	E/ TIS	E/ TIS	E/ TIS	E/ TIS	TIS	TIS	TIS	F	N/A	N/A

Note [1]: w – water present, d – wetland dry
Note [2]: U – unknown, E – environmental water allocation, TIS – Torrumbarry Irrigation System, F- flood inundation
Note [3]: as at November 2013.

Plate 2: Lake Elizabeth at 71.5m AHD in March 2009

Plate 3: Lake Elizabeth at 72.3m AHD in August 2013

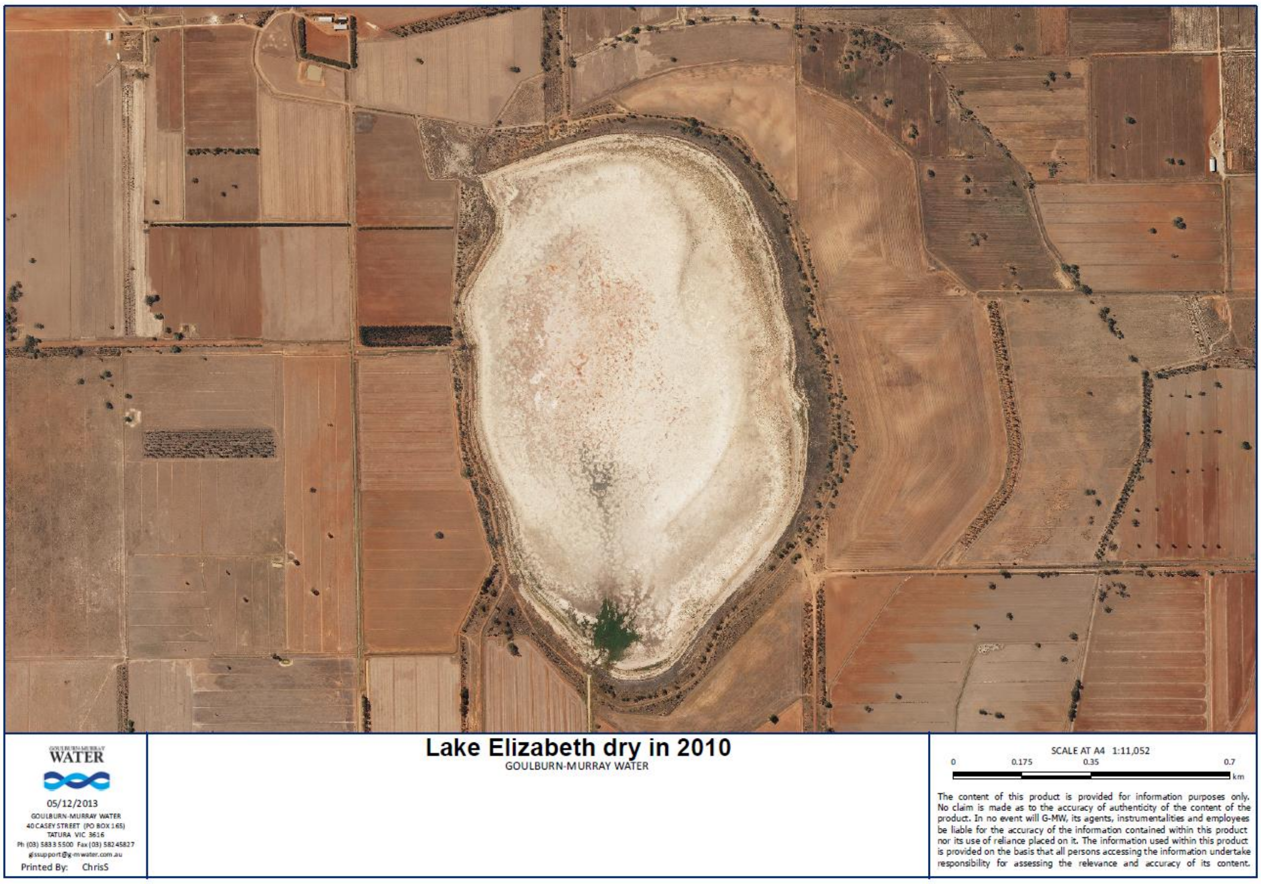


Figure 5: Aerial photograph of Lake Elizabeth 2010 C. Solum from G-MW CP, 2013

4.1.3. Surface water/ groundwater interactions

Lake Elizabeth is formed in the uppermost regional stratigraphic unit of the Riverine Plains known as the Shepparton Formation. The Formation comprises layers of clay and sand and it varies in thickness from approximately 20 metres in the east of the wetland through to about five metres in the west. The difference in thickness appears to be attributable to post-depositional vertical displacement along the north-south trending Leaghur fault.

The Shepparton Formation conformably overlies the regional Parilla sand aquifer at depth. This fine-grained marine sand varies in thickness from about 30 to 50 metres. The Parilla Sand comprises saline groundwater that ranges in salinity from 30,000 to 50,000 EC (Macumber, 1991).

Prior to the 1990s it was assumed that Lake Elizabeth was a closed system, with a sealed and impermeable wetland bed that had no potential to exchange water (and salt) with the underlying groundwater system. This raised concern that without intervention the wetland would increase by 1,650 EC/ year and eventually become hypersaline (>110,000 EC) (Hydrotechnology, 1995 and SKM, 1998). However through the use of extensive data and interpretation, Macumber (2002, 2006 and 2007) concluded that Lake Elizabeth was in fact a through-flow system (groundwater, including salt moves into and out of the wetland) and that large amounts of salt entered and exited the wetland seasonally. The regional groundwater flow direction was determined to be north-westerly with a hydraulic head generated from the Loddon floodplain and the Wandella Forest to the south-east. In wetter periods, the groundwater flow towards the wetland is strong, but in drier periods flow is significantly reduced.

The ability for Lake Elizabeth to exchange surface and groundwater has been exacerbated by increased European development in the Kerang Lakes area. This includes the removal of deep rooted trees, the advent of irrigation practices as well as the construction of road crossing and levees which has increased accession to the watertable (Kelly, 1996). Compounding this is the cumulative impact of winter rainfall followed by summer and autumn irrigation application. This has resulted in regional groundwater heads within and around Lake Elizabeth rising from approximately 4-6 metres to 0-2 metres below the surface (72 to 74m AHD). As the Parilla Sand is not confined by the Shepparton Formation, groundwater heads in the Parilla are consistent with the elevated watertable in the vicinity of Lake Elizabeth. This was the cause of the 117,000 EC groundwater outcrop (as confirmed by a sample tested in September 2013) recently recorded at Lake Elizabeth. The high salinity is the likely result of saline groundwater in the base of the wetland that has been concentrated further by evaporation. This is supported by Figure 6 which shows that the groundwater has remains above the bed level (71.01m AHD) at all times. Appendix 10 shows the location of groundwater bores surrounding Lake Elizabeth.

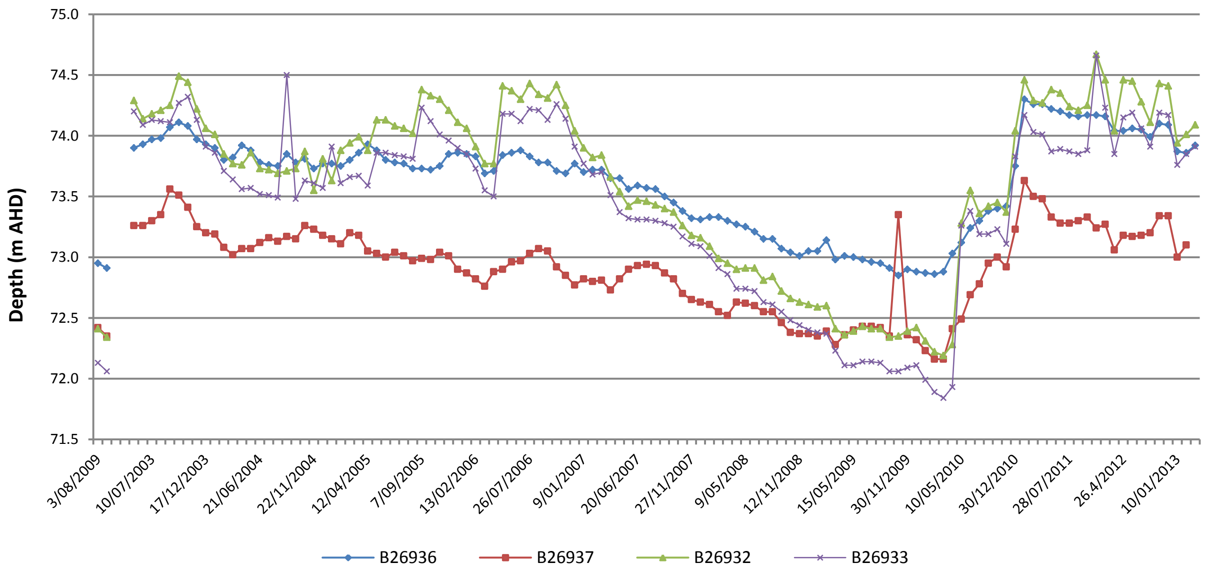


Figure 6: Groundwater bore data (August 2009 to January 2013)

4.1.3.1. Salt and water balance model

A salt and water balance model was developed specifically for this EWMP to investigate the surface and groundwater interactions at Lake Elizabeth when filled. The model further predicts the time required to reduce salinity to a set target level if fresh inflows are continually provided.

Previously, the EWP used a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) model however this particular model did not take into account groundwater and was therefore deemed inappropriate for future use at Lake Elizabeth, which requires an understanding of both surface and groundwater interactions.

A range of scenarios, with varying salinity, water height, seepage and re-filling regimes, were tested using the salt and water balance model. The following data, steps and assumptions underpin the results of the model as outlined below:

Climate: The salt and water balance model utilises Class A pan data dating back to the early 1990s. The data was supplied by Roger (Climate Change expert) and Elaine Jones from the 'Model Farm' in Kerang. A bird gauge fitted over the monitoring station has been estimated to reduce evaporation to 82 per cent of pan which was compensated for in the model (pan evaporation rates were brought back to 100 percent before actual evaporation was calculated). A pan coefficient of 0.78 was then applied to all monthly values to estimate actual evaporation from Lake Elizabeth.

Wetland Filling: The model assumes that the wetland would be re-filled at the end of each month after evaporation and seepage until a target salinity of 40,000 EC (the maximum operating salinity level) is reached. The model therefore begins by filling Lake Elizabeth at the end of December and computes heads and salinities during the months of the following year. The model fills the wetland each month to a target head level. For Lake Elizabeth the model was run for two water height scenarios, 73m AHD and 73.5m AHD.

Bathymetry and estimation of volumes: A regression equation was used to estimate wetland volume from level based on the bathymetric rating table for Lake Elizabeth shown in Appendix 9 (Price Merrett, 2013).

Evaporation and leakage: The model allows the wetland to fall each month by an amount dictated by evaporation and leakage to groundwater. The former is taken from 'Kerang farm' data whilst the latter is nominated in accordance with expected values. Muirhead *et al.* (1997) suggests that leakage might be in the range of 1 to 3 mm/day for the Riverine Plains region. This is also supported by Girdwood (1978) who found that the average seepage rate in Kerang evaporation basins over a three to four year periods was of 3 mm/day. This seepage rate was further adopted by Macumber (2007) for the Lake Elizabeth conceptual model. Therefore a conservative rate of 1mm/day was adopted in this model; however it is important to note that a rate higher than 1mm/day would result in a faster loss of salt from the system. Further to this, leakage in this model is computed after each wetland fill using the wetland full area and volume at a chosen depth. The model also assumes that hydraulic pressure and subsequently leakage is greatest when the wetland is filled. However the model does not take into account that evaporation reduces as salinity increases. For example evaporation in saline water can be reduced as much as ten per cent if salinities are 40,000-50,000 EC.

Starting salinity and level: The model uses a starting salinity of 117,000 EC and a level of 72.3m AHD, as recorded in the field in September 2013. The model deals with salinity and seepage in the following ways:

(a) It calculates the mass of salt in the wetland prior to filling. This is simply a matter of multiplying the volume of water in the wetland by the salinity of the water.

(b) It allows the wetland to fill to the nominated supply level (73 and 73.5m AHD used) and computes the additional salt added to the wetland through the feed water.

(c) It calculates the salinity of the wetland at the nominated supply level. The calculation simply divides the total salt load by the volume at the nominated level.

(d) Salt loss from the wetland is calculated by multiplying the nominated daily seepage value (1mm/day) by the period of interest. In this case monthly re-filling was used in the time step therefore the length of time in each increment was either 30 or 31 days. Hence seepage for a 30 day period is 30mm, or 0.3 ML per hectare. For example at the target level of 73.5m AHD the area of the wetland is about 88 hectares, so monthly seepage is about 26 ML. The seepage volume is then multiplied by the computed target level salinity to get salt lost from the wetland over the month.

(e) The model then refills the wetland at the end of the month and calculated the new salinity by accounting for salt introduced in the feed water and the salt lost over that month through seepage. When the wetland is receiving regular top-ups more water than salt is being introduced and as a result the salinity will fall over time.

(f) The model runs all of the above through an iterative process of each month of the year and combines it with evaporation. This approach afforded a simple water balance that provides some useful estimated within a narrow timeframe.

Note: Evaporative concentration can only increase the salt load of the wetland when it is near empty and the water it holds is outcropped saline groundwater. When the wetland begins to fill the regional groundwater head is overcome by the head added to the watertable. That is, a vertical downward gradient is produced and the wetland begins to leak. From this point onwards the only salt that can enter the wetland is from the feed water and in this instance that mass is considered fairly small (300 EC).

The results of the model show that the Lake Elizabeth is extremely sensitive to leakage. The model predicts that leakage as small as 1 mm/day will reduce salinity within the wetland from about 48,000 EC through to about 37,000 EC in December if filled to 73.5m AHD. This occurs because seepage removes large amounts of salt from the wetland. When the wetland is re-filled (i.e. from the addition of environmental water) the salinity of the wetland is diluted further. The model calculates the residual salt load of the wetland and computes salinity after refilling. It also calculates salinity after evaporation and seepage ahead of each fill. Those values range from around 53,000 EC in January through to about 42,000 EC in the following December when using a target height of 73.5m AHD. The pre and post filling values provide that range of salinities that will occur throughout the year.

The model also demonstrates that when both evaporation and seepage are accounted for on a monthly basis, the salinity of Lake Elizabeth will decrease over time. At a salinity target of 40,000 EC, these substantive changes might be expected over a period as short as 12 months, as shown in Figure 7.

Once the target is reached, it is assumed that environmental water delivery could be used to further manipulate salinity and mimic natural water level fluctuations on an annual basis. This could be undertaken to further reduce salinity (continuing to top-up to target level), maintain salinity (reduce the volume delivered) or increase salinity (not providing environmental water). It is however vital that the assumptions underpinning this model are proven in the field to provide certainty for environmental water management and the future health of the wetland (see Section 6).

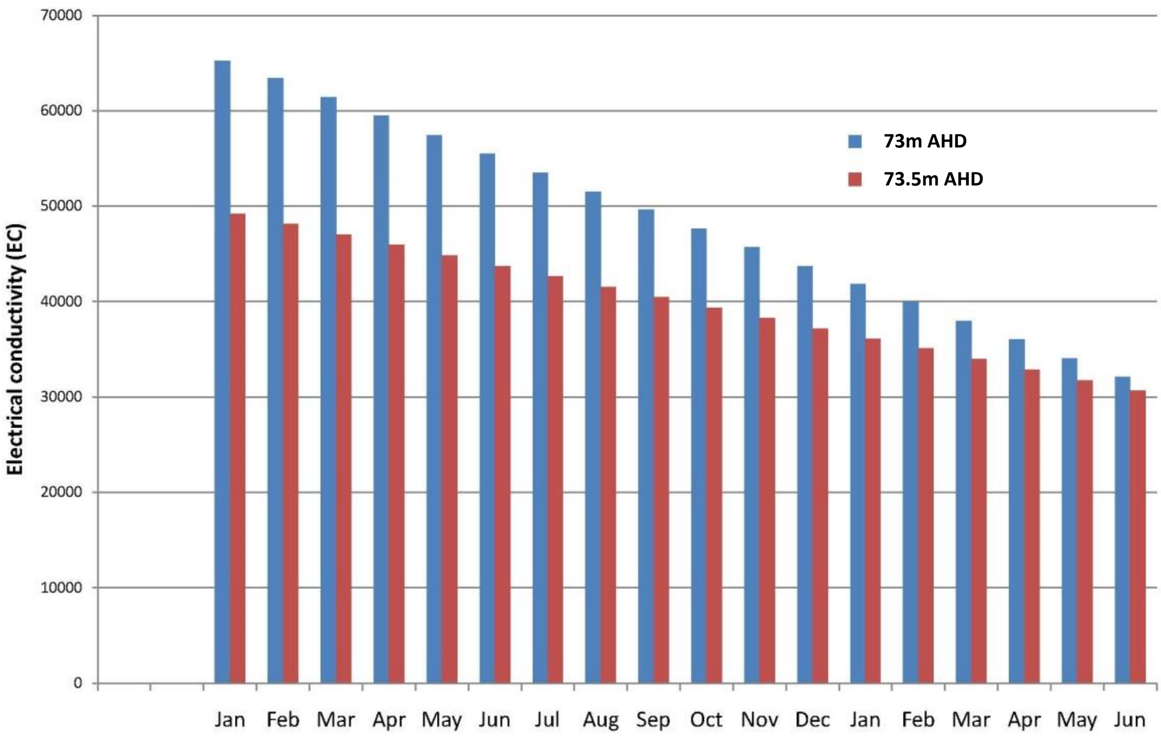


Figure 7: Salinity prediction after monthly refill

5. Condition and threats

5.1. Current condition

An Index of Wetland Condition (IWC) assessment was undertaken at Lake Elizabeth over 2009-10 period. The IWC defines wetland condition as the state of the biological, physical, and chemical components of the wetland ecosystem and their interactions. Future information on the IWC process can found in Appendix 11 (DSE, 2007).

The method undertaken under the IWC involves measuring five sub indices based on the catchment of the wetland and its fundamental characteristics of physical form, hydrology, water properties, soil and biota.

Table 10 shows the IWC scores for Lake Elizabeth and highlights that the wetland was considered in moderate condition overall, with the main concern relating to the wetland catchment, followed by hydrology, water properties and wetland biota (the diversity, health and weediness of the native wetland vegetation).

Table 10: Index of Wetland Condition score recorded for Lake Elizabeth (2009-10)

IWC Sub-Index	Score	Condition Category
Wetland catchment	7/20	Poor
Physical form	20/20	Excellent
Hydrology	10/20	Moderate
Water properties	10/20	Moderate
Soils	20/20	Excellent
Biota	15.78/20	Moderate
Overall IWC Score	**6/10**	**Moderate**

In 2012, the biota component of the IWC was reassessed at Lake Elizabeth as part of a wetland terrestrial and vegetation condition monitoring study undertaken by Australian Ecosystems (2012). The study revealed that the original 2009-10 vegetation assessment was compared against benchmarks correlating to what the vegetation appeared to be in its current form, rather than against the likely EVCs present prior to European development, as specified in the IWC methodology (DSE, 2012). Therefore two scores were developed, one that used the previous methodology, and one that used the conventional methodology. The results are shown in Table 11.

Table 11: Index of Wetland Condition Biota score comparison

IWC biota score survey	Score	Condition category
2009-10	15.8/20	Moderate
2012 (as per 2009-10 methodology)	18.7/20	Excellent
2012 (as per IWC methodology)	12/20	Poor condition

When comparing the 2009-10 score with the 2012 (as per 2009-10 methodology) score, the condition of the vegetation appears to have improved and is now in excellent condition. However these scores are based on the wetland being a naturally saline lake, which in reality is not the case. When the IWC is assessed against the actual pre-European classification of freshwater lake, a much lower score is generated, and the biota is considered in poor condition. Australian Ecosystems has recommended that in the future, the conventional IWC methodology is adopted for all assessment of Lake Elizabeth. This will see the wetland assessed as a freshwater system that has become saline, rather than a naturally saline lake.

5.2. Water dependent threats

General threats to the wetlands analysed through the Plan process have been informed by the Aquatic Value Identification and Risk Assessment (AVIRA) process developed by DEPI (DSE, 2009b). The threat categories are outlined below and these have been used to identify specific threats and their likelihood of impacting Lake Elizabeth (shown in Table 12).

Altered water regime (specifically relating to a changed water regime):

The hydrology of a wetland is an important component to consider for the overall ecological functioning of a site. Hydrology drives the development of wetland soils and the biotic communities (DSE 2009b).

AVIRA (DSE, 2009b) specify that activities with the potential to cause a change in water regime are those that:

- change the flow regime of the water source of the wetland
- interfere with the natural connectivity of flow to and from the wetland
- involve disposal of water into the wetland or extraction of water from the wetland
- change wetland depth and, therefore, alter the duration of inundation by changing the rate of evaporation (DSE, 2005c cited in DSE, 2009b).

Altered physical form (specifically relating to reduced wetland area and altered wetland form):

Physical form of a wetland is related to the wetland area and wetland bathymetry (DSE, 2005c cited in DSE, 2009b). AVIRA notes the key threats to physical form as being (DSE, 2009b):

- reduction in wetland area (through drainage or infilling)
- alteration in wetland form – depth, shape, bathymetry (through excavation, landforming or sedimentation).

AVIRA also notes that the realisation of the threats listed above can modify the availability of wetland for biota through changes in water depth and its resultant impact on duration and inundation area (DSE, 2005c, DSE, 2006b cited in DSE, 2009b).

Poor water quality (specifically relating to degraded water quality):

Degrading water quality in this instance is particularly focused on landuse activities which impact the water in, or entering the wetland. Within the wetland itself, examples of landuse activities which can degrade the water quality include livestock grazing, feral animals and aquaculture. Catchment land practices with potential to degrade wetland water quality include clearing of vegetation, land uses such as agriculture or urbanisation, fire, poor irrigation practices and point source discharges (DSE, 2009b). Both these aspects may be manifested by changes in several physical and chemical water properties (e.g. nutrient enrichment, salinisation and turbidity) (DSE, 2005c cited in DSE, 2009b).

Degraded habitats (soil disturbance in particular):

The soils of wetland habitats are vital component for the wetland to function as a whole. It provides the physical substrate which aquatic vegetation requires to establish, and provides habitat for benthic invertebrates and microorganisms. The threatening processes which can impact wetland soils include pugging by livestock and feral animals, human trampling, driving of vehicles in the wetland and carp disturbance (DSE, 2009b), resulting in soil disturbance which can reduce water storage capacity of soil, can have negative impacts on some invertebrates and increase turbidity during wetland filling events (DSE, 2008e cited in DSE 2009b).

Exotic flora and fauna (including terrestrial and aquatic species):

The presence of exotic flora (i.e. species introduced from outside Australia) in the terrestrial and aquatic zones of wetlands causes harm when the extent of the exotic species replaces the native EVC components. When this occurs, there can be a threat to biodiversity and primary production of the wetland, increasing the land and water degradation and impacting the native flora and fauna species of the site.

Exotic fauna species can also pose a threat to the biodiversity of wetlands, along with its primary production potential (DSE, 2009b). This occurs when the exotic species disturb the functioning of the native vegetation and/or displace native fauna species.

Reduced connectivity (reduced wetland connectivity):

Wetland connectivity is most likely to occur where there are a series of habitat areas arranged in close proximity through the landscape, for example the Kerang wetland complex and the Boort wetland complex (DSE, 2009b). DEWHA and DAFF (2008) cited in DSE (2009b) define connectivity as 'the location and spatial distribution of natural areas in the landscape to provide species and populations with access to resources (food, breeding sites and shelter), increase habitat availability and facilitate population processes (dispersal, migration, expansion and contraction) and enable ecological processes (evolution, water, fire and nutrients)'.

When connectivity is reduced through a landscape, there is less opportunity for population to move from one spot to another in the search for food, habitat and population processes.

Table 12: Possible threats and likelihood of detrimental impacts occurring at Lake Elizabeth

Threat	Likelihood of detrimental impact on wetland[1]	Comment
Altered water regime	Medium	Lake Elizabeth has changed from a permanent freshwater lake to a permanent saline lake through its inclusion and later exclusion in the Torrumbarry Irrigation System. The construction of levees and roads has also cut the wetland off from its natural floodplain. Although these changes have caused severe impacts to the wetland, it is unlikely that future change will take place. The threat is therefore considered relatively stable and future alterations to the water regime are unlikely in the future.
Altered physical form	Low	Physical form has not changed significant from historical, and is unlikely to alter significantly in the future.
Poor water quality	High	The change from a freshwater lake to a saline lake has dramatically altered the wetlands water quality. The inability to flush the wetland as well as the strong interaction between groundwater and surface water continues to influence the wetlands salinity. There is however potential to improve this threat by focusing water management on water quality.
Degraded habitats	Medium	The habitat of Lake Elizabeth has changed considerably due to the shift in wetland classification. Historically a number of revegetation programs have been undertaken to assist with habitat improvement.
Exotic flora and fauna	Low - medium	Exotic fish (European Carp and Gambusia) impacting on water quality (i.e. mumbling) and native species (i.e. predate on Murray Hardyhead). Terrestrial species such as European rabbit, foxes and hares also seek harbour in the thick salt bush at Lake Elizabeth.
Reduced connectivity	High	Connectivity has reduced as compared to natural conditions through the construction of roads and levees. Species and propagules dependent on water for moving are selectively disadvantaged, and will only reach the site in major floods.

[1]**Key:**
- Low- little to no impact likely
- Medium- some impact likely
- High- detrimental impacts expected

5.3. Condition trajectory

The main concern for the trajectory of Lake Elizabeth relates to the ability to dry the wetland under the EWPs optimum one in three year watering regime. The investigations undertaken to develop this EWMP have revealed that the current water level is the product of groundwater outcropping and subsequently a complete dry is unachievable under current watertable levels. Therefore allowing the wetland to remain in its current highly saline form poses significant risks to not only the flora values but the wetlands ability to provide habitat for waterbirds and macroinvertebrates (see Plate 4).

A more appropriate management scenario for Lake Elizabeth would be to operate it as a permanent wetland. The EWP includes this option under its maximum regime; however the EWP fails to fully address the relationship between water level and salinity and the implications of this relationship on flora and fauna values.

Further to this, it is vital that additional Murray Hardyhead sites are established in Victoria to prevent extinction of the species in the future. Records indicate Lake Elizabeth has maintained a Murray Hardyhead population from the 1970s through to the early 2000s, whilst supporting high waterbird numbers. The salt and water balance model predicts that salinity levels appropriate for Murray Hardyhead could be achieved in the near future. However a trial filling should be undertaken to monitor the assumptions that underpin the model and to examine the wetland's response (both vegetation and salinity) to re-filling prior to translocation of Murray Hardyhead.

Plate 4: Lake Elizabeth 15 of August 2013 and 27 November 2013 showing the wetland's condition

6. Management objectives

6.1. Management goal

Two management goals have been proposed at Lake Elizabeth focusing on short term (over the next one to three years) and long term (future) management. Both goals are derived from a variety of sources, including historic management goals, groundwater investigations, the Lake Elizabeth EWP and the Recovery Plan for Murray Hardyhead. It considers the values the wetland supports and potential risk factors that need to be managed e.g. salinity, translocation.

Short term (next one to three years) environmental water management goal for Lake Elizabeth

To provide an appropriate water regime that maintains Lake Elizabeth as a permanent, saline wetland that supports Saline Aquatic Meadow (EVC 842) vegetation, particularly Large-fruit Sea Tassel, Long-fruit Water-mat and Stonewort.

Long term (future) environmental water management goal for Lake Elizabeth

To provide an appropriate water regime that maintains Lake Elizabeth as a permanent, saline wetland whilst providing habitat for reintroduction of the critically endangered Murray Hardyhead through maintenance of appropriate water quality and the provision of Saline Aquatic Meadow (EVC 842) vegetation, particularly Large-fruit Sea Tassel, Long-fruit Water-mat and Stonewort.

Please note: *the potential to achieve the above long term management goal should be trialled using a rigorous field based monitoring program. This program will monitor the response of the wetland to environmental water delivery and test the assumptions underpinning the salt and water balance model. The results of the trial will reveal the feasibility of achieving conditions appropriate for Murray Hardyhead translocation in the future.*

6.2. Ecological and hydrological objectives

6.2.1. Ecological objectives

Ecological objectives are the desired ecological outcomes of the site. In line with the Victorian waterway management strategy, the ecological objectives are based on the key values of the site (as outlined in Section 3) (e.g. Campbell *et al.,* 2005). The ecological objectives are expressed as the target condition or functionality for each key value. The ecological objectives involve establishing one of the following trajectories for each key value, which is related to the present condition or functionality of the value (informed by Marquis-Kyle and Walker, 1994; Campbell *et al.,* 2005).

Protect – retain the biodiversity and/or the ecosystems at the existing stages of succession.

Improve – improve the condition of existing ecosystems by either returning an area of land to an approximation of the natural condition or to a known state.

Maintain – maintain the biodiversity and/or ecosystems while allowing natural processes of regeneration, disturbance and succession to occur.

Reinstate – reintroduce natural values that can no longer be found in an area.

Reduce - reduce the abundance and cover of undesirable exotic species that impact upon native values.

As part of the Lake Elizabeth EWP, a range of ecological objectives and hydrological requirements were presented to agency stakeholders and technical experts through the Wetland Workshop and the Expert Review Panel (ERP) in March 2009. These objectives and requirements focused primarily on supporting the submerged salt tolerant aquatic plant assemblage whilst providing habitat for a range of waterbird species through expansion of the littoral zone (NCCMA, 2010).

Similarly, this EWMP focuses on supporting the same ecological values however emphasis is placed on the values that may assist with the long term management goal of Murray Hardyhead translocation. It is also worth noting that although the goals previously identified in the EWP revolved around a semi-permanent system, all can still be achieved to some extent under a permanent regime. For example the goal of promoting mudflat margins can still be achieved by providing water height variability throughout the year, which also aligns with the lifecycle requirement of Murray Hardyhead. Table 13 details the short and long term ecological objectives for Lake Elizabeth.

Table 13: Ecological objectives for the site

<table>
<tr><th rowspan="2">Ecological objective</th><th colspan="2">Justification (value based)</th></tr>
<tr><th>Short term</th><th>Long term (in addition to short term)</th></tr>
<tr><td colspan="2">Habitat objectives</td><td></td></tr>
<tr><td>Maintain/ reinstate submerged aquatics (i.e. Large-fruit Sea Tassel, Stonewort and Long-fruit Water-mat)</td><td>• Provision of habitat and food sources for waterbird species
• Provision of vegetation seed source for on-going recruitment
• Key primary producer</td><td>• Food and habitat (shelter and spawning substrate) for Murray Hardyhead</td></tr>
<tr><td>Restore and maintain (expansion) of chenopod shrubland from the littoral zones to wetland margins</td><td>• Habitat and food source (fruits) for waterbirds and waders
• Improves soil condition and structure for micro-organisms and invertebrates</td><td>• Micro-organism and invertebrates provide a food source for Murray Hardyhead in the littoral zone</td></tr>
<tr><td>Restore littoral zone of wetland</td><td>• Open water and mudflat habitat for waterbirds
• Seed germination and recruitment</td><td>• Fluctuation of littoral zone causes release of nutrients important during Murray Hardyhead spawning periods</td></tr>
<tr><td colspan="2">Species/ community objectives</td><td></td></tr>
<tr><td>Restore breeding of waterbirds</td><td colspan="2">• Linked to habitat objectives
• Records of Australian Pelican, Blue-billed Duck and Black Swan breeding at Lake Elizabeth</td></tr>
<tr><td>Restore feeding opportunities (food source for waterbirds)</td><td colspan="2" rowspan="2">• Linked to habitat objectives
• Vegetation supports high abundance of invertebrates as a food source for waterbirds</td></tr>
<tr><td>Restore diversity and abundance of invertebrates</td></tr>
<tr><td>Maintain and support breeding of Murray Hardyhead</td><td>N/A</td><td>• Linked closely to habitat objectives
• A critically endangered fish species
• Increase the number of Murray Hardyhead populations in Victoria</td></tr>
<tr><td colspan="3">Process objectives</td></tr>
<tr><td>Maintain salinity within 25,000 to 40,000 EC</td><td>• Linked to water dependent habitat objectives
• Promotes high productivity for waterbirds</td><td>• Excludes Gambusia the primary predator of Murray Hardyhead
• Supports aquatic vegetation required by Murray Hardyhead for food and shelter</td></tr>
</table>

6.2.2. Hydrological objectives

Hydrological objectives describe the components of the water regime required to achieve the ecological objectives at this site. The hydrological objectives are derived from an understanding of the local hydrology, using a 'landscape logic' for the site (Figure 9). The landscape logic identifies the relationship between vegetation communities, ecological objectives, position in the landscape and hydrological objectives (i.e. flow requirements).

The hydrological objectives defined for Lake Elizabeth has been based on the Lake Elizabeth EWP (North Central CMA, 2010), Rakali (2013) as well as various Murray Hardyhead resources (see Reference section) and local knowledge.

As noted in section 6.2.1, Lake Elizabeth should initially be managed for a short-term management goal. This goal focuses primarily on regeneration of the salt tolerant aquatic plants that drive the ecological of the wetland. Ideally the wetland should be slowly filled (increments of approximately 30cm each month) in late winter/ early spring to reduce the potential for turbidity and increase the opportunity for multiple germination events. This slow delivery will further benefit aquatic vegetation by allowing adequate time to adapt to changes in salinity, water temperature and depth.

The target level of Lake Elizabeth should be dictated by salinity (not a prescribed height) and therefore delivery should cease if salinity reaches 25,000 EC (minimum salinity requirement for Murray Hardyhead) or if a maximum height of 73.2m AHD is reached (whichever comes first). This upper height limit has been recommended based on the maximum level that the surrounding landholders are comfortable with, as per community consultation undertaken on 8 January 2014. Reasons for the level include a concern for localise groundwater impacts on surrounding land and flood mitigation (see Appendix 2).

Once filled, the wetland should than be managed with fresh inflows monthly to reduce/ maintain salinity in a range between 25,000-40,000 EC. The salt and water balance model predicts that this range should be reached approximately 12 to 18 months post filling if seepage is 1mm/day (see Figure 7).

If vigorous aquatic plant growth occurs management should then shift to the long term goal outlined in Section 6.2.1. This focuses on priming conditions for the translocation of Murray Hardyhead, and specifically relates to manipulation of salinity levels. Figure 8 represents a simple hydrograph of the preferred conditions for Murray Hardyhead over a yearly basis. Management should attempt to mimic natural rainfall patterns, with peak water height (and lowest EC) in October and November and lowest water levels (and highest EC) in winter (D. Stoessel *pers comm*., 2013). Previous work undertaken by Stoessel (2012), suggests that during the winter period, intervention through delivery of environmental water should be limited to allow natural variability (i.e. rainfall events) to influence the system. This also exposes macrophytes such as Large-fruit Sea Tassel to aeration, which upon re-wetting promotes a surge of nutrients important for juvenile Murray Hardyhead. All fluctuations in water level should occur gradually, taking months rather than weeks to happen. If conditions are deemed appropriate, translocation should occur in autumn to allow adequate time for individuals to acclimatise prior to the spring breeding season (D. Stoessel, *pers comm.,* 2013). Table 14 details the hydrological objectives for Lake Elizabeth including general requirements of Murray Hardyhead.

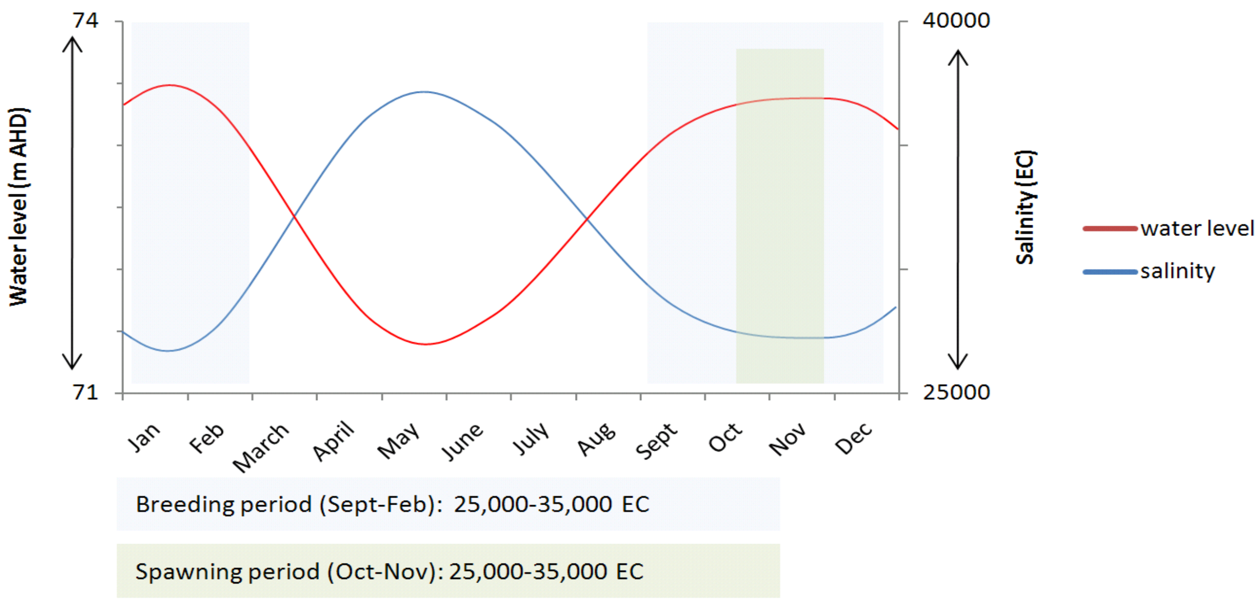
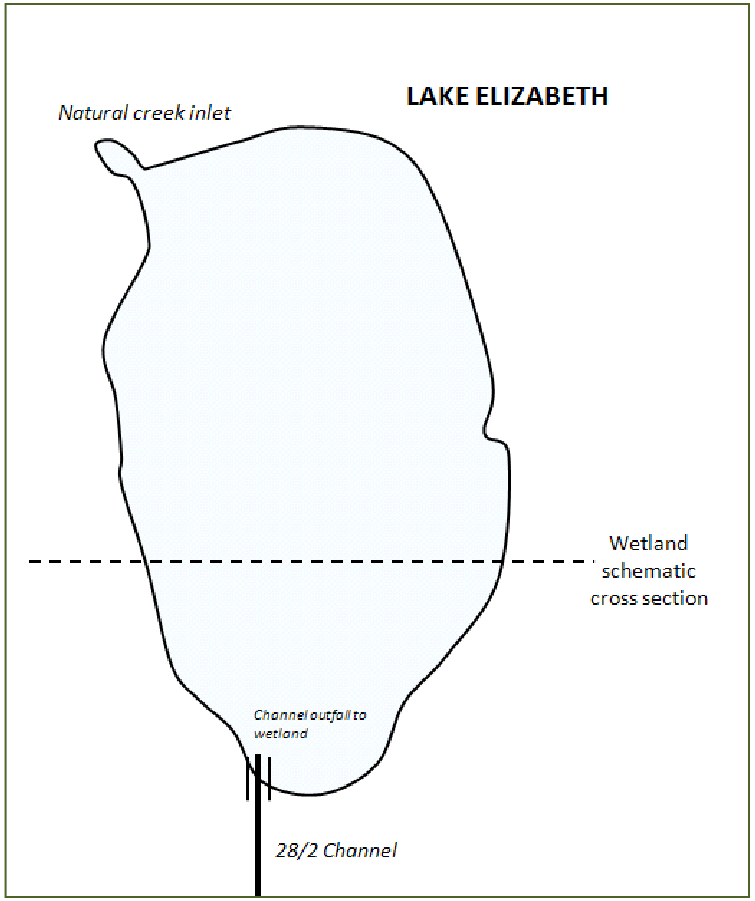


Figure 8: Preferred hydrograph for Murray Hardyhead (based on D. Stoessel *pers comm.,* 2013)



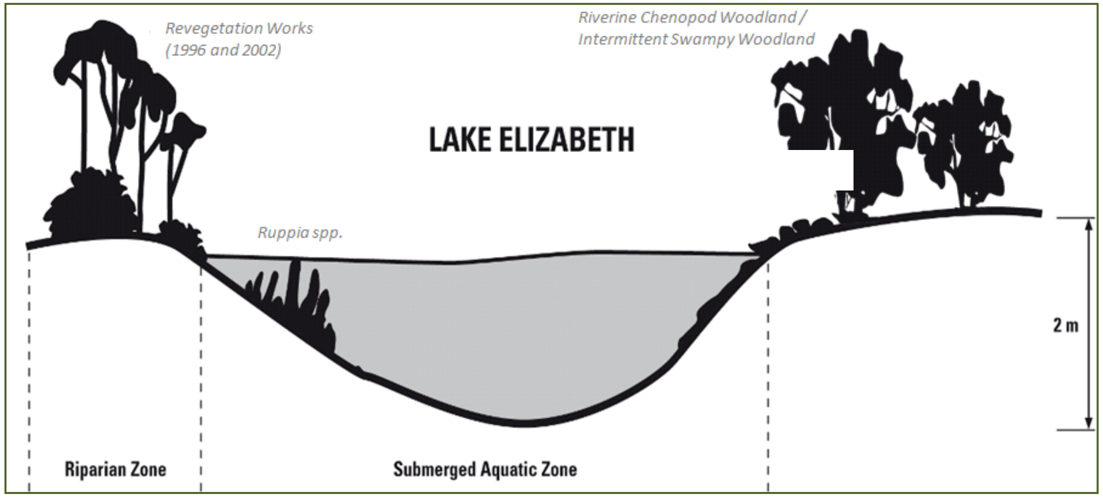


Figure 9: Schematic representation of the ecological components of Lake Elizabeth

Table 14: Hydrological objectives for Lake Elizabeth

Ecological objective	Hydrological objectives										
	Water management area	Recommended frequency of events (number per 10 years)[1]	Duration of flooding (months)	Preferred timing of inflows	Additional requirements			Target supply level (m ADH)	Volume to fill to target supply level[2] (ML)	Volume to maintain at TSL[2] (ML)	Total volume per event[2] (ML)
					Salinity	Turbidity	Temperature				
Habitat objectives											
Maintain/ reinstate submerged aquatics (i.e. *Large-fruit Sea Tassel, Stonewort and Long-fruit Water-mat*)	Bed and fringe	Vigorous growth if watering frequency of between two and four events per ten years (ideal number is three events). However can persist in permanent conditions.	Between 24 and 48 months to ensure sufficient recruitment for current and future events	Late winter/ early spring with top ups (slow or incremental delivery to assist with multiple germination events)	**Large-fruit Sea Tassel**: 8,000-80,000 EC with tolerance of up to 150,000 EC. Threshold for germination of 60,000 EC **Long-fruit Water-mat:** 1,900-150,000 EC **Stonewort:** Germinates at ~80,000 EC *all species germinate best at low EC conditions[3]	**All:** Low turbidity (<10 NTU)	**All:** 16-26 degrees Celsius (warmer temperatures aid in germination)	Based on salinity but likely to range between 73-74m AHD	914 to 1,632 ML	797 to 925 ML	1,711 to 2,557 ML
Restore and maintain (expansion) of chenopod shrubland from the littoral zones to wetland margins	Riparian zone to fringe	Variability in water level	Variable	Late winter/ early spring	N/A						
Restore littoral zone of wetland	fringe	Variability in water level	Variable	Late winter/ early spring	N/A						
Species/ community objectives											
Murray Hardyhead	Within wetland	Permanent regime	variable	Winter/ spring to freshen conditions during spawning	**Min:** 25,000 EC (excludes predators) **Max:** 40,000 EC **Breed:** 25,000-35,000 EC	0.3-62.7 NTU	5.8-30.5 degree Celsius	Variable based on Figure 5 and salinity	914 to 1,632 ML	797 to 925 ML	1,711 to 2,557 ML

Note: Flooding frequency and duration of flooding have been based on Roberts and Marston (2011), North Central CMA (2010), Stoessel (2010), Rakali (2013) and stakeholder opinions on the tolerance of species.

[1]The frequency of watering events only relates to wetland watering from dry, and does not show top-up events.

[2]Based on rating table by Price Merrett (2013)

[3]Germination trials by Rakali (2013) showed that seed bank germination was more successful under 10,000 EC conditions (660 Stoneworts and 12 Large-fruit Sea Tassel germinates) compared to 28,000 EC conditions (127 Stoneworts and 3 Large-fruit Sea Tassel)

6.3. Watering regime

The wetland watering regime has been derived from the ecological and hydrological objectives. To allow for adaptive and integrated management, the watering regime is framed using the seasonally adaptive approach. This means that a watering regime is identified for optimal conditions, as well as the maximum and minimum tolerable watering scenarios. The minimum watering regime is likely to be provided in drought or dry years, the optimum watering regime in average conditions and the maximum watering regime in wet or flood years.

The optimal, minimum and maximum watering regimes are described below. Due to the inter-annual variability of these estimates (particularly the climatic conditions), determination of the volume needed for any given year will need to be undertaken by the environmental water manager when watering is planned.

The management of environmental water at Lake Elizabeth needs to be undertaken in conjunction with associated complementary works such as exotic pest plant and animal control. Further to this a robust monitoring program should be adopted over the short term to determine the suitability of Lake Elizabeth for Murray Hardyhead translocation.

Minimum watering regime

Provide one (1.5) watering events every three years.

Fill wetland to 73.2m AHD one in three years and ensure inundation period at this level is for at least 18 months. Allow wetland to recede to approximately 72m AHD over following 18 months before topping up in following year.

**Please note: this regime is an adaption of the Lake Elizabeth EWP optimum watering regime. Due to groundwater outcropping, the wetland will not completely dry. Therefore the regime focuses on exposing maximum mudflat habitat however is unlikely to support Murray Hardyhead in the long term.*

Optimal watering regime

Provide environmental water to maintain a permanent regime.

Fresh inflows to be delivered annually to regulate salinity levels between 25,000-40,000 EC. Inflows preferably delivered in spring to freshen the system and coincide with the germination period of aquatic macrophytes and the peak breeding season of Murray Hardyhead (should translocation occur). Allow the wetland to recede naturally in winter. Water level of 73.2m AHD should not be exceeded.

**Please note: management under this regime is dictated by salinity targets for the purpose of Murray Hardyhead. See Figure 8 for preferred timing of inflows.*

Maximum watering regime

Provide environmental water to maintain a permanent regime.

Fresh inflows to be delivered annually to maintain the level at approximately 73-73.2m AHD. Inflows preferably delivered in spring to coincide with germination period of aquatic macrophytes and to promote waterbird breeding.

** Please note: this regime focuses primarily on aquatic macrophytes and waterbird breeding and feeding and does not take into consideration Murray Hardyhead requirements.*

6.4. Seasonally adaptive approach

Victoria has adopted an adaptive and integrated management approach to environmental management. A key component of this approach for environmental watering is the 'seasonally adaptive' approach, developed through the Northern Region Sustainable Water Strategy (DSE, 2009a) and incorporated into the Victorian Strategy for Healthy Rivers, Estuaries and Wetlands (VSHREW).

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

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

Table 15: The seasonally adaptive approach to river and wetland management (DSE, 2009a)

	Drought	Dry	Average	Wet to very wet
Long-term ecological objectives	Long-term objectives to move towards ecologically healthy rivers - set through regional river health strategies and sustainable water strategies and reviewed through the 15-year resource review			
Short-term ecological objectives	• Priority sites have avoided irreversible losses and have capacity for recovery	• Priority river reaches and wetlands have maintained their basic functions	• The ecological health of priority river reaches and wetlands has been maintained or improved	• The health and resilience of priority river reaches and wetlands has been improved
Annual management objectives	• Avoid critical loss • Maintain key refuges • Avoid catastrophic events	• Maintain river functioning with reduced reproductive capacity • Maintain key functions of high priority wetlands • Manage within dry-spell tolerances	• Improve ecological health and resilience	• Maximise recruitment opportunities for key river and wetland species • Minimise impacts of flooding on human communities • Restore key floodplain linkages
Environmental water reserve	• Water critical refuges • Undertake emergency watering to avoid catastrophic events • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• In priority river reaches provide summer and winter baseflows • Water high priority wetlands • Provide river flushes where required to break critical dry spells • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• Provide all aspects of the flow regime • Provide sufficient flows to promote breeding and recovery • Provide carryover to accrue water for large watering events • If necessary, use the market to sell or purchase water	• Provide overbank flows • Provide flows needed to promote breeding and recovery • If necessary, use the market to sell or purchase water
River and wetland catchment activities	• Protect refuges (including stock exclusion) • Increase awareness of the importance of refuges • Enhanced monitoring of high risk areas and contingency plans in place • Investigate feasibility of translocations • Environmental emergency management plans in place • Protect high priority river reaches and wetlands through fencing; pest, plant and animal management; and water quality improvement works • Implement post-bushfire river recovery plans	• Protect refuges • Protect high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Environmental emergency management plans in place • Improve connectivity • Implement post-bushfire river recovery plans	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands • Emergency flood management plans in place • Implementation of post-flood river restoration programs

7. Potential risks of and mitigation measures for environmental watering

A risk identification process has been undertaken to investigate the risks associated with environmental water delivery and site management at Lake Elizabeth and is presented in Table 16.

These risks are considered as potential only, and may not eventuate during environmental water delivery and management at Lake Elizabeth. In addition, a detailed risk assessment process will be undertaken prior to delivering environmental water in any given season and provided in the site's environmental water delivery plan.

Table 16: Possible risks and potential mitigation measures associated with environmental water delivery to Lake Elizabeth

Risk	Description	Potential Impacts								Potential mitigation measures
		Environmental (Water regime does not support breeding and feeding requirements or vegetation establishment and growth)					Social		Economic	
		Fish	Birds	Amphibians	Invertebrates	Native aquatic flora	Reduced public access and use	Degradation of cultural heritage sites	Flooding of adjacent land	
Required watering regime not met	Flood duration too long or short	✓				✓				• Determine environmental water requirements based on water level, salinity level and current seasonal conditions • Monitor water levels and salinity response to watering throughout season and adaptively manage watering events accordingly
	Flood timing too late or early	✓				✓				• Undertake a water balance based on seasonal conditions before placing water order • Consult with water corporation throughout season • Development of EWMP to aid
	Flooding depth too shallow or deep	✓				✓	✓		✓	• Determine environmental water requirements based on water level, salinity level and current seasonal conditions • Monitor water levels and salinity response to watering throughout season and adaptively manage watering events accordingly • Add or drawdown water where appropriate or practical • Development of EWMP to aid • Monitor groundwater bores
	Flood frequency too long or short	✓				✓				• Determine environmental water requirements based on water level, salinity level and current seasonal conditions • Monitor water levels and salinity response to watering throughout season and adaptively manage watering events accordingly
Poor water quality	Low dissolved oxygen	✓			✓	✓				• Monitor dissolved oxygen levels and the ecological response of the wetland to flooding • Add or drawdown water where appropriate or practical
	High turbidity	✓			✓	✓				• Monitor turbidity levels and the ecological response of the wetland to flooding • deliver water in slow increments to reduce turbidity • manage carp (mumbling) • Add or drawdown water where appropriate or practical
	High or low water temp	✓			✓	✓				• Deliver water from channel system as slowly as practical to minimise disturbance to the wetland and Murray Hardyhead • Add or drawdown water where appropriate or practical

Risk	Description	Potential Impacts								Potential mitigation measures
		Environmental (Water regime does not support breeding and feeding requirements or vegetation establishment and growth)					Social		Economic	
		Fish	Birds	Amphibians	Invertebrates	Native aquatic flora	Reduced public access and use	Degradation of cultural heritage sites	Flooding of adjacent land	
	Altered salinity levels	✓		✓	✓	✓			✓	• Monitor salinity levels and the ecological response of the wetland to flooding • Ensure salinity levels remain within the tolerances for Murray Hardyhead and below 73.2m AHD for surrounding landholders • water requirements based on water level, salinity level and current seasonal conditions • Monitor water levels and salinity response to watering throughout season and adaptively manage watering events accordingly • Add or drawdown water where appropriate or practical • Monitor/ investigate seepage and evaporation levels
	Increased nutrient levels	✓	✓	✓	✓		✓			• Monitor nutrient and Blue Green Algae levels within the wetland and channel system • Place public warning signs at the wetland if BGA levels are a public health risk
Invasive aquatic plant and animal invasion	Introduction of invasive aquatic fauna	✓		✓	✓	✓				• Ensure wetland salinity levels are maintained within the tolerance levels of Murray Hardyhead (these levels are generally considered beyond the tolerances of predatory fish species)
	Growth and establish-ment of aquatic invasive plants	✓	✓	✓	✓	✓				• Monitor the abundance of native and invasive aquatic plants • Control invasive plants in connected waterways • Spray or mechanically remove invasive plants (if appropriate and practical)
Third party impacts	Flooding of surrounding land						✓	✓	✓	• Monitor water delivery and ensure wetland remains below full supply level (allowing some flood mitigation)

8. Environmental water delivery infrastructure

8.1. Constraints

The total volume of water that can be delivered to Lake Elizabeth (and subsequently the salinity level) is constrained by the potential impact on surrounding land. Adjacent landholders have voiced their concern regarding management of the wetland above 73.2m AHD due to the potential for salinisation of surrounding farm land. Although this scenario is unlikely due to regional not local groundwater tables influencing Lake Elizabeth, the salt and water balance model still predicts that appropriate salinity levels can be achieved at this level. This may however increase the priming time required by the wetland to reach target salinity levels appropriate for Murray Hardyhead.

The salt water balance model uses a rate of 1mm/day to estimate seepage from the wetland. This rate is based on a review of hydrogeological literature and has not been tested at Lake Elizabeth. If the rate is higher than 1mm/day salinity will be lost from the wetland faster however, if the rate is lower a longer priming period may be required. Initial trial monitoring suggests that the rate may be as high as 5mm/day (see Appendix 13), which will result in a reduction to the time required to reach the salinity target.

Further to this the 28/2 channel and outfall structure that supply Lake Elizabeth has a reported capacity of 30 ML/day, however outfall capacity is restricted to 15 ML/day due to a culvert (Figure 10). In the past this volume was considered sufficient, with the wetland only receiving top-up flows to maintain it as a permanent system. Due to the current water level in the wetland (as at November 2013), it is likely that a fill event in the absence of competing customer demands, would take up to 90 days. This volume also limits the ability to maintain the wetland within a narrow salinity band, particularly during summer when evaporation rates are high and there may be a need to respond to peak salinity events (should they occur). Further to this delivery of environmental water must be adaptively managed around the competing demand for irrigation water delivery, particularly during the summer months.

Figure 10: Infrastructure at Lake Elizabeth. Left: 28/2 outfall structure, middle: culvert, right: 28/2 channel

8.2. Irrigation modernisation

The Goulburn-Murray Water Connections Project is a program which aims to upgrade existing irrigation infrastructure in the Goulburn-Murray Water Irrigation district to achieve water savings. As detailed previously, a EWP was developed for Lake Elizabeth in 2010. As part of this process the backbone, which originally terminated approximately three regulators south of Lake Elizabeth, was extended to the wetland. Shortly before these works, the gate on the outfall structure was also upgraded to allow 30-50 ML/day (C. Solum, G-MW CP *pers comm.,* 2013).

8.3. Infrastructure recommendations

As indicated above, the culvert that conveys flows from the 28/2 channel restricts the capacity of the outfall from 30 ML/day to 15 ML/day. Previously, Lake Elizabeth has only required top-up flows to maintain it as a permanent system; therefore the flow rate was not a large limiting factor. With changed operating arrangements and an increased need to be able to respond quickly to salinity peaks, it is recommended that the capacity of the culvert is increased to reduce the fill time. Options for upgrading include:

- Upgrading the culvert and Gitsham #2 spur to 30 ML/day which will reduce the fill time to a minimum of 45 days based on a level of 73.5m AHD. The cost estimate to undertake these works is $60,000 (P. Lacy and R. Chant, *pers comm.* 2009 cited in North Central CMA, 2010).
- Upgrading the culvert, channel outfall, Gitsham #2 spur and increasing the 28/2 channel capacity (desilting) to 50 ML/day. Based on a level of 73.5m AHD, this will reduce the fill time to a minimum of 26 days. The total cost estimate to undertake these works is $130,000 as per the following breakdown:
    - culvert and outfall structure- $100,000
    - Gitsham #2 spur- $20,000 and;
    - 28/2 channel capacity $10,000 (P. Lacy and R. Chant, *pers comm.* 2009 cited in North Central CMA, 2010).

Note: the estimates above to not include the costs associated with increasing the size of the modernised regulators upstream of Lake Elizabeth, which may be required (C. Solum, pers comm. 2013).

Common Carp are abundant within the G-MW channel system and there is currently no carp screen between the channel system and Lake Elizabeth. It is therefore recommended that a carp screen is installed to prevent enter into the wetland. A screen with a spacing size of 50 mm would minimise blockage while restricting the passage of large breeding sized Common Carp (SKM, 2005). Although it would not totally exclude the passage of Common Carp it would significantly reduce the population size, facilitating regeneration of wetland vegetation. The following should be considered prior to installation:

- The screen should be positioned to prevent fish entrainment.
- It should be designed to rotate about a vertical axis (to clear any weed or debris accumulating).
- It should be fitted so it can be easily removed and readily accessible.
- Regular maintenance will be required during regulator operation to prevent blockages.
- Installation will reduce the hydraulic capacity of the regulator (SKM, 2005).

Although high salinity levels (>25,000 EC) cause the death of Common Carp, fresh inflows (which currently carry Common Carp into the wetland) allow individuals to persist in a narrow band at the outlet until either delivery ceases or water mixes and become saline. This may result in mumbling and increased turbidity, greater competition with native species for resource and may prevent establishment of aquatic vegetation important for waterbirds and Murray Hardyhead.

9. Knowledge gaps and recommendations

There are a number of knowledge gaps in relation to environmental water management of Lake Elizabeth as detailed below.

The first one to three years of the optimum watering regime is designed to prime conditions for possible Murray Hardyhead translocation. At a minimum, vegetation, salinity and groundwater need to be monitored throughout this period to facilitate adaptive environmental water management. Further to this, the assumptions that underpin the salt and water balance model presented in this EWMP have not been tested in the field. As part of the development of this EWMP, the North Central CMA proposed that a simple trial watering event be undertaken to better understand how the system operates upon delivery of environmental water. This event commenced at Lake Elizabeth on 9 December 2013 delivering at 15 ML/day. Salinity, water level and groundwater data from December 2013 and January 2014 has been gathered by DEPI and analysed by the North Central CMA. The results of this analysis can be sourced from Appendix 13. It is recommended that continued analysis and monitoring is undertaken for at least another 12 to 18 months, to fully understand the behaviour over the long term.

An ongoing monitoring program should also be established to ensure appropriate fish, waterbird, macroinvertebrate, zooplankton, vegetation, groundwater and water quality monitoring is undertaken. Recommendations include quadrat surveys to monitor aquatic vegetation extent and health, continued monitoring of groundwater bores as well as the use of continuous probes (or at the least frequent spot monitoring) with multi-depth monitoring to advise on the potential for stratification (see Appendix 12 for full suite of recommended monitoring actions).

Although investigated in this EWMP, groundwater impacts on Lake Elizabeth including seepage rates and salinity need to be further researched. An in-depth water balance should be undertaken to understand these interactions better and to predict the behaviour of the wetland under different conditions.

It is also recommended that bird netting is utilised particularly during the establishment phase, to protect aquatic vegetation (especially Large-fruit Sea-tassel) from grazing waterbirds. Rakali (2013) recommended that this be done using 50 square metre waterbird exclusion plots across the wetland. It is crucial that this habitat is preserved in Lake Elizabeth as it is the major driver of productivity (i.e. waterbird use) and will provide crucial habitat should Murray Hardyhead translocation occur.

Further to this, other management activities need to be taken into account when managing Lake Elizabeth. This includes fencing of the wetland and pest plant and animal management (for example Spiny Rush management and rabbit baiting programs). Currently the North Central CMAs 'Protecting and Enhancing Priority Wetlands Project' includes such works at Lake Elizabeth however ongoing management beyond the life of the project needs to be considered.

Finally, the gauge board located at Lake Elizabeth was identified to be defunct for the purposes outlined in this EWMP, reading at levels above the proposed regime (74-75m AHD). The North Central CMA would like to acknowledge the kind support of Dean Radcliffe from G-MW (Kerang) who installing an additional two gauge boards in December 2013, for readings of 72-73m AHD and 73-74m AHD.

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Appendix 1: EWMP Community Interaction/Engagement (2010)

Undertaken by Rob O'Brien (Department of Primary Industries)

Background and purpose

EWPs are currently being developed for three wetlands in the Kerang–Boort area to determine the ecological impact of the current irrigation outfall (surplus water). An important component of this work involves identifying the environmental objective and wetland type for each of these wetlands. This requires an understanding of physical attributes, the history and the main biological processes associated with each of the wetlands.

There have been various levels of planning and monitoring on each of the wetlands currently being studied. To assist in collating all relevant information on each wetland it is important to capture and record information from the local community. In many cases adjoining landholders have had a long association with a wetland and have developed good understanding that is useful to include in the development of the plan. This is particularly important if only limited monitoring records exist.

This process is also useful to increase community ownership and acceptance of the EWP, particularly if ongoing work involves onground works.

These plans are required to be developed over a relatively short timeframe (6–8 weeks). To achieve the best result, a targeted community/agency engagement process was developed where a list of people with a good technical understanding of the wetland was developed by the technical working group.

This list included key adjoining landholders who have had a long association with the wetland and proven interest in maintaining its environmental value. A minimum of two landholders should be invited to provide input for each wetland

Other community and agency people who can provide useful technical and historic information include G-MW water bailiffs, duck hunters (Field & Game), bird observers and field naturalist. These people often process valuable information across several of the wetlands currently being studied.

The information is captured in brief dot point form and only technical information and observations have been noted that will add value to the development of the plan.

A list of participants has been recorded; however, comments for each wetland have been combined so individual comments are not referenced back to individuals.

It is important that the people approached for this information have a brief, straight summary of the purpose of the EWPs and type of information that will be useful to include in the planning process. Refer to summary below:

Information provided to participants

We are currently completing a study for NVIRP Northern Victoria Irrigation Renewal Project. It involves completing plans for, Lake Murphy, Lake Elizabeth and Johnson Swamp.

As part of this, it would be valuable to gather information that is broadly described below with a focus on the water regime and associated wetland values. It is recognised that these wetlands have been altered significantly since European settlement and the expansion of irrigated agriculture.

Providing information on these changes and how they influenced and altered the wetlands is important. It is particularly important to collate information or observations over more recent times, such as the last 30–50 years.

- What was the original (pre-European settlement) condition of the wetland, including any details of the water regime and values (environmental, cultural)?
- What broad changes to the wetlands have occurred, particularly changed water regimes, as agricultural development influence the floodplains and wetland.

- What connection does the wetland have to the floodplain in providing floodwater or local catchment runoff?
- To what extent does the current irrigation supply channel impact the water regime over time?
- During more recent times (i.e. last 50 years) how did the productivity of the wetland vary with the altered water regimes?
- Describe the health of the wetland and notable plants and animals (both aquatic/terrestrial) associated with its water management.
- Comment on pest plants (box thorns, willows, cumbungi, etc.)
- What influence – both positive and negative – has grazing domestic stock had on reserve?
- Given the history and current condition, what type of water regime would be needed to achieve the best environmental results for the wetland?
- What other management practices could be adopted to improve the environmental value of the wetland?

List of community and agency participants

- Ernie Moore (landholder)
- Colin and Jeff Gitsham (landholders)
- Robin Algie (G-MW water bailiff)
- Tom Lowe (field naturalist, Birds Australia representative)
- Murray Rohda (DSE Senior Wildlife Officer)

Comments and feedback from participants for Lake Elizabeth

- Lake Elizabeth has been kept constantly full over a long period of time.
- Large quantities of outfall water escaped into the wetland for a very long period.
- The Conservation Department also added water, on top of outfall, to keep it full.
- There has always been good waterbird numbers present on the wetland.
- There were probably more ducks on the wetland when it was fresher.
- Outfall has reduced significantly over the past 12 years and there is hardy any outfall water presently entering the wetland.
- The wetland may need to be kept dry into the future as there is a big shortage of water.
- It may be useful to link the filling of the wetland to wetter weather cycles when more water is available.
- Since going saline, Lake Elizabeth has developed blue clear water that is very scenic.
- The wetland is one of the few wetlands that people visit and drive completely around the perimeter.
- The fencing and revegetation works completed over the past 12 years have been very successful and improved the frontage attracting a host of different birds.
- The vegetative corridors planted on the farms that link back to Lake Elizabeth make the whole area more attractive and environmentally improved.
- Historically, drovers would hold their stock on the Lake Elizabeth frontage and overgraze the area.

- The vegetation that is currently growing around the frontage areas might require some controlled grazing in the future since total exclusion of stock has occurred.
- The wetland is almost dry and will need a water supply; however; it's important not to overfill the wetland.
- There is a large area of farmland that naturally drains back into Lake Elizabeth. It's important not to overfill the wetland to ensure it retains enough 'air space' to accept the local catchment runoff, particularly in wet years
- Overfilling the wetland may be increasing the groundwater and soil salinity levels on nearby adjoining farmland.
- There are areas of farmland to the south of the wetland where landholders pump water into the channel and it outfalls into the wetland.
- Last Spring, around the 16th October, there was a large outfall event as water over-topped the G-MW channel.
- Automation of the channels isn't always reliable and mistakes happen.
- Lake Elizabeth almost went dry in 1929 where there was a large fish kill. This seemed to be caused by a heavy thunderstorm and resulted in a significant amount of dirty water flowing into Lake Elizabeth, which was very low at the time. This dirty water flowing off the surrounding land killed large Murray Cod present in the wetland.
- Roy Gitsham (father of Geoff and Colin) was only a small boy in 1929 and present in a photograph showing the fish kill. These fish were very large, which suggests Lake Elizabeth had been kept full for a long period of time prior to the 1920s.
- In 1975, there were 42 fishing boats present on the Lake Elizabeth one weekend when the Redfin were biting
- The Redfin disappeared soon after the mid 1970s as the salinity levels rose.
- European Carp then dominated the wetland through the late 1970s until the wetland became too saline even for them.
- The Murray Hardyhead was discovered after all of the Carp and larger fish died when the wetland became too salty.

Appendix 2: EWMP Consultation (2013)

Undertaken by Amy Russell and Bree Bisset (North Central CMA)

Method

To finalise the Lake Elizabeth EWMP local knowledge and input was required. Community consultation has been undertaken by the North Central CMA via a landholder house visit on the 15 August and 19 September 2013. The interviews focused on collecting information from the community members specifically regarding Murray Hardyhead and the draft environmental watering recommendations, but also the wetlands values, threats and history. A second community meeting was held on 27 November 2013 to update the community on the project including the outcomes of the salt and water balance model and next steps. Finally, landholders were invited to make comment on the final draft EWMP in December 2013 before attending a fourth on site community meeting on the 8 January 2014. The information collected has been summarised below and has been used to update, revise and complete the plan. The community consultation component of developing the plan is essential in ensuring that the plan is meaningful and robust into the future.

Community representatives interviewed:

Colin Gitsham, Geoff Gitsham, Chris Gitsham, Ernie Moore, Neil Hampton, Dennis Carmichael, Glenice Ficken & Bruce Mathers (DEPI).

1. **Wetland information (general)**
   - Lake Elizabeth has been held permanently full for a long period of time
   - Historically Lake Elizabeth filled from the North end receiving water that had passed through Wandella Forest
   - Management practices in the area have changed dramatically and a lot of water has now left the district
   - Historically farmers around Lake Elizabeth would drain water into the wetland
   - During wet conditions, water use to be sent through Wandella Forest every year which resulted in the Black Box trees in the forest turning yellow
   - Farm land was also impacted by this movement and in the 1980s there was talk about changing Gannon's Weir to stop this movement
   - When Chris Gitsham was a child, his school often took salinity readings at the wetland- he recalls the salinity being higher than sea water
   - In 2003-2004 there was a significant algae bloom at the wetland. The participants think that this may have attributed to the loss of Murray Hardyhead in the wetland as this was around the same time as their disappeared
   - 10 years ago it wouldn't have went dry, farming practices have changed and there are much more deep rooted crops.
   - Water level was too high in the 1950's (1956?), drains put in towards Duck Lake.
2. **Wetland values**
   - habitat for waterbirds and recreational use such as duck hunting
   - During the drought the wetland still supported a high number of swans, Ruppia was very thick and birds thrived on this
   - In the 1970-1980s Redfin use to be caught in the wetland all the time making the wetland a popular recreational fishing spot. Approximately 40 boats were noted in the 1950s fishing on Lake Elizabeth
   - Bony Bream and Tench were commonly discharged onto property when water was pumped from the wetland

- Turtles and water rats were also present
- The disappearance of Redfin coincided with the increase in European Carp
- Approximately 85 years ago the wetland level dropped considerably and a large rainfall event caused a spike in turbidity and the death of Murray Cod
- When the wetland was fresher, there used to be Cumbungi around the edge of the wetland. This disappeared when the salinity level rose
- Small fish (presumed to be Murray Hardyhead) used to be seen all the time at Lake Elizabeth in large schools, particularly in the shallows
- Prior to going dry recent, Lake Elizabeth had always had dense swards of Fruit Tassel (described as large blobs floating on the wetland). Other patches of aquatic vegetation was also scattered through the wetland during this time.
- Fruit Tassel remained dense even after Murray Hardyhead was declared locally extinct in the early 2000s
- Fruit Tassel has not been seen at the wetland since it started to dry
- Over 40 years ago it was recalled that the wetland had more than 40 boats on it fishing for Murray Cod.
- The wetland and surrounding land has always been over watered

3. **Threats**
   - Bull Rush and Spiny Rush use to be thick particularly around the concrete structure at the south
   - Rabbits are a large problem within the area and participants suggest that works should focus on their management
   - Spiny Rush has been flagged as an issue with Parks Victoria. It is known to harbours foxes which impact on stock in the area
   - Most participants didn't consider Spiny Rush as an issue as the proposed permanent regime would likely cause the species to die
   - Now that the wetland level has dropped there are a number of Carp skeletons present at the margins of the wetland
   - Carp is not a concern as they are rarely seen in the wetland (with the exception of small congregations at the regulator when water is released. These individuals die as soon as freshwater input ceases and salinity levels rises)
   - Some of the local bore levels rise when irrigation is occurring. Levels have dropped by 5-10cm when irrigation ceases
   - Noted that there is a strong interaction between groundwater and surface water at Lake Elizabeth
   - One participant believed that the interaction between the wetland and the groundwater has reduced due to a change in the seasonality of watering. For example in the past watering was winter based, but now there is a large area of deep rooted Lucerne to the south of Lake Elizabeth (approximately 1,000 acres) that is watered in summer. This would assist with keeping groundwater levels low
   - In the past the water level has only been an issue when lots of water was being passed through Wandella Forest
   - Water level has been the lowest over the last 2 years than ever remembered, due to a change in irrigation practices.
4. **Draft environmental watering regime**
   - The participants believed nothing good will come from drying the wetland out completely

- The main concern is that the wetland with turn into something like Lake Tutchewop (hypersaline)
- There were not issues voice regarding maintaining the wetland as a permanent regime or the translocation of Murray Hardyhead
- There is however large concern that the level (if too high) may impact on the surrounding farmland (i.e. push saline groundwater into paddocks)
- Landholders stressed that they were not comfortable with the wetland being managed above 73.2m AHD due to the risk of groundwater intrusion on surrounding land. Landholders believe that the higher operating levels in the past (above 73.5m AHD) cause a number of salinity issues on farmland in the immediate area.
- In the past the level generally operated at 72.5- 74m AHD (as confirmed in the field)
- At 74m AHD some water would backfill into the original fill point (north of the wetland) however this would be minimal
- The north west edge of the wetland (Ernie Moore's property) will be the most effected by a permanent regime if water levels are held high

5. **Other comments**
   - In 1956 the wetland level was extremely high (hasn't been at this level since). A drainage line was cut to allow water to move towards Duck Lake
   - In the past the options to pump/pipe water to Duck Lake was investigated, however the cost was considered way to expensive
   - There is concern as to how excess salt will be flushed out of the system if it starts to accumulate
   - The drain on Ernie Moore's property could be used to allow flushing to Duck Creek
   - Evaporation is severe particularly in summer- increasing the outlet capacity may be needed to ensure that an adequate delivery rate can be maintained to compensate for the loss. It was noted that once the water level gets down to about 30cm in depth that the late evaporates very quickly (in Summer)
   - The gauge board needs replacing (currently the level is below the board and however during the floods the level was above the board)
   - Landholders would not like to see the wetland 'full' during the winter, for flood mitigation reasons
   - Lake Elizabeth has been the target of considerable investment to the wetland (one participant estimated this as $500,000). There is concern that money isn't being spent where it is needed the most (i.e. strategy for managing salinity and rabbit control).
   - Landholders would like to see the wetland completely dried out before fresh water added to it, but realise having water in it is essential (for crops, evaporation in the water cycle etc).
6. **Community comments on EWMP final draft (13 December 2013)**
   - Page 18, Section 4.1.1 states that water flows from Flaxy's Swamp and enters in the north-west corner of the wetland. Landholder suggests this is not physically possible, but likely however that water did enter from further north (backing up from Third Reedy Lake and Mick's Lake) coming back down through the East side of Lake Elizabeth.
   - In making reference to the Wetland being used as fresh irrigation water storage, adjoining landholders have diverted water from the wetland in the past, however at its peak it is reported that they only pumped approximately 250 ML/year. This was blended with the fresh water from the channel system as the water from the wetland proved to be unsuitable due to its high salt concentration.

- A greater emphasis should be placed on the impacts or grazing by rabbits and hares around the wetland. This problem will need to be addressed for the 'whole' of wetland management in the future. It has been suggested by a landholder that a rabbit proof fence be erected around the wetland.
- A request for further monitoring to be included in the management of Lake Elizabeth, especially regarding ground water levels in the area surrounding the wetland.

Appendix 3: Corrick and Norman Classification of wetland categories

Source: DSE, 2007

Category	Sub-category	Depth (m)	Duration of inundation
Flooded river flats These include many areas of agricultural land that become temporarily inundated after heavy rains or floods. Water may be retained in local depressions for just a few days or for several months.		< 2	
Freshwater meadow These include shallow (up to 0.3 m) and temporary (less than four months duration) surface water, although soils are generally waterlogged throughout winter.	1 Herb-dominated 2 Sedge-dominated 3 Red gum- dominated 4 Lignum dominated	< 0.3	< 4 months/year
Shallow freshwater marsh Wetlands that are usually dry by mid-summer and fill again with the onset of winter rains. Soils are waterlogged throughout the year and surface water up to 0.5 m deep may be present for as long as eight months.	1 Herb-dominated 2 Sedge-dominated 3 Cane grass dominated 4 Lignum dominated 5 Red gum-dominated	< 0.5	< 8 months/year
Deep freshwater marsh Wetlands that generally remain inundated to a depth of 1 – 2 m throughout the year.	1 Shrub-dominated 2 Reed-dominated 3 Sedge-dominated 4 Rush-dominated 5 Open water 6 Cane grass dominated 7 Lignum-dominated 8 Red gum-dominated	< 2	permanent
Permanent open freshwater Wetlands that are usually more than 1 m deep. They can be natural or artificial. Wetlands are described to be permanent if they retain water for longer than 12 months, however they can have periods of drying.	1 Shallow 2 Deep 3 Impoundment	<2 >2	permanent
Semi-permanent saline These wetlands may be inundated to a depth of 2 m for as long as eight months each year. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	1 Salt pan 2 Salt meadow 3 Salt flat 4 Sea rush-dominated 5 Hypersaline lake	< 2	< 8 months/year
Permanent saline These wetlands include coastal wetlands and part of intertidal zones. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	Shallow Deep Intertidal flats	< 2 > 2	permanent
Sewage oxidation basin These include artificial wetlands used for sewage treatment.	Sewage oxidation basin		
Salt evaporation basin These include artificial wetlands used salt concentration.	Salt evaporation basin		

Appendix 4: Environmental water sources

Commonwealth Environmental Water Holder (CEWH)

Under Water for the Future the Commonwealth Government committed $3.1 billion to purchase water in the Murray-Darling Basin over 10 years. The Commonwealth Environmental Water Holder will manage their environmental water.

The Commonwealth Water Act 2007 identified that "the Commonwealth Environmental Water Holder must perform its functions for the purpose of protecting or restoring environmental assets so as to give effect to relevant international agreements". Wetlands listed as of International Importance (Ramsar) are considered priority environmental assets for use of the commonwealth environmental water (CEWH, 2012).

Victorian Environmental Water Holder (VEWH)

The VEWH (when established in June 2011) will be responsible for holding and managing Victorian environmental water entitlements and allocations and deciding upon their best use throughout the State. The environmental entitlements held by the VEWH that could potentially be made available to this site include:

Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999 (incl. Amendments Orders and Notices 2005, 2006, 2007 and 2009)

- In 1987 an annual allocation of 27,600 ML of high security water was committed to flora and fauna conservation in Victorian Murray wetlands. In 1999, this became a defined entitlement for the environment called the Victorian River Murray Flora and Fauna Bulk Entitlement.

Environmental Entitlement (Murray System- NVIRP Stage 1) 2010

- The Goulburn-Murray Water Connections Project (G-MW CP) (formerly known as the Northern Victoria Irrigation Renewal Project (NVIRP)) water savings are predicted to provide up to 75 GL as a statutory environmental entitlement, which will be used to help improve the health of priority stressed rivers and wetlands in northern Victoria (DSE, 2008). The entitlement will have properties which enable the water to be used at multiple locations as the water travels downstream (provided losses and water quality issues are accounted for); meaning that the water can be called out of storage at desired times to meet specific environmental needs.

River Murray Unregulated Flow (RMUF)

Unregulated flows in the River Murray system are defined as water that cannot be captured in Lake Victoria and is, or will be, in excess of the required flow to South Australia. If there is a likelihood of unregulated flow event in the River Murray system, the Authority provides this advice to jurisdictions The Upper States then advise the Authority on altered diversion rates and environmental releases within their existing rights to unregulated flows.

Based on the information received from Jurisdictions, the Authority reassesses the event and, if necessary, limits Upper States' access to ensure that the unregulated flow event is not over committed. The Authority then issues formal unregulated flow advice to jurisdictions including any limits to States access.

Depending on the volume of water remaining, the Authority advises EWG and the Water Liaison Working Group (WLWG) on the availability and volume of RMUF. Whilst there is a range of measures that can be undertaken by Upper States as part of their 'prior rights' during unregulated flows, RMUF events are prioritised solely for the environment.

Appendix 5: Legislative framework

International agreements and conventions

Ramsar Convention on Wetlands (Ramsar)

The Australian Government is a Contracting Party to the convention, which is an inter-governmental treaty whose mission is “the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

Bilateral migratory bird agreements

Australia is a signatory to the following international bilateral migratory bird agreements:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA);
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA); and
- The Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention or CMS).

These agreements require that the parties protect migratory birds by:

- limiting the circumstances under which migratory birds are taken or traded;
- protecting and conserving important habitats;
- exchanging information; and
- building cooperative relationships.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn)

This convention (known as the Bonn Convention or CMS) aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Programme, concerned with the conservation of wildlife and habitats on a global scale. The Convention was signed in 1979 in Bonn, Germany, and entered into force in 1983.

Commonwealth legislation

*Environment Protection and Biodiversity Conservation Act 199*9 (EPBC)

This is the key piece of legislation pertaining to biodiversity conservation within Australia. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places - defined in the EPBC Act as matters of national environmental significance.

Water Act 2007 (Commonwealth Water Act)

This establishes the Murray-Darling Basin Authority (MDBA) with the functions and powers, including enforcement powers, needed to ensure that Basin water resources are managed in an integrated and sustainable way.

Aboriginal and Torres Strait Islander Heritage Protection Act 1984

This aims to preserve and protect areas and objects in Australia and Australian waters that are of particular significance to indigenous people from injury or desecration.

State legislation and listings

Flora and Fauna Guarantee Act 1988 (FFG)

This is the key piece of Victorian legislation for the conservation of threatened species and communities and for the management of potentially threatening processes.

Advisory lists of rare or threatened species in Victoria (DSE)

Three advisory lists are maintained by DSE for use in a range of planning process and in setting priorities for actions to conserve biodiversity. Unlike other threatened species lists, there are no legal requirements or consequences that flow from inclusion of a species on an advisory list. The advisory lists comprise:

- Advisory List of Rare or Threatened Plants In Victoria – 2005
- Advisory List of Threatened Vertebrate Fauna in Victoria - 2007
- Advisory List of Threatened Invertebrate Fauna in Victoria - 2009

Environmental Effects Act 1978

Potential environmental impacts of a proposed development are subject to assessment and approval under this Act. A structural works program and any associated environmental impacts would be subject to assessment and approval under the Act.

Planning and Environment Act 1987

This controls the removal or disturbance to native vegetation within Victoria by implementation of a three-step process of avoidance, minimisation and offsetting.

Water Act 1989 (Victorian Water Act)

This is the key piece of legislation that governs the way water entitlements are issued and allocated in Victoria. The Act also identifies water that is to be kept for the environment under the Environmental Water Reserve. The Act provides a framework for defining and managing Victoria's water resources.

Aboriginal Heritage Act 2006

All Aboriginal places, objects and human remains in Victoria are protected under this Act.

Other relevant legislation

The preceding legislation operates in conjunction with the following other Victorian legislation to influence the management and conservation of Victoria's natural resources as well as outline obligations with respect to obtaining approvals for structural works:

- *Environment Protection Act 1970*
- *Catchment and Land Protection Act 1994*
- *Heritage Act 1995*
- *Conservation, Forests and Lands Act 1987*
- *Land Act 1958*
- *Heritage Rivers Act 1992*
- *Wildlife Act 1975*
- *Murray Darling Basin Act 1993*
- *National Parks Act 1975*
- *Parks Victoria Act 1998*
- *Forests Act 1958.*

Appendix 6: Flora and fauna species list

Common name	*Scientific name*	Dates recorded	Sources
Fauna- Birds			
Australasian Grebe	*Tachybaptus novaehollandiae*	1987-1989, 1991, 1995, 1999-2001, 2003, 2006, 2013	Birds Australia; DEPI, 2013
Australasian Shoveler	*Anas rhynchotis*	1987-1992, 1994, 1997, 1999, 2001, 2003, 2012, 2013	Birds Australia; DEPI, 2012; DEPI, 2013
Australian Magpie	*Cracticus tibicen*	1985, 1999-2001, 2003, 2007	Birds Australia; DEPI, 2013
Australian Pelican	*Pelecanus conspicillatus*	1987-1990, 1992, 1995-1996, 1999, 2001, 2006 , 2012	Birds Australia; DEPI, 2012; DEPI, 2013
Australian Raven	*Corvus coronoides*	1999-2001, 2003	Birds Australia; DEPI, 2013
Australian Reed-Warbler	*Acrocephalus australis*	1990	Birds Australia
Australian Shelduck	*Tadorna tadornoides*	1977, 1985, 1987-2006, 2012-13	Birds Australia; DEPI, 2012; DEPI, 2013
Australian White Ibis	*Threskiornis molucca*	1995, 1999, 2001, 2004	Birds Australia; DEPI, 2013
Australian Wood Duck	*Chenonetta jubata*	1987, 1989, 1990	DEPI, 2013
Banded Stilt	*Cladorhynchus leucocephalus*	1999, 2001	Birds Australia; DEPI, 2013
Black Falcon	*Falco subniger*	1999	Birds Australia
Black Kite	*Milvus migrans*	1999	Birds Australia
Black Swan	*Cygnus atratus*	1985, 1987-2007, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	1999	Birds Australia
Black-tailed Native-hen	*Tribonyx ventralis*	1987- 1993, 2013	Birds Australia; DEPI, 2013
Black-winged Stilt	*Himantopus himantopus*	1988-1989, 1993-1994, 1999, 2013	Birds Australia; DEPI, 2013
Blue-billed Duck	*Oxyura australis*	1987-1994, 2003-2004	Birds Australia; DEPI, 2013
Brolga	*Grus rubicunda*	2009	DEPI, 2013
Brown Falcon	*Falco berigora*	1999, 2001	Birds Australia
Buff-rumped Thornbill	*Acanthiza reguloides*	1999	Birds Australia
Chestnut Teal	*Anas castanea*	1990-1992, 1997, 1999, 2006, 2013	Birds Australia; DEPI, 2013
Common Blackbird	*Turdus merula*	2000	Birds Australia
Common Greenshank	*Tringa nebularia*	1988-1989, 1991-1992	Birds Australia; DEPI, 2013
Crested Pigeon	*Ocyphaps lophotes*	1999	Birds Australia
Curlew Sandpiper	*Calidris ferruginea*	1989	DEPI, 2013
Double-banded Plover	*Charadrius bicinctus*	1987	DEPI, 2013
Dusky Moorhen	*Gallinula tenebrosa*	1991, 1995	Birds Australia; DEPI, 2013
Eastern Great Egret	*Ardea modesta*	1985, 2001	DEPI, 2013
Eastern Rosella	*Platycercus eximius*	2000, 2007	Birds Australia
Eurasian Coot	*Fulica atra*	1985, 1987-1994, 1996-2004, 2006, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Freckled Duck	*Stictonetta naevosa*	1989, 1991, 2013	DEPI, 2013
Galah	*Eolophus roseicapillus*	1999, 2003	Birds Australia
Great Cormorant	*Phalacrocorax carbo*	1990, 1993	DEPI, 2013
Great Crested Grebe	*Podiceps cristatus*	1987-1991, 1994, 1996, 1999, 2001, 2003	Birds Australia; DEPI, 2013
Grey Teal	*Anas gracilis*	1977, 1985, 1987-2006, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Hardhead	*Aythya australis*	1989-1992, 1999, 2001, 2005, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013

Hoary-headed Grebe	*Poliocephalus poliocephalus*	1985, 1987-1996, 1999, 2001-2003, 2005, 2007, 2012	Birds Australia; DEPI, 2012; DEPI, 2013
Horsfield's Bushlark	*Mirafra javanica*	2000	Birds Australia
Intermediate Egret	*Ardea intermedia*	1990	Birds Australia
Little Black Cormorant	*Phalacrocorax sulcirostris*	1990-1991, 1995, 2001	Birds Australia; DEPI, 2013
Little Eagle	*Hieraaetus morphnoides*	2001	Birds Australia
Little Pied Cormorant	*Microcarbo melanoleucos*	1985, 1988- 1990, 1992-1993, 1996, 2000-2001	Birds Australia; DEPI, 2013
Little Raven	*Corvus mellori*	1999, 2000, 2007	Birds Australia; DEPI, 2013
Magpie-lark	*Grallina cyanoleuca*	2001	Birds Australia
Marsh Harrier	*Circus aeruginosus*	2012-2013	DEPI, 2012; DEPI, 2013
Marsh Sandpiper	*Tringa stagnatilis*	1988, 1990-1991	Birds Australia; DEPI, 2013
Masked Lapwing	*Vanellus miles*	1985, 1987-1997, 1999- 2001, 2003-2004, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Musk Duck	*Biziura lobata*	1985, 1987-1994, 1996-2007, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Nankeen Kestrel	*Falco cenchroides*	1999, 2000	Birds Australia
New Holland Honeyeater	*Phylidonyris novaehollandiae*	2007	Birds Australia
Noisy Miner	*Manorina melanocephala*	1999	Birds Australia
Pacific Black Duck	*Anas superciliosa*	1987-1990, 1992-1997,1999, 2001, 2004-2005	Birds Australia; DEPI, 2013
Pacific Gull	*Larus pacificus*	1991	Birds Australia
Peregrine Falcon	*Falco peregrinus*	1999, 2001	Birds Australia
Pied Butcherbird	*Cracticus nigrogularis*	1999	Birds Australia
Pied Cormorant	*Phalacrocorax varius*	1988	Birds Australia
Pink-eared Duck	*Malacorhynchus membranaceus*	1985, 1987-1992, 1999, 2001-2006, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Purple Swamphen	*Porphyrio porphyrio*	1990, 1992, 2003	Birds Australia; DEPI, 2013
Red-capped Plover	*Charadrius ruficapillus*	1987-1992, 1999	Birds Australia; DEPI, 2013
Red-kneed Dotterel	*Erythrogonys cinctus*	1989, 1990-1992	Birds Australia; DEPI, 2013
Red-necked Avocet	*Recurvirostra novaehollandiae*	1988-1990, 1993, 1996, 2001	Birds Australia; DEPI, 2013
Red-necked Stint	*Calidris ruficollis*	1989	DEPI, 2013
Royal Spoonbill	*Platalea regia*	1988, 1995	Birds Australia
Sharp-tailed Sandpiper	*Calidris acuminata*	1985, 1987-1989, 1991-1992	Birds Australia; DEPI, 2013
Silver Gull	*Chroicocephalus novaehollandiae*	1988-1992, 2000, 2012-2013	Birds Australia; DEPI, 2012; DEPI, 2013
Singing Honeyeater	*Lichenostomus virescens*	2007	Birds Australia
Straw-necked Ibis	*Threskiornis spinicollis*	1991-1992, 2001, 2007	Birds Australia; DEPI, 2013
Striated Pardalote	*Pardalotus striatus*	1999	Birds Australia
Stubble Quail	*Coturnix pectoralis*	2001	Birds Australia; DEPI, 2013
Superb Fairy-wren	*Malurus cyaneus*	1999-2000, 2003	Birds Australia; DEPI, 2013
Swamp Harrier	*Circus approximans*	1991, 1995, 2000	Birds Australia; DEPI, 2013
Tree Martin	*Petrochelidon nigricans*	1999	Birds Australia
Wedge-tailed Eagle	*Aquila audax*	1999, 2001	Birds Australia
Welcome Swallow	*Hirundo neoxena*	1999	Birds Australia
Whistling Kite	*Haliastur sphenurus*	1999	Birds Australia
White-backed Swallow	*Cheramoeca leucosterna*	1999	Birds Australia
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	1990, 2006	Birds Australia; DEPI, 2013
White-faced Heron	*Egretta novaehollandiae*	1987-1992, 1994-1995, 1997,	Birds Australia; DEPI, 2013

		1999, 2001, 2013	
White-fronted Chat	*Epthianura albifrons*	1988, 1990, 1999, 2013	Birds Australia; DEPI, 2013
White-necked Heron	*Ardea pacifica*	1987, 1993, 2001, 2003	Birds Australia; DEPI, 2013
White-plumed Honeyeater	*Lichenostomus penicillatus*	1999, 2000, 2003	Birds Australia; DEPI, 2013
White-winged Fairy-wren	*Malurus leucopterus*	1999, 2001, 2007	Birds Australia; DEPI, 2013
Willie Wagtail	*Rhipidura leucophrys*	1999, 2003, 2007	Birds Australia; DEPI, 2013
Yellow-billed Spoonbill	*Platalea flavipes*	1990, 1993	DEPI, 2013
Zebra Finch	*Taeniopygia guttata*	1999, 2001	Birds Australia
Fauna- Fish			
Australian Smelt	*Retropinna semoni*	197	DEPI, 2013
Bony Herring	*Nematalosa erebi*	1981	DEPI, 2013
Flat-headed Gudgeon	*Philypnodon grandiceps*	2004	DEPI, 2013
Murray Cod	*Maccullochella peelii peelii*	1920s	Anecdotal (community consultation)
Murray Hardyhead	*Craterocephalus fluviatilis*	1971, 1989, 2002	DEPI, 2013
Fauna- Other			
Koala	*Phascolarctos cinereus*	1982	DEPI, 2013
Freshwater Shrimp	*Paratya australiensis*	2004	DEPI, 2013
Fauna- Exotic			
Brown Trout	*Salmo trutta*	1982	DEPI, 2013
Common Starling	*Sturnus vulgaris*	1985, 1999, 2001, 2003	Birds Australia; DEPI, 2013
Double-banded Plover	*Charadrius bicinctus*	1989-1990	DEPI, 2013
Eastern Gambusia	*Gambusia holbrooki*	1964, 1971	DEPI, 2013
Goldfish	*Carassius auratus*	1981	DEPI, 2013
House Sparrow	*Passer domesticus*	1985, 1999-2001, 2003, 2007	Birds Australia; DEPI, 2013
Rainbow Trout	*Oncorhynchus mykiss*	1982	DEPI, 2013
Redfin	*Perca fluviatilis*	1949, 1981-1982	DEPI, 2013
Tench	*fam. Cyprinidae gen. Tinca*	1949, 1981	DEPI, 2013
Flora- native			
Australian Saltmarsh Grass	*Puccinellia stricta*	1990	DEPI, 2013
Berry Saltbush	*Atriplex semibaccata*	1974, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Black Box	*Eucalyptus largiflorens*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Black Cotton-bush	*Maireana decalvans*	2012	Australian Ecosystems, 2012
Blackseed Glasswort	*Halosarcia pergranulata spp. Pergranulata*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Bonefruit	*Osteocarpum spp.*	1990	DEPI, 2013
Bristly Wallaby-grass	*Rytidosperma setaceum var. setaceum*	2012	Australian Ecosystems, 2012
Broombush	*Melaleuca uncinata*	2012	Australian Ecosystems, 2012
Buloke	*Allocasuarina luehmannii*	2012	Australian Ecosystems, 2012
Cane Grass	*Eragrostis australasica*	1990	DEPI, 2013
Climbing Saltbush	*Einadia nutans*	1990, 2004	DEPI, 2013
Common Spike-sedge	*Eleocharis acuta*	2012	Australian Ecosystems, 2012
Common Wallaby-grass	*Rytidosperma caespitosum*	2012	Australian Ecosystems, 2012
Corky Saltbush	*Atriplex lindleyi subsp. inflata*	2012	Australian Ecosystems, 2012
Cotton Fireweed	*Senecio quadridentatus*	2012	Australian Ecosystems, 2012
Creeping Monkey-flower	*Mimulus repens*	2012	Australian Ecosystems, 2012

Curly Windmill Grass	*Enteropogon acicularis*	1990	DEPI, 2013
Deane's Wattle	*Acacia deanei*	2012	Australian Ecosystems, 2012
Dillion Bush	*Nitraria billardierei*	1990	DEPI, 2013
Dumosa Mallee	*Eucalyptus dumosa*	2012	Australian Ecosystems, 2012
Eumong#	*Acacia stenophylla*	2012	Australian Ecosystems, 2012
Fine-leaf Desert Cassia	*Senna form taxon 'filifolia'*	2012	Australian Ecosystems, 2012
Five Spined Roly Poly	*Sclerolaena muricata*	1990	DEPI, 2013
Fuzzweed	*Vittadinia sp*	1990	DEPI, 2013
Fuzzy New Holland Daisy	*Vittadinia cuneata*	2012	Australian Ecosystems, 2012
Glaucous Goosefoot	*Chenopodium glaucum*	2012	Australian Ecosystems, 2012
Gold-dust Wattle	*Acacia acinacea s.l.*	2012	Australian Ecosystems, 2012
Golden Wattle	*Acacia pycnantha*	2012	Australian Ecosystems, 2012
Grassland Wood-sorrel	*Oxalis perennans*	2012	Australian Ecosystems, 2012
Grey Copper Burr	*Sclerolaena diacatha*	1989-1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Grey Germander	*Teucrium racemosum s.l.*	2012	Australian Ecosystems, 2012
Grey Mulga	*Acacia brachybotrya*	2008; 2012	Australian Ecosystems, 2012; DEPI, 2013
Grey Roly-poly	*Sclerolaena muricata var. villosa*	2012	Australian Ecosystems, 2012
Hairy Bluebush	*Maireana pentagona*	2012	Australian Ecosystems, 2012
Halosarcia	*Halosarcia spp.*	2004	DEPI, 2013
Hedge Saltbush#	*Rhagodia spinescens*	2012	Australian Ecosystems, 2012
Hooked Needlewood	*Hakea tephrosperma*	2012	Australian Ecosystems, 2012
Jersey Cudweed	*Pseudognaphalium luteoalbum*	2012	Australian Ecosystems, 2012
Large-fruit Tassel	*Ruppia megacarpa*	1990; 2012	Australian Ecosystems, 2012; DEPI, 2013
Large-fruit Tassel	*Ruppia megacarpa*	1990	DEPI, 2013
Long-fruit Water-mat	*Lepilaena cylindrocarpa*	2012	Australian Ecosystems, 2012
Mallee Love-grass	*Eragrostis dielsii*	2012	Australian Ecosystems, 2012
Mallee Wattle	*Acacia montana*	2012	Australian Ecosystems, 2012
Moonah#	*Melaleuca lanceolata subsp. lanceolata*	2012	Australian Ecosystems, 2012
Native Sow-thistle	*Sonchus hydrophilus*	2012	Australian Ecosystems, 2012
Nealie	*Acacia rigens*	2008; 2012	Australian Ecosystems, 2012; DEPI, 2013
Nitella	*Nitella sp.*	2012	Australian Ecosystems, 2012
Nitre Goosefoot	*Chenopodium nitrariaceum*	2012	Australian Ecosystems, 2012
Nitre-bush	*Nitraria billardierei*	2012	Australian Ecosystems, 2012
Nodding Saltbush	*Einadia nutans subsp. nutans*	2012	Australian Ecosystems, 2012
Old-man Saltbush	*Atriplex nummularia*	2012	Australian Ecosystems, 2012
Pale Goodenia	*Goodenia glauca*	2012	Australian Ecosystems, 2012
Pink Bindweed	*Convolvulus erubenscens*	1989-1990	DEPI, 2013
Plump Spear-grass	*Austrostipa aristiglumis*	2012	Australian Ecosystems, 2012
Poison Pratia	*Lobelia concolor*	2012	Australian Ecosystems, 2012
Prickly Saltwort	*Salsola tragus subsp. tragus*	2012	Australian Ecosystems, 2012
Quena	*Solanum esuriale*	2012	Australian Ecosystems, 2012
Rat-tail Couch	*Sporobolus mitchellii*	2012	Australian Ecosystems, 2012
Red Sandspurrey	*Spergularia rubra*	1990	DEPI, 2013
River Red-gum	*Eucalyptus camaldulensis*	2012	Australian Ecosystems, 2012
Rosinweed	*Cressa cretica*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013

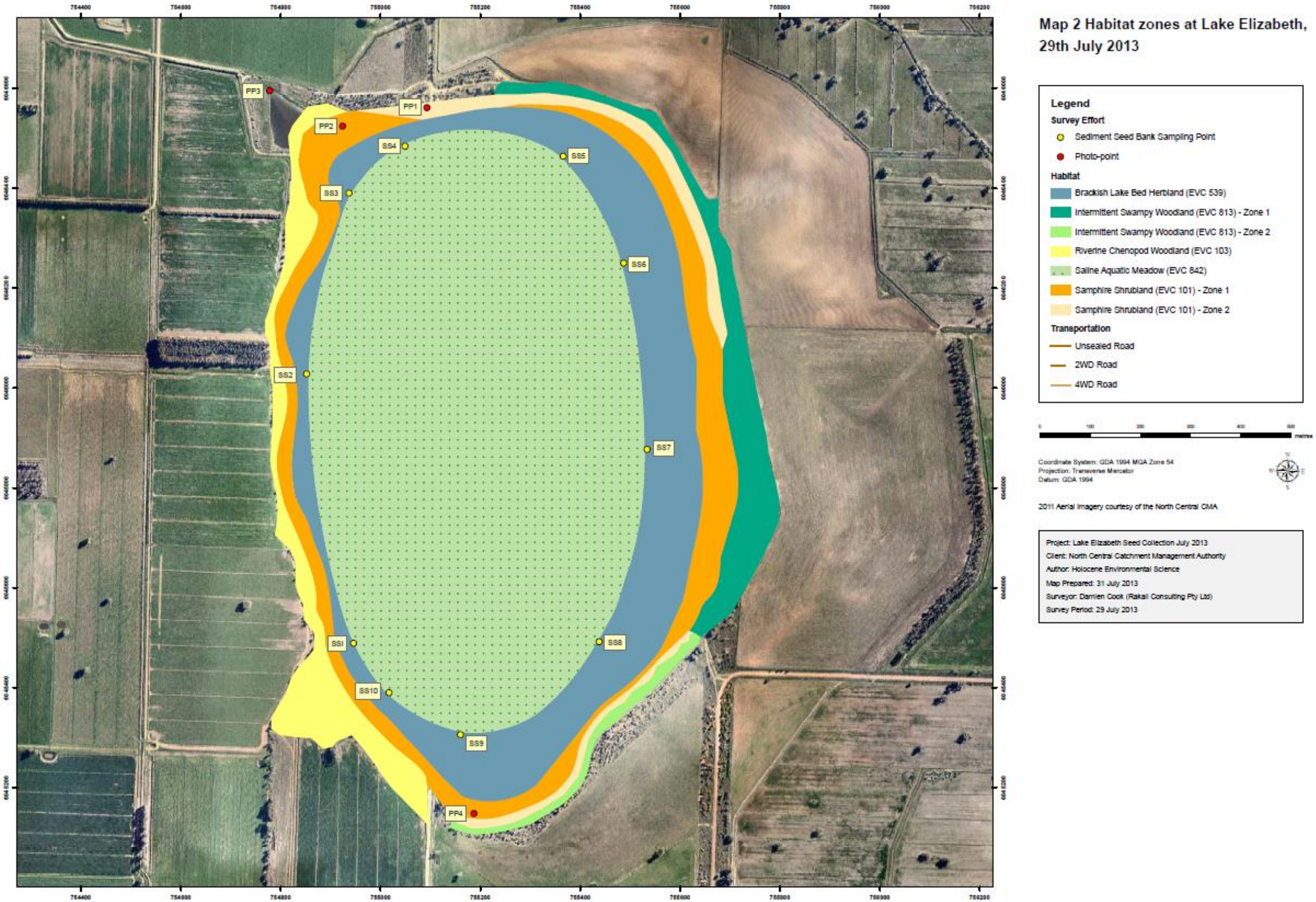
Rough Spear-grass	*Austrostipa scabra subsp. falcata*	2012	Australian Ecosystems, 2012
Rounded Noon-flower	*Disphyma crassifolium subsp. clavellatum*	2012	Australian Ecosystems, 2012
Round-leaf Wilsonia	*Wilsonia rotundifolia*	2012	Australian Ecosystems, 2012
Ruby Salt-bush	*Enchylaena tomentosa var. tomentosa*	2012	Australian Ecosystems, 2012
Saloop Saltbush	*Einadia hastata*	2004	DEPI, 2013
Salt Bush	*Atriplex prostrata*	1990	DEPI, 2013
Salt Paperbark	*Melaleuca halmaturorum subsp. halmaturorum*	2012	Australian Ecosystems, 2012
Salt Sand-spurrey	*Spergularia marina s.l.*	2012	Australian Ecosystems, 2012
Sea Tassel	*Ruppia maritima*	1990	DEPI, 2013
Short Rat-tail Grass	*Sporobolus mitchellii*	1990, 2004	DEPI, 2013
Short-Leaf Bluebush	*Maireana brevifolia*	2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Silver Mulga	*Acacia argyrophylla*	1990	DEPI, 2013
Slender Cypress-pine	*Callitris gracilis subsp. murrayensis*	2012	Australian Ecosystems, 2012
Slender Fissure Weed	*Maireana pentagona*	1990	DEPI, 2013
Slender Hop-bush	*Dodonaea viscosa subsp. angustissima*	2012	Australian Ecosystems, 2012
Slender-fruit Saltbush	*Atriplex leptocarpa*	1974, 2004	Australian Ecosystems, 2012; DEPI, 2013
Small Cooba	*Acacia ligulata*	2012	Australian Ecosystems, 2012
Small Loosestrife	*Lythrum hyssopifolia*	2012	Australian Ecosystems, 2012
Smooth Heliotrope	*Heliotropium curassavicum*	2012	Australian Ecosystems, 2012
Snow-wort	*Abrotanella nivigena*	1974, 1990	DEPI, 2013
Spider-grass	*Enteropogon acicularis*	2012	Australian Ecosystems, 2012
Spiny Flat-sedge	*Cyperus gymnocaulos*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Spiny Saltbush	*Rhagodia spinescens*	1990, 2004	DEPI, 2013
Stonewort	*Lamprothamnium macropogon*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Sweet Swamp Grass	*Poa fordeana*	1990	DEPI, 2013
Tall GrounDEPIl	*Senecio runcinifolius*	1990	DEPI, 2013
Tangled Lignum	*Muehlenbeckia florulenta*	1990, 2004, 2008, 2012	Australian Ecosystems, 2012; DEPI, 2013
Umbrella Wattle	*Acacia oswaldii*	2012	Australian Ecosystems, 2012
Variable Sida	*Sida corrugata*	2012	Australian Ecosystems, 2012
Variable Spear Grass	*Stipa variabilis*	1990	DEPI, 2013
Wallaby Grass	*Danthonia spp.*	1990, 2004	DEPI, 2013
Wedge-leaf Hop-bush	*Dodonaea viscosa subsp. cuneata*	2012	Australian Ecosystems, 2012
Weeping Myall#	*Acacia pendula*	2012	Australian Ecosystems, 2012
Weeping Pittosporum	*Pittosporum angustifolium*	2012	Australian Ecosystems, 2012
Willow Wattle	*Acacia salicina*	2012	Australian Ecosystems, 2012
Windmill grass	*Chloris truncata*	1990	DEPI, 2013
Woolly New Holland Daisy	*Vittadinia gracilis*	2012	Australian Ecosystems, 2012
Yanga Bush	*Maireana brevifolia*	1990	DEPI, 2013
Flora- exotics			
African Box-thorn	*Lycium ferocissimum*	1974, 1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Annual Beard-grass	*Polypogon monspeliensis*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Aster-weed	*Aster subulatus*	2012	Australian Ecosystems, 2012
Barley-grass	*Critesion murinum*	1990, 2004	DEPI, 2013

Berry Seablite	*Suaeda baccifera*	2012	Australian Ecosystems, 2012
Black Nightshade	*Solanum nigrum s.l.*	2012	Australian Ecosystems, 2012
Buck's-horn Plantain	*Plantago coronopus subsp. coronopus*	2012	Australian Ecosystems, 2012
Burr Medic	*Medicago polymorpha*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Capeweed	*Arctotheca calendula*	1990	DEPI, 2013
Coast Barb-grass	*Parapholis incurva*	2012	Australian Ecosystems, 2012
Common Heliotrope	*Heliotropium europaeum*	1990	DEPI, 2013
Common Ice-plant	*Mesembryanthemum crystallinum*	2012	Australian Ecosystems, 2012
Common Sow-thistle	*Sonchus oleraceus*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Couch	*Cynodon dactylon var. dactylon*	1990; 2012	Australian Ecosystems, 2012; DEPI, 2013
Curled Dock	*Rumex crispus*	1990; 2012	Australian Ecosystems, 2012; DEPI, 2013
Curly Barb Grass (Curly Rye Grass)	*Parapholis incurva*	1990, 2004	DEPI, 2013
Drain Flat-sedge	*Cyperus eragrostis*	2012	Australian Ecosystems, 2012
Ferny Cotula	*Cotula bipinnata*	2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Flat Weed	*Hypochoeris radicata*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Great Brome	*Bromus diandrus*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Hairy Hawbit	*Leontodon taraxacoides*	1989-1990	DEPI, 2013
Hastate Orache	*Atriplex prostrata*	2012	Australian Ecosystems, 2012
Horehoud	*Marrubium vulgare*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Madrid Brome	*Bromus madritensis*	1990	DEPI, 2013
Medic	*Medicago spp.*	2004	DEPI, 2013
Mediterranean Barley-Grass	*Critesion hystrix*	1989-1990	DEPI, 2013
Oat	*Avena spp.*	2012	Australian Ecosystems, 2012
Onion Weed	*Asphodelus fistulosus*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Ox Tongue	*Helminthotheca echnioides*	1989-1990	DEPI, 2013
Ox-tongue	*Helminthotheca echioides*	1990; 2012	Australian Ecosystems, 2012; DEPI, 2013
Paspalum	*Paspalum dilatatum*	2012	Australian Ecosystems, 2012
Peppercress	*Lepidium africanum*	1990	DEPI, 2013
Prickly Lettuce	*Lactuca serriola*	2012	Australian Ecosystems, 2012
Prickly Sow-thistle	*Sonchus asper*	2004	DEPI, 2013
River Oak	*Casuarina cunninghamiana subsp. cunninghamiana*	2012	Australian Ecosystems, 2012
Rye Grass	*Lolium spp.*	1990	DEPI, 2013
Scorzonera	*Scorzonera laciniata*	1990	DEPI, 2013
Sea Barley-grass	*Hordeum marinum*	2012	Australian Ecosystems, 2012
Sharp Rush	*uncus acutus ssp. Acutus*	1989-1990	DEPI, 2013
Silvery Grass	*Vulpia spp.*	2004	DEPI, 2013
Small Ice plant	*Mesembryanthemum nodiflorum*	2004	DEPI, 2013
Small-flowered Mallow	*Malva parviflora*	2004	DEPI, 2013
Smooth Cat's-ear	*Hypochoeris glabra*	2012	Australian Ecosystems, 2012
Soursob	*Oxalis pres-caprae*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Spear Thistle	*Cirsium vulgare*	1990; 2012	Australian Ecosystems, 2012; DEPI, 2013
Spiny Rush	*Juncus acutus subsp. acutus*	1974, 1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Stinkwort	*Dittrichia graveolens*	2012	Australian Ecosystems, 2012

Sweat Melilot	*Melilotus indicus*	2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Tall Wheat-grass	*Lophopyrum ponticum*	2012	Australian Ecosystems, 2012
Tamarisk	*Tamarix ramosissima*	1990, 2012	Australian Ecosystems, 2012; DEPI, 2013
Toowoomba Canary-grass	*Phalaris aquatica*	2012	Australian Ecosystems, 2012
Variegated Thistle	*Silybum marianum*	2012	Australian Ecosystems, 2012
Water Buttons	*Cotula coronopifolia*	1990	DEPI, 2013
Wild Oats	*Avena fatua*	1990, 2004, 2012	Australian Ecosystems, 2012; DEPI, 2013
Wimmera Rye-grass	*Lolium rigidum*	2004, 2012	Australian Ecosystems, 2012; DEPI, 2013

Appendix 7: Ecological vegetation classes

Ecological Vegetation Classes mapped at Lake Elizabeth (Rakali Ecological Consulting, 2013).



Department of Sustainability and Environment

EVC/Bioregion Benchmark for Vegetation Quality Assessment

Victorian Riverina bioregion

EVC 101: Samphire Shrubland

Description:

Low open shrub layer to 0.5 m tall of succulent chenopods on saline clay pans. Found in association with the various halite salinas that have developed within evaporative basins or 'boinkas'.

Life forms:

Life form	#Spp	%Cover	LF code
Small Shrub	4	20%	SS
Medium Herb	7	5%	MH
Small or Prostrate Herb	3	5%	SH
Medium to Small Tufted Graminoid	2	1%	MTG
Medium to Tiny Non-tufted Graminoid	2	1%	MNG
Total understorey projective foliage cover		**20%**	

LF Code		Species typical of at least part of EVC range	Common Name
SS		Halosarcia pruinosa	Bluish Glasswort
SS		Halosarcia halocnemoides ssp. halocnemoides	Grey Glasswort
SS		Halosarcia pergranulata	Blackseed Glasswort
SS	r	Frankenia sessilis	Small-leaf Sea-heath
MH		Senecio glossanthus	Slender Groundsel
MH		Hymenolobus procumbens	Oval Purse
MH		Brachyscome lineariloba	Hard-head Daisy
MH	r	Brachyscome exilis	Finger-leaved Daisy
SH		Disphyma crassifolium ssp. clavellatum	Rounded Noon-flower
SH		Pogonolepis muelleriana	Stiff Cup-flower
SH		Crassula sieberiana	Sieber Crassula
SH		Millotia muelleri	Common Bow-flower
MTG		Triglochin calcitrapum s.l.	Spurred Arrowgrass
MNG		Triglochin nanum	Dwarf Arrowgrass

Recruitment:

Continuous

Weediness:

LF Code	Typical Weed Species	Common Name	Invasive	Impact
LH	Sonchus oleraceus	Common Sow-thistle	high	l
LH	Brassica tournefortii	Mediterranean Turnip	high	o
MH	Reichardia tingitana	Reichardia	high	w
MH	Hypochoeris glabra	Smooth Cat's-ear	high	
MH	Carrichtera annua	Ward's Weed	high	h
MH	Spergularia diandra	Lesser Sand-spurrey	high	low
SH	Medicago minima	Little Medic	high	h
SH	Spergularia rubra s.l.	Red Sand-spurrey	high	i
MTG	Critesion murinum subsp. glaucum	Blue Barley-grass	high	g
MNG	Bromus rubens	Red Brome	high	h
MNG	Vulpia bromoides	Rat's-tail Fescue	high	
SNG	Schismus barbata	Arabian Grass	high	l
SNG	Lamarckia aurea	Golden-top	high	o
SNG	Parapholis incurva	Coast Barb-grass	high	w
SNG	Critesion murinum subsp. glaucum	Blue Barley-grass	high	high

EVC/Bioregion Benchmark for Vegetation Quality Assessment

Victorian Riverina bioregion

EVC 103: Riverine Chenopod Woodland

Descriptio:

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.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus spp.	50 cm	5/ha

Tree Canopy Cover:

%cover	Character Species	Common Name
10%	Eucalyptus largiflorens	Black Box

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Understorey Tree or Large Shrub	1	5%	T
Medium Shrub	3	30%	MS
Small Shrub	5	25%	SS
Prostrate Shrub	1	1%	PS
Medium Herb	5	5%	MH
Small or Prostrate Herb*	5	10%	SH
Medium to Small Tufted Graminoid	2	5%	MTG
Soil Crust	na	10%	S/C

* Largely seasonal life form

Total understorey projective foliage cover *65%*

LF Code	Species typical of at least part of EVC range	Common Name
T	Acacia stenophylla	River Coobah
MS	Atriplex nummularia	Old-man Saltbush
MS	Chenopodium nitrariaceum	Nitre Goosefoot
MS	Eremophila divaricata ssp. divaricata	Spreading Emu-bush
SS	Sclerolaena tricuspis	Streaked Copperburr
SS	Enchylaena tomentosa var. tomentosa	Ruby Saltbush
SS	Atriplex lindleyi	Flat-top Saltbush
SS	Rhagodia spinescens	Hedge Saltbush
PS	Sclerochlamys brachyptera	Short-wing Saltbush
MH	Einadia nutans ssp. nutans	Nodding Saltbush
MH	Calocephalus sonderi	Pale Beauty-heads
MH	Senecio glossanthus	Slender Groundsel
MH	Brachyscome lineariloba	Hard-head Daisy
SH	Disphyma crassifolium ssp. clavellatum	Rounded Noon-flower
SH	Maireana pentagona	Hairy Bluebush

Recruitment:

Continuous

Organic Litter:5% cover

Logs: 5 m/0.1 ha.

EVC 103: Riverine Chenopod Woodland - Victorian Riverina bioregion

Weediness:

LF Code	Typical Weed Species	Common Name	Invasive	Impact
T	Olea europaea subsp. europaea	Olive	low	high
MS	Lycium ferocissimum	Boxthorn	low	high
LH	Sisymbrium erysimoides	Smooth Mustard	high	high
LH	Critesion spp.	Barley-grass	high	low
LH	Gazania linearis	Gazania	high	high
LH	Opuntia spp.	Prickly Pear	low	high
LH	Sisymbrium irio	London Mustard	high	high
LH	Psilocaulon granulicaule	Noon-flower	high	high
MH	Limonium sinuatum	Notch-leaf Sea-lavender	high	high
MH	Limonium lobatum	Winged Sea-lavender	high	high
MH	Trifolium arvense var. arvense	Hare's-foot Clover	high	low
MH	Mesembryanthemum nodiflora	Ice-plant	high	high
MH	Carrichtera annua	Ward's Weed	high	high
MH	Marrubium vulgare	Horehound	high	high
MH	Carpobrotus aequilaterus	Angled Pigface	low	high
MH	Silene apetala var. apetala	Sand Catchfly	high	low
MH	Medicago spp.	Medic	high	low
MH	Oxalis pes-caprae	Soursob	high	high
MH	Silene gallica	French Catchfly	high	low
MH	Silene nocturna	Mediterranean Catchfly	high	low
SH	Mesembryanthemum crystallinum	Common Ice-plant	high	high
MTG	Vulpia bromoides	Squirrel-tail Fescue	high	high
MTG	Lolium rigidum	Wimmera Rye-grass	high	low
MTG	Asphodelus fistulosus	Onion Weed	high	high
MNG	Bromus rubens	Red Brome	high	high
MNG	Vulpia myuros	Rat's-tail Fescue	high	low
MNG	Bromus spp.	Brome	high	high
MNG	Schismus barbatus	Arabian Grass	high	low
SC	Asparagus asparagoides	Bridal Creeper	high	high

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EVC/Bioregion Benchmark for Vegetation Quality Assessment

Victorian Riverina bioregion

EVC 813: Intermittent Swampy Woodland

Description:

Eucalypt woodland to 15 m tall with a variously shrubby and rhizomatous sedgy - turf grass understorey, at best development dominated by flood stimulated species in association with flora tolerant of inundation. Flooding is unreliable but extensive when it happens. Occupies low elevation areas on river terraces (mostly at the rear of point-bar deposits or adjacent to major floodways) and lacustrine verges (where sometimes localised to narrow transitional bands). Soils often have a shallow sand layer over heavy and frequently slightly brackish soils.

Large trees:

Species	DBH(cm)	#/ha
Eucalyptus camaldulensis	70 cm	15 / ha
Eucalyptus largiflorens	50 cm	

Tree Canopy Cover:

%cover	Character Species	Common Name
20%	Eucalyptus camaldulensis	River Red-gum
	Eucalyptus largiflorens	Black Box

Understorey:

Life form	#Spp	%Cover	LF code
Immature Canopy Tree		5%	IT
Understorey Tree or Large Shrub	1	5%	T
Medium Shrub	1	5%	MS
Small Shrub	1	5%	SS
Large Herb	2	5%	LH
Medium Herb	5	10%	MH
Small or Prostrate Herb	1	5%	SH
Medium to Small Tufted Graminoid	3	30%	MTG
Medium to Tiny Non-tufted Graminoid	2	10%	MNG
Total understorey projective foliage cover		**70%**	

LF Code	Species typical of at least part of EVC range	Common Name
T	Acacia stenophylla	River Coobah
MS	Muehlenbeckia florulenta	Tangled Lignum
SS	Cressa cretica	Rosinweed
LH	Stemodia florulenta	Blue Rod
LH	Wahlenbergia fluminalis	River Bluebell
MH	Haloragis aspera	Rough Raspwort
MH	Centipeda cunninghamii	Common Sneezeweed
MH	Calocephalus sonderi	Pale Beauty-heads
SH	Epaltes australis	Spreading Nut-heads
MTG	Sporobolus mitchellii	Rat-tail Couch
MTG	Cyperus gymnocaulos	Spring Flat-sedge
MTG	Lachnagrostis filiformis	Common Blown-grass
MNG	Cynodon dactylon var. pulchellus	Native Couch

Recruitment: Continous

Organic Litter: *20 % cover*

Logs: *20 m/0.1 ha.*

Weediness: *There are no consistent weeds in this EVC*

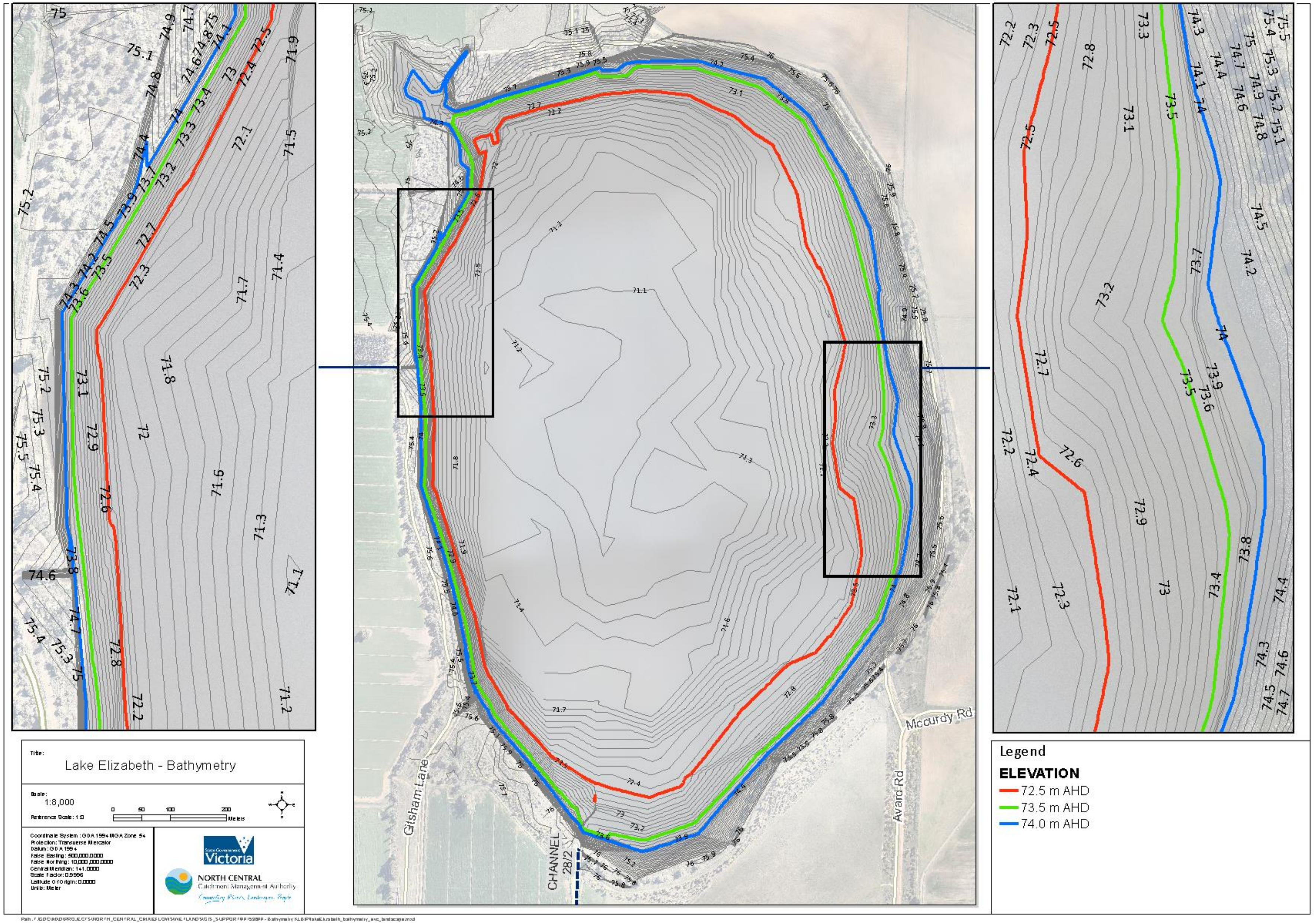
Appendix 8: Recent watering history

	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
Status [1]	W	W	W	W	W	W	W	W	W
Water source [2]	C	C	C	C	C	C	C	E/ C	E/ C
Volume delivered (if available) (ML)	U	U	U	782 (C)	471 (C)	510 (C)	495 (C)	1632.2 (E)/ 413 (C)	599 (E)/ 416 (C)
Comment								Environmental water supplied for Murray Hardyhead	

	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-13
Status [1]	W	W	W-D	W-D	W-D	W-D	D-W	W	W
Water source [2]	E/ C	E/ C	C	C	C	C	F	N/A	N/A
Volume delivered (if available) (ML)	307 (E)/ 401 (C)	598 (E)/ 456 (C)	473 (C)	104.1 (C)	80.2 (C)	U	N/A	N/A	N/A
Comment	Environmental water supplied for Murray Hardyhead		No environmental water provided				Flood inundation	No environmental water provided	

KEY:
W- wet/ D- dry/ W-D- drying
E- environmental allocation/ C- Channel outfall/ F- flood flows/ U- unknown

Appendix 9: Contour Plan and Capacity Table (Price Merrett, 2013)



Avg. End Area Cumulative Vol (ML)	***Elevation (m AHD)***	***Plane Surface Area (Ha)***	***Avg. End Area Incremental Vol (ML)***
0.000	71.01	0.031	N/A
0.008	71.02	0.124	0.008
0.028	71.03	0.276	0.020
0.066	71.04	0.489	0.038
0.132	71.05	0.839	0.066
0.246	71.06	1.437	0.114
0.428	71.07	2.206	0.182
0.692	71.08	3.067	0.264
1.051	71.09	4.119	0.359
1.258	71.10	5.333	0.206
1.525	71.11	6.610	0.268
1.858	71.12	7.988	0.333
2.261	71.13	9.421	0.402
2.723	71.14	10.755	0.462
3.266	71.15	12.170	0.543
3.880	71.16	13.657	0.615
5.304	71.17	15.294	1.424
6.918	71.18	16.987	1.614
8.702	71.19	18.691	1.784
9.647	71.20	20.769	0.945
10.718	71.21	23.470	1.070
11.847	71.22	24.126	1.129
13.023	71.23	24.842	1.176
14.244	71.24	25.554	1.221
15.510	71.25	26.258	1.266
16.818	71.26	26.991	1.308
18.147	71.27	27.732	1.329
19.532	71.28	28.477	1.385
22.415	71.29	29.198	2.883
25.368	71.30	29.878	2.954
28.387	71.31	30.488	3.018
31.466	71.32	31.103	3.080
34.607	71.33	31.703	3.140
37.807	71.34	32.300	3.200
41.068	71.35	32.918	3.261
44.391	71.36	33.539	3.323
47.776	71.37	34.171	3.385
51.226	71.38	34.829	3.450
54.742	71.39	35.485	3.516
58.325	71.40	36.182	3.583
60.135	71.41	36.878	1.810
61.982	71.42	37.567	1.847
63.866	71.43	38.246	1.884
67.712	71.44	38.859	3.846
71.628	71.45	39.463	3.916
75.604	71.46	40.052	3.976
79.637	71.47	40.617	4.033
83.726	71.48	41.158	4.089
87.867	71.49	41.674	4.142
92.060	71.50	42.173	4.192
96.300	71.51	42.637	4.240
100.586	71.52	43.084	4.286
104.916	71.53	43.511	4.330
109.287	71.54	43.915	4.371
113.698	71.55	44.311	4.411
118.148	71.56	44.684	4.450
122.635	71.57	45.056	4.487
127.159	71.58	45.420	4.524
131.719	71.59	45.776	4.560

Avg. End Area Cumulative Vol (ML)	Elevation (m AHD)	Plane Surface Area (Ha)	Avg. End Area Incremental Vol (ML)
136.314	71.60	46.124	4.595
140.943	71.61	46.461	4.629
145.605	71.62	46.783	4.662
150.298	71.63	47.065	4.692
155.019	71.64	47.351	4.721
159.768	71.65	47.634	4.749
164.545	71.66	47.912	4.777
169.351	71.67	48.197	4.805
174.185	71.68	48.484	4.834
179.047	71.69	48.771	4.863
183.939	71.70	49.060	4.892
188.859	71.71	49.350	4.921
193.809	71.72	49.642	4.950
198.788	71.73	49.934	4.979
203.796	71.74	50.226	5.008
208.833	71.75	50.520	5.037
213.900	71.76	50.814	5.067
218.996	71.77	51.109	5.096
224.122	71.78	51.404	5.126
229.277	71.79	51.700	5.155
234.462	71.80	51.996	5.185
239.676	71.81	52.293	5.214
244.920	71.82	52.588	5.244
250.194	71.83	52.887	5.274
255.497	71.84	53.184	5.304
260.831	71.85	53.482	5.333
266.194	71.86	53.781	5.363
271.587	71.87	54.079	5.393
277.010	71.88	54.379	5.423
282.463	71.89	54.678	5.453
287.946	71.90	54.978	5.483
293.458	71.91	55.279	5.513
299.001	71.92	55.579	5.543
304.574	71.93	55.881	5.573
310.177	71.94	56.182	5.603
315.811	71.95	56.484	5.633
321.474	71.96	56.787	5.664
327.168	71.97	57.090	5.694
332.892	71.98	57.393	5.724
338.646	71.99	57.686	5.754
344.431	72.00	58.000	5.784
350.246	72.01	58.306	5.815
356.092	72.02	58.615	5.846
361.969	72.03	58.926	5.877
367.877	72.04	59.240	5.908
373.817	72.05	59.557	5.940
379.789	72.06	59.871	5.971
385.792	72.07	60.191	6.003
391.827	72.08	60.516	6.035
397.895	72.09	60.836	6.068
403.995	72.10	61.166	6.100
410.127	72.11	61.480	6.132
416.291	72.12	61.793	6.164
422.486	72.13	62.110	6.195
428.712	72.14	62.415	6.226
434.969	72.15	62.725	6.257
441.257	72.16	63.035	6.288
447.576	72.17	63.344	6.319
453.926	72.18	63.652	6.350

Avg. End Area Cumulative Vol (ML)	Elevation (m AHD)	Plane Surface Area (Ha)	Avg. End Area Incremental Vol (ML)
460.306	72.19	63.957	6.380
466.717	72.20	64.250	6.410
473.157	72.21	64.550	6.440
479.626	72.22	64.844	6.470
486.125	72.23	65.134	6.499
492.653	72.24	65.419	6.528
499.208	72.25	65.683	6.555
505.787	72.26	65.898	6.579
512.388	72.27	66.118	6.601
519.011	72.28	66.343	6.623
522.329	72.29	66.580	3.317
525.658	72.30	66.887	3.329
529.002	72.31	67.158	3.345
535.729	72.32	67.390	6.727
542.480	72.33	67.630	6.751
549.258	72.34	67.919	6.777
553.084	72.35	68.241	3.826
559.494	72.36	68.565	6.410
566.367	72.37	68.899	6.873
573.273	72.38	69.212	6.906
580.209	72.39	69.522	6.937
587.176	72.40	69.817	6.967
594.172	72.41	70.104	6.996
601.197	72.42	70.391	7.025
604.716	72.43	70.646	3.520
608.249	72.44	70.886	3.532
611.793	72.45	71.097	3.544
615.348	72.46	71.309	3.555
618.913	72.47	71.520	3.565
622.489	72.48	71.730	3.576
626.076	72.49	71.939	3.587
629.673	72.50	72.146	3.597
633.280	72.51	72.351	3.607
636.898	72.52	72.557	3.618
640.526	72.53	72.756	3.628
644.163	72.54	72.959	3.638
647.811	72.55	73.163	3.648
651.469	72.56	73.369	3.658
655.138	72.57	73.572	3.668
662.505	72.58	73.771	7.367
669.892	72.59	73.969	7.387
677.299	72.60	74.165	7.407
684.725	72.61	74.358	7.426
692.170	72.62	74.545	7.445
699.634	72.63	74.729	7.464
707.116	72.64	74.912	7.482
714.616	72.65	75.093	7.500
722.134	72.66	75.272	7.518
729.671	72.67	75.454	7.536
737.225	72.68	75.627	7.554
744.796	72.69	75.801	7.571
752.385	72.70	75.978	7.589
759.991	72.71	76.143	7.606
767.614	72.72	76.313	7.623
775.254	72.73	76.483	7.640
782.910	72.74	76.653	7.657
790.584	72.75	76.823	7.674
798.275	72.76	76.996	7.691
805.815	72.77	77.158	7.540

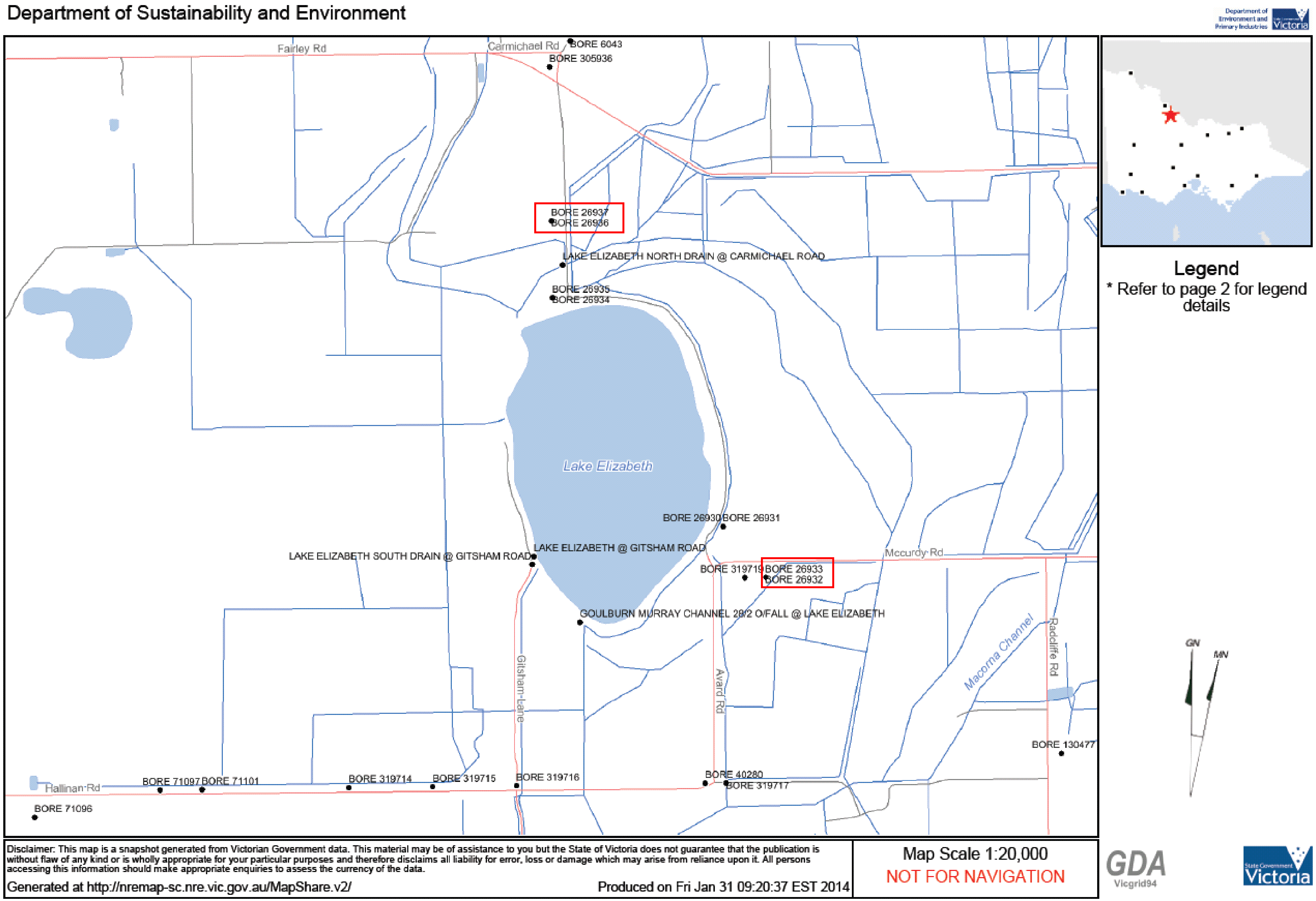
Avg. End Area Cumulative Vol (ML)	*Elevation (m AHD)*	*Plane Surface Area (Ha)*	*Avg. End Area Incremental Vol (ML)*
809.849	72.78	77.323	4.034
817.589	72.79	77.487	7.741
825.346	72.80	77.651	7.757
833.119	72.81	77.806	7.773
840.908	72.82	77.966	7.789
844.806	72.83	78.127	3.898
848.713	72.84	78.285	3.906
852.627	72.85	78.445	3.914
856.549	72.86	78.603	3.922
860.479	72.87	78.761	3.930
864.417	72.88	78.920	3.938
868.363	72.89	79.079	3.946
872.317	72.90	79.238	3.954
876.279	72.91	79.398	3.962
880.249	72.92	79.563	3.970
884.227	72.93	79.721	3.978
888.213	72.94	79.876	3.986
892.207	72.95	80.034	3.994
896.209	72.96	80.191	4.002
900.218	72.97	80.345	4.010
904.236	72.98	80.502	4.017
908.261	72.99	80.657	4.025
912.294	73.00	80.811	4.033
916.334	73.01	80.966	4.041
920.382	73.02	81.124	4.048
924.439	73.03	81.271	4.056
928.502	73.04	81.425	4.064
932.573	73.05	81.579	4.071
936.652	73.06	81.731	4.079
940.739	73.07	81.884	4.086
944.833	73.08	82.037	4.094
948.935	73.09	82.190	4.102
953.044	73.10	82.341	4.110
957.161	73.11	82.498	4.117
961.286	73.12	82.653	4.125
965.419	73.13	82.808	4.133
969.559	73.14	82.968	4.140
973.708	73.15	83.128	4.148
977.864	73.16	83.291	4.156
982.028	73.17	83.446	4.165
986.201	73.18	83.606	4.172
990.381	73.19	83.765	4.180
994.569	73.20	83.923	4.188
998.766	73.21	84.085	4.196
1002.970	73.22	84.240	4.204
1007.182	73.23	84.395	4.212
1011.402	73.24	84.551	4.220
1015.629	73.25	84.708	4.228
1019.865	73.26	84.863	4.235
1028.358	73.27	85.017	8.494
1036.868	73.28	85.172	8.509
1045.393	73.29	85.330	8.525
1053.933	73.30	85.467	8.540
1062.487	73.31	85.613	8.554
1071.055	73.32	85.760	8.569
1079.638	73.33	85.898	8.583
1088.235	73.34	86.042	8.597
1096.846	73.35	86.184	8.611
1105.472	73.36	86.325	8.625

Avg. End Area Cumulative Vol (ML)	*Elevation (m AHD)*	*Plane Surface Area (Ha)*	*Avg. End Area Incremental Vol (ML)*
1114.112	73.37	86.469	8.640
1122.766	73.38	86.611	8.654
1131.434	73.39	86.752	8.668
1140.116	73.40	86.890	8.682
1148.812	73.41	87.029	8.696
1157.522	73.42	87.167	8.710
1166.245	73.43	87.305	8.724
1174.982	73.44	87.442	8.737
1183.733	73.45	87.579	8.751
1192.498	73.46	87.715	8.765
1201.276	73.47	87.852	8.778
1210.068	73.48	87.986	8.792
1218.874	73.49	88.121	8.805
1227.692	73.50	88.256	8.819
1236.525	73.51	88.390	8.832
1245.371	73.52	88.524	8.846
1254.230	73.53	88.658	8.859
1263.102	73.54	88.792	8.873
1271.988	73.55	88.925	8.886
1280.887	73.56	89.058	8.899
1289.800	73.57	89.191	8.912
1295.223	73.58	89.323	5.423
1303.198	73.59	89.458	7.975
1312.150	73.60	89.587	8.952
1321.116	73.61	89.721	8.965
1330.094	73.62	89.837	8.978
1339.084	73.63	89.960	8.990
1348.085	73.64	90.074	9.002
1357.098	73.65	90.178	9.013
1366.121	73.66	90.277	9.023
1375.153	73.67	90.375	9.033
1384.195	73.68	90.466	9.042
1393.246	73.69	90.556	9.051
1402.306	73.70	90.636	9.060
1406.838	73.71	90.720	4.532
1411.374	73.72	90.799	4.536
1420.457	73.73	90.876	9.084
1428.417	73.74	90.950	7.959
1434.100	73.75	91.027	5.683
1443.206	73.76	91.092	9.106
1447.761	73.77	91.160	4.555
1452.319	73.78	91.230	4.558
1456.880	73.79	91.300	4.562
1461.446	73.80	91.382	4.565
1466.015	73.81	91.449	4.569
1470.588	73.82	91.528	4.573
1476.427	73.83	91.584	5.840
1484.325	73.84	91.657	7.898
1493.495	73.85	91.735	9.170
1502.671	73.86	91.797	9.177
1511.855	73.87	91.873	9.184
1521.046	73.88	91.951	9.191
1530.245	73.89	92.026	9.199
1539.452	73.90	92.112	9.207
1548.667	73.91	92.193	9.215
1557.891	73.92	92.284	9.224
1567.124	73.93	92.372	9.233
1576.365	73.94	92.460	9.242
1585.616	73.95	92.549	9.250

Avg. End Area Cumulative Vol (ML)	Elevation (m AHD)	Plane Surface Area (Ha)	Avg. End Area Incremental Vol (ML)
1594.875	73.96	92.638	9.259
1604.144	73.97	92.727	9.268
1613.421	73.98	92.817	9.277
1622.707	73.99	92.908	9.286
1632.002	74.00	92.998	9.295
1641.307	74.01	93.089	9.304
1650.620	74.02	93.178	9.313
1659.942	74.03	93.270	9.322
1669.274	74.04	93.362	9.332
1678.432	74.05	93.457	9.158
1683.293	74.06	93.553	4.860
1692.653	74.07	93.643	9.360
1702.022	74.08	93.739	9.369
1711.400	74.09	93.836	9.379
1720.789	74.10	93.933	9.388
1730.187	74.11	94.031	9.398
1739.595	74.12	94.130	9.408
1749.013	74.13	94.229	9.418
1758.441	74.14	94.332	9.428
1758.441	74.15	94.411	0.000
1767.725	74.16	94.479	9.284
1767.885	74.17	94.530	0.159
1772.611	74.18	94.600	4.727
1772.691	74.19	94.670	0.079
1777.345	74.20	94.740	4.654
1786.663	74.21	93.300	9.319
1786.667	74.22	93.367	0.004
1791.334	74.23	93.434	4.666
1791.336	74.24	93.498	0.002
1796.008	74.25	90.445	4.673
1800.512	74.26	90.477	4.504
1804.364	74.27	78.467	3.851
1804.368	74.28	78.440	0.004
1804.423	74.29	78.415	0.056
1808.273	74.30	78.388	3.849
1808.382	74.31	78.360	0.110
1808.440	74.32	78.337	0.058
1808.444	74.33	78.305	0.004
1808.593	74.34	44.358	0.149
1810.625	74.35	78.627	2.032
1814.473	74.36	78.600	3.848
1814.492	74.37	78.575	0.018
1814.498	74.38	78.551	0.006
1814.576	74.39	78.525	0.078
1814.579	74.40	78.500	0.003
1818.405	74.41	78.475	3.826
1822.242	74.42	78.450	3.837
1822.260	74.43	78.425	0.018
1822.293	74.44	78.400	0.034
1826.127	74.45	78.355	3.833
1826.143	74.46	78.334	0.016
1826.275	74.47	78.309	0.132
1833.894	74.48	78.284	7.619
1833.914	74.49	78.259	0.020
1833.933	74.50	78.233	0.019
1837.751	74.51	78.303	3.819
1837.886	74.52	78.254	0.134
1837.906	74.53	78.215	0.020
1837.912	74.54	78.177	0.006

Avg. End Area Cumulative Vol (ML)	*Elevation (m AHD)*	*Plane Surface Area (Ha)*	*Avg. End Area Incremental Vol (ML)*
1845.504	74.55	78.141	7.591
1845.523	74.56	77.858	0.019
1845.532	74.57	77.819	0.010
1845.588	74.58	77.780	0.056
1845.597	74.59	77.744	0.009
1845.649	74.60	77.709	0.052
KEY			
	Level at time of survey (August 2013)		
	Previously nominated FSL (in EWP 2010)		
	Target supply range 72.5-74m AHD		

Appendix 10: Location of groundwater bores surrounding Lake Elizabeth



Appendix 11: Index of wetland condition method

Sub-indices

The table below shows what is measured for each of the six sub-indices and how each sub-index is scored. The sections below describe this in greater detail. Further information can be found on the IWC website (www.dse.vic.gov.au/iwc).

IWC sub-indices and measures

Sub-index	What is measured	How it is scored
Wetland catchment	The intensity of the land use within 250 metres of the wetland	The more intensive the landuse the lower the score
	The width of the native vegetation surrounding the wetland and whether it is a continuous zone or fragmented	The wider the zone and more continuous the zone, the higher the score
Physical form	Whether the size of the wetland has been reduced from its estimated pre-European settlement size	A reduction in area results in a lowering of the score
	The percentage of the wetland bed which has been excavated or filled	The greater the percentage of wetland bed modified, the lower the score
Hydrology	Whether the wetland's water regime (i.e. the timing, frequency of filling and duration of flooding) has been changed by human activities	The more severe the impacts on the water regime, the lower the score
Water properties	Whether activities and impacts such as grazing and fertilizer run-off that would lead to an input of nutrients to the wetland are present	The more activities present, the lower the score
	Whether the wetland has become more saline or in the case of a naturally salty wetland, whether it has become more fresh	An increase in salinity for a fresh wetland lowers the score or a decrease in salinity of a naturally salty wetland lowers the score
Soils	The percentage and severity of wetland soil disturbance from human, feral animals or stock activities	The more soil disturbance and the more severe it is, the lower the score
Biota	The diversity, health and weediness of the native wetland vegetation	The lower the diversity and poorer health of native wetland vegetation, the lower the score
		The increased degree of weediness in the native wetland vegetation, the lower the score

Scoring method

Each subindex is given a score between 0 and 20 based on the assessment of a number of measures as outline above. Weightings are then applied to the scores as tabulated below. The maximum possible total score for a wetland is 38.4. For ease of reporting, all scores are normalised to an integer score out of 10 (i.e. divide the total score by 38.4, multiply by 10 and round to the nearest whole number).

IWC sub-index	Weight
Biota	0.73
Wetland catchment	0.26
Water properties	0.47
Hydrology	0.31
Physical form	0.08
Soils	0.07

Five wetland condition categories have been assigned to the sub-index scores and total IWC scores as tabulated over page. The five category approach is consistent with the number of categories used in other condition indices such as the Index of Stream Condition. Biota sub-index score categories were determined by expert opinion and differ to those of the other sub-indices.

Non-biota sub-index score range	Biota sub-index score range	Total score range	Wetland condition category
0-4	0-8	0-2	Very poor
5-8	9-13	3-4	Poor
9-12	14-16	5-6	Moderate
13-16	17-18	7-8	Good
16-20	19-20	9-10	Excellent
N/A	N/A	N/A	Insufficient data

Appendix 12: Monitoring program recommendations

The following recommendations have been made for variables to be monitored in order to assess the response to the provision of environmental water, test the assumptions underpinning the salt and water balance model and to inform adaptive management for Lake Elizabeth. It is therefore recommended that an environmental monitoring plan is developed for the site, to ensure planned analysis and reporting of the impacts of the adopted watering regime.

The monitoring plan should initial focus on physical attributes (water quality, water level) as well as habitat values relating to the short term management goal. If conditions are appropriate, future monitoring should also include Murray Hardyhead surveys.

It should be noted that the following monitoring components are presented as recommendations only and the degree to which they are undertaken will be dictated by year to year funding circumstances.

Water quality and level monitoring

Bi-monthly salinity and water level readings should be undertaken to assess the relationship between water level and salinity. Further to this salinity readings should be taken at multiple depths to determine the potential for stratification in the water column. Please note that it is paramount that salinity is measured using an EC meter calibrated to read high EC (initially conditions were in excess of 100,000 EC).

Further to this, measurement of turbidity, water temperature, dissolved oxygen, nutrients and pH would provide additional information to determine the health and growth of aquatic vegetation in Lake Elizabeth. The information collected will inform the delivery of environmental water.

Groundwater monitoring

Long term monitoring of groundwater within the immediate vicinity of Lake Elizabeth is recommended to identify potential risks associated with watering the wetland and for consideration in adaptive management. DEPI currently undertakes monthly groundwater monitoring at the wetland. It is recommended that this continues with particular regard to groundwater level and the potential for saline groundwater intrusion.

It is important that the monthly monitoring results are provided by DEPI to the North Central CMA and/ or the land manager to facilitate data analysis and inform adaptive management.

Vegetation condition and distribution

It is recommended that the condition and distribution of vegetation communities, including exotic species, throughout Lake Elizabeth are assessed regularly.

Information on vegetation communities has been gathered most recently by Australian Ecosystems (2012), Rakali (2013) and the North Central CMAs ‘Protecting and Enhancing Priority Wetlands Project’. This information has been digitalised using GIS to enable comparison in distribution over time.

Further to this quadrats should be established to monitor aquatic vegetation (i.e. Large-fruit Sea Tassel) during the germination and growth phase. Monitoring plots should be set up both within and outside water bird exclusion plots to determine the impact of waterbirds on recruitment.

Additional methods that could also be employed in the evaluation of change to vegetation condition and distribution include:

- Index of Wetland Condition (assessed against the wetland pre-European state)
- Habitat Hectares.

The below table summarises methods that could be adopted to monitor vegetation response:

Component	Target	Method
Vegetation distribution	Submerged aquatic vegetation, chenopod shrubland, availability of open water and mudflat habitat	- Distribution mapping - Photo points - IWC
Vegetation condition		
Species diversity	Additional species with a focus on submerged saline aquatics	Species list comparison

A number of photo points have been also established around Lake Elizabeth (below) to enable the assessment of changes in wetland condition over time. It is recommended that photos are taken from these points (at a minimum), facing the same direction, on a regular basis to capture vegetation condition and distribution. It is recommended that a database be compiled in order to store details of the monitoring photos captured.

Wetland	Photo ID	Easting	Northing	Facing
Lake Elizabeth (GDA94 Zone 55)	PH83	212156.5728	6045630.383	South
	PH85	211984.3787	6045512.228	South
	PH88	211833.52	6045574.045	South east
	PH91	212330.7358	6044155.108	East

PH83

PH85

PH88

PH91

Waterbirds

The diversity and abundance of waterbirds at Lake Elizabeth needs to be monitored following watering in order to assess the success of implementation and achievement of objectives relating to waterbirds. Monthly monitoring will ensure changes in bird communities are captured. Numerous surveys and records are available to provide baseline data in order to evaluate the response of waterbirds to the provision of water. Lake Elizabeth has also been included in the North Central CMAs waterbird monitoring program since October 2012. The following information is capture in the database:

Component	Target	Method
Species diversity	All species including those of conservation significance	Monthly area and quadrat searches
Waterbird abundance		
Breeding populations	Australian Pelican, Blue-billed Duck, and Black Swan	
Habitat availability	Open water, mudflat, Chenopod shrubland and surrounding Black Box, lignum and chenopod vegetation	To be undertaken in conjunction with vegetation monitoring

Zooplankton and macroinvertebrates

Zooplankton is an important food source for Murray Hardyhead (should translocation occur) whilst macroinvertebrates are important for waterbirds. In most cases macroinvertebrates are too large for both adult and juvenile Murray Hardhead, therefore determining whether there is a substantial and diverse population of zooplankton would be critical for providing a food source for the Murray Hardyhead. Numerous surveys and records exist to provide baseline data to allow evaluation of the response to watering. A database has also been compiled of all recordings made at Lake Elizabeth and should be updated regularly following monitoring. The below table details the components that should be monitored for macroinvertebrates and zooplankton.

The results of the monitoring should be used to inform the assessment of habitat availability for waterbirds as they provide a significant food source for a number of species. Further to this the results will also assist with indicating the likely of Murray Hardyhead translocation. Incidental observations of reptiles and amphibians can also be recorded.

Component	Target	Method
Species diversity	All species including those of conservation significance	Sweep netting/AUSRIVAS
Species abundance		

Fish

If translocation of Murray Hardyhead at Lake Elizabeth is deemed feasible a thorough monitoring program should be adopted. The Murray Hardyhead Recovery Team (coordinated by DEPI) currently undertakes a range of monitoring at Round Lake, including monthly water quality and annual surveys. It is recommended that monitoring is undertaken at least biannually in the first few years following translocation to ensure the population is responding. Previous sampling methods adopted have included the use of randomly spaced overnight (minimum of 12 hours) fyke nets (single winged, small double wing and large double wing fyke nets) as well as bait traps.

Appendix 13: Results from trial watering analysis

As part of the development of this EWMP, the North Central CMA proposed a simple trial watering event to monitor filling behaviour and test the assumptions that underpin the salt and water balance model (Section 4.1.3.1). Table 17 shows the filling history of Lake Elizabeth up until 30 January 2014. Table 18 further expands by summarising the results of December 2013 and January 2014 groundwater, physical and water quality monitoring undertaken by DEPI. A brief hydrogeologist analysis of the findings can be found below.

Table 17: Fill history for trial watering event

Date	Day number	Rate (ML/d)	Event to date (ML)	Comment
9-Dec	1	15	15	Level at approximately 72.3m AHD
10-Dec	2	15	30	
11-Dec	3	15	45	
12-Dec	4	15	60	
13-Dec	5	15	75	
14-Dec	6	15	90	
15-Dec	7	15	105	
16-Dec	8	15	120	
17-Dec	9	15	135	
18-Dec	10	15	150	
19-Dec	11	15	165	
20-Dec	12	15	180	
21-Dec	13	15	195	
22-Dec	14	15	210	
23-Dec	15	15	225	
24-Dec	16	15	240	
25-Dec	17	15	255	
26-Dec	18	15	270	
27-Dec	19	15	285	
28-Dec	20	15	300	
29-Dec	21	15	315	
30-Dec	22	15	330	
31-Dec	23	15	345	
1-Jan	24	15	360	
2-Jan	25	15	375	
3-Jan	26	15	390	
4-Jan	27	15	405	
5-Jan	28	15	420	
6-Jan	29	15	435	
7-Jan	30	15	450	See Table 18 for bore data taken on this date
8-Jan	31	15	465	Site visit- level recorded at 72.48m AHD
9-Jan	32	15	480	
10-Jan	33	15	495	
11-Jan	34	15	510	
12-Jan	35	15	525	
13-Jan	36	15	540	
14-Jan	37	15	555	
15-Jan	38	15	570	See Table 18 for data taken on this date
16-Jan	39	15	585	
17-Jan	40	15	600	
18-Jan	41	15	615	
19-Jan	42	15	630	
20-Jan	43	15	645	Site visit- level recorded at 72.6m AHD

21-Jan	44	15	660	
22-Jan	45	15	675	
23-Jan	46	15	690	
24-Jan	47	15	705	
25-Jan	48	15	720	
26-Jan	49	15	735	
27-Jan	50	15	750	
28-Jan	51	15	765	
29-Jan	52	15	780	
30-Jan	53	15	795	Site visit- level recorded at 72.7m AHD
31-Jan	54	15	810	
1-Feb	55	15	825	
2-Feb	56	15	840	
3-Feb	57	15	855	
4-Feb	58	15	870	
5-Feb	59	15	885	Site visit- level recorded at 72.78m AHD
6-Feb	60	15	900	

Table 18: Results from trial watering event

Attribute	Measure	December 2013 (6/12/2013)	January 2014 (15/01/2014)	February 2014 (06/02/2014)
Physical	Level (m AHD)	Below gauge	72.56	72.78
	Volume delivered	0 ML	570 ML	900 ML
Water quality	Salinity Sample 1	152,300	40,900	20,100
	Salinity Sample 2	149,600	41,300	35,000
	pH	9.08	9.11	11.55/ 12.13
	Turbidity (NTU)	185	-	-
	Dissolved Oxygen	6.15	-	-
		December 2013 (N/A)	**January 2014 (7/1/2014)**	
Groundwater bores (depth)	26936- Lake Elizabeth	-	1.77	
	26937- Lake Elizabeth	-	2.60	
	26932- Lake Elizabeth	-	4.32	
	26933- Lake Elizabeth	-	4.60	
	130477- Wandella North	-	3.48	
	130478- Wandella North	-	3.18	
	130479- Wandella North	-	4.27	
	130472- Wandella North	-	4.19	

Analysis:

Over a 52 day period (9 December 2013 until 30 January 2014) a total of 795 ML of environmental water was delivered to Lake Elizabeth resulting in the wetland rising from approximately 72.3m AHD to 72.7m AHD. When discounting evaporation and seepage, the bathymetry (as shown in Appendix 9) indicates that a total volume 226.7 ML would be required to achieve this height. This suggests that a total volume of 568.3 ML must have been lost to evaporation and seepage during this period.

Pan evaporation for January is of the order of 300 mm. Actual evaporation is estimated at 225 mm or 7.21 mm/day if a pan coefficient of 0.75 is adopted (see Section 4.1.3.1). Accordingly, evaporation over the 52 day period is conservatively (most likely higher than actual) estimated at about 377 ML from an average lake area of 72.15 hectares (based on bathymetry).

Therefore, the volume of environmental water required to achieve this level (based on the bathymetry) plus the volume lost to evaporation, would account for about 603 ML. Given 795 ML was required in total; seepage appears to account for about 192 ML or 192,000 cubic metres. As the average wetland area over the period was 72.146 hectares, seepage is, thus, estimated to be at least 5 mm/ day, not 1mm/day as originally assumed in the salt and water balance model. This would account for the faster reduction in salinity compared to what was expected using the salt and water balance model.

Further monitoring and analysis is required to determine if this pattern is indicative of the wetlands behaviour over the long term.