Connecting Rivers, Landscapes, People

Pig Swamp
Environmental Water Management Plan

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

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EXECUTIVE SUMMARY

The Pig Swamp Environmental Water Management Plan (EWMP) sets out the long-term objectives for the priority environmental values of Pig Swamp, in the Gunbower Forest Ramsar Site. The EWMP is an important part of the Victorian Environmental Water Planning Framework. It provides the five to ten year management intentions, based on scientific information and stakeholder consultation, which can be used by the respective agencies; North Central Catchment Management Authority (CMA), Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH); for both short and longer-term environmental water planning.

This EWMP is not a holistic management plan for the wetland, but is focused on environmental water management so that Pig Swamp can continue to provide environmental, social, cultural and economic values for all users. Actions such as infrastructure upgrades and pest plant and animal works are documented as complementary to environmental water management in this EWMP.

The following components are the main sections featured in the Pig Swamp EWMP. The main conclusions to facilitate appropriate environmental water management into the future are summarised below.

Hydrology and system operations

Prior to European settlement, Pig Swamp would have naturally filled from the south during a Murray River flood event >50 GL/day via a series of connecting creeks and drainage lines. The Straight Cut Channel was constructed through Pig Swamp in the 1870's to carry irrigation water pumped out of the Murray River into the Upper Gunbower Creek. After the construction of the Torrumbarry Weir, the Straight Cut Channel was used to deliver water from the Upper Gunbower Creek to a farm adjacent to the Murray River. Irrigation water leaked continuously through breaches in the channel into Pig Swamp and maintained it as a permanent wetland during the irrigation season. In 2007, an earthen block was placed in the channel to reduce losses from the irrigation system and the swamp dried out soon afterwards. A natural Murray River flood refilled the wetland in 2010/11. It has remained dry since 2011.

Water dependent values

Pig Swamp is part of a wetland of international and national significance, the Gunbower Forest Ramsar Site, and listed on the Directory of Important Wetlands in Australia. The vegetation in Pig Swamp comprises Sedgy Riverine Forest (EVC 817), Tall Marsh (EVC 821) and fringing River Red Gums (*Eucalyptus camaldulensis*) and it is surrounded by Riverine Chenopod Woodland (EVC 103). Pig Swamp provides a diverse range of habitats for aquatic and amphibious plants as well as habitat and food sources for waterbirds, frogs and reptiles.

Ecological condition and threats

Vegetation surveys of the wetland in 2011 following a natural flood revealed that large stands of Cumbungi established on the northern side of the wetland. The southern side of Pig Swamp had a mosaic of open water, *Carex tereticaulis*, *Paspalum distichum* and River Red Gum. Fringing River Red Gums were generally in good health. Since 2011, the wetland has been dry and there has not been a detailed ecological condition assessment undertaken. However, site observations since 2011 suggest the sedges have died from the long dry spell, and weeds have invaded the wetland.

Management objectives

A long-term management goal has been defined for Pig Swamp:

Management goal

To support flora and fauna that are typical of a shallow freshwater marsh, in particular providing habitat for frogs and waterbirds, while also improving the health and increasing the distribution of the current mosaic of plant communities.

The ecological objectives and hydrological objectives that sit under the long-term management goal for Pig Swamp were informed by the *Pig Swamp Environmental Watering Plan 2015* and other technical investigations and were refined during the development of this EWMP.

Managing risks to achieving objectives

The threats to achieving the ecological objectives that are external to environmental water are identified by this EWMP. These include proliferation and encroachment of native plant species such as Cumbungi (*Typha spp.*), high threat weeds, as well as introduced fauna species (i.e. foxes and rabbits). The present lack of water delivery infrastructure is also a significant risk to achieving objectives.

Environmental water delivery infrastructure

At present, the Straight Cut Channel is operated to deliver water to the two remaining service points west of Pig Swamp. The earthen block in the Straight Cut Channel prevents the delivery of water to the wetland. Therefore, Pig Swamp can only be filled via high flows in the Murray River that exceed 50 GL/day.

Two options are being investigated to enable water delivery to Pig Swamp. Option one (delivery from Upper Gunbower Lagoon) requires installation of a pipe and outlet structure at the wetland entry point in the Straight Cut Channel and building a structure in the channel on the east side of Pig Swamp. The preferred option (option two) involves pumping water from the Murray River via the eastern section of the Straight Cut Channel. This option is being considered as part of the Gunbower Forest Sustainable Diversion Limits Program to also target watering of flood dependant vegetation in the upper forest. Option two would require installation of two regulators, one to control delivery to Pig Swamp and the other to control delivery to the upper forest. Both options would require the capacity of the Straight Cut Channel to be restored by removing debris, vegetation and accumulated sediment.

Demonstrating outcomes

Monitoring is required to allow adaptive management of annual environmental watering (intervention monitoring). It is also required to enable the CMA and VEWH to demonstrate the long-term outcomes of the implementation of the Pig Swamp EWMP. Pig Swamp EWMP recommends a suite of intervention and long-term monitoring activities that will meet the monitoring requirements.

Consultation

Key stakeholders, including DELWP, Parks Victoria and Goulburn Murray Water (GMW) were engaged during the development of this EWMP. Community consultation for the EWMP consisted of phone conversations with the community members originally consulted for the EWP, specifically focussing on changes to Pig Swamp over the last 5 years

Knowledge gaps

The management actions recommended for Pig Swamp are based on the best available information. Key knowledge gaps identified during the development of the EWMP include the future operation of the Straight Cut Channel and modification required (including ownership and maintenance) to enable the delivery of environmental water to the wetland, and further information on the fauna (particularly species of high conservation significance) that use Pig Swamp for feeding and/or breeding.

ACKNOWLEDGEMENTS

The information contained in the Pig Swamp EWMP has been sourced from a variety of reports and field inspections and from individual knowledge and expertise. The North Central CMA acknowledges the assistance of the following people in preparing this EWMP and previous Pig Swamp EWPs, which the EWMP was largely based on:

- Ross Stanton, Anne Graesser, Geoff McIvor and Dan Radcliffe (GMW)
- Karen Weaver, Michael Dedini and Glenn Smith (Department of Sustainability and Environment, amalgamated into DELWP in 2015)
- Mark Tscharke (PV)
- Environmental Technical Advisory Committee
- Wetland workshop attendees
- Bazil Brereton, Roger Brereton, Kurt Brereton, Ray Harrower, George and Marion Mc Gilivray and Graham and Ursler Sutcliff (community) (listed in Appendix 5)
- Jon Bartley (Bartley Consulting)
- Wes Pye (Northern Land Solutions)
- Chris Gippel (Fluvial Systems)
- Expert Review Panel (for EWP): Jane Roberts and Terry Hillman
- Expert Review (for EWMP): Marcus Cooling
- Andrea Keleher and Bruce Mathers (DELWP)
- Goulburn-Murray Water Connections Project Environmental Technical Advisory Committee: Chris Solum, Ross Plunkett, Ed Thomas, and Scott Morath (GMW).
- Emer Campbell, Lyndall Rowley, Melanie Tranter, Rebecca Horsburgh; Michelle Maher, Bree Bisset, Louissa Rogers, Genevieve Smith, Peter Rose, Anna Parker and Andrew Sharpe (North Central CMA).

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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1. Introduction

1.1. Pig Swamp

Pig Swamp is a small, shallow freshwater marsh situated towards the southern end of Gunbower Forest in northern Victoria. The wetland occupies approximately 50 ha within the Gunbower Forest (Northern Land Solutions 2011). For much of the last 100 years the wetland has been operated as part of the water supply infrastructure of the Torrumbarry Irrigation District. A water supply channel passing through the wetland caused persistent annual flooding, promoting dense stands of Cumbungi and degrading natural values.

Recent upgrades to the irrigation infrastructure now allow the water regime of the wetland to be managed independently. This Environmental Water Management Plan sets out ecological objectives for Pig Swamp and recommends a water regime to achieve them.

1.2. Environmental Water Administration

Management of environmental water is planned and implemented through a framework of key documents. Figure 1 illustrates the strategies, scientific reports and operational documents required for environmental water management in Victoria. The North Central Catchment Management Authority (CMA) has recently developed the *North Central Waterway Strategy 2014-2022* (NCWS) which is an integrated strategy aimed at managing and improving the North Central CMA's waterways (rivers, streams and wetlands). The NCWS sets priorities and outlines a regional works program to guide investment over the next eight years (North Central CMA 2014). The NCWS is guided by the *Victorian Waterway Management Strategy 2013* (VWMS) and the *North Central Regional Catchment Strategy 2012* (RCS).

Pig Swamp is identified as a priority wetland in the NCWS, with the aim to influence long-term resource condition by:

- Providing an intermittent water regime that supports flora and fauna that are typical of a shallow freshwater marsh, in particular providing habitat for frogs and waterbirds, while also improving the health and increasing the distribution of the current mosaic of plant communities.

These targets are reflected in the overall management goals and objectives described by this EWMP (Section 6). A number of management activities are recommended to achieve these targets including pest plant and animal control, appropriate delivery of environmental water and ecological monitoring and assessments to improve knowledge of the wetland. The North Central CMA will deliver these activities in partnership with Parks Victoria (PV), Goulburn Murray Water (GMW), the Victorian Environmental Water Holder (VEWH), the Department of Environment, Land, Water and Planning (DELWP) and local landholders.

The North Central CMA has received funding through DELWP 'Victorian Basin Plan Environmental Water Management Plan Program' to prepare an EWMP for Pig Swamp. This EWMP aims to establish the long-term environmental water management goals for Pig Swamp to guide future management.

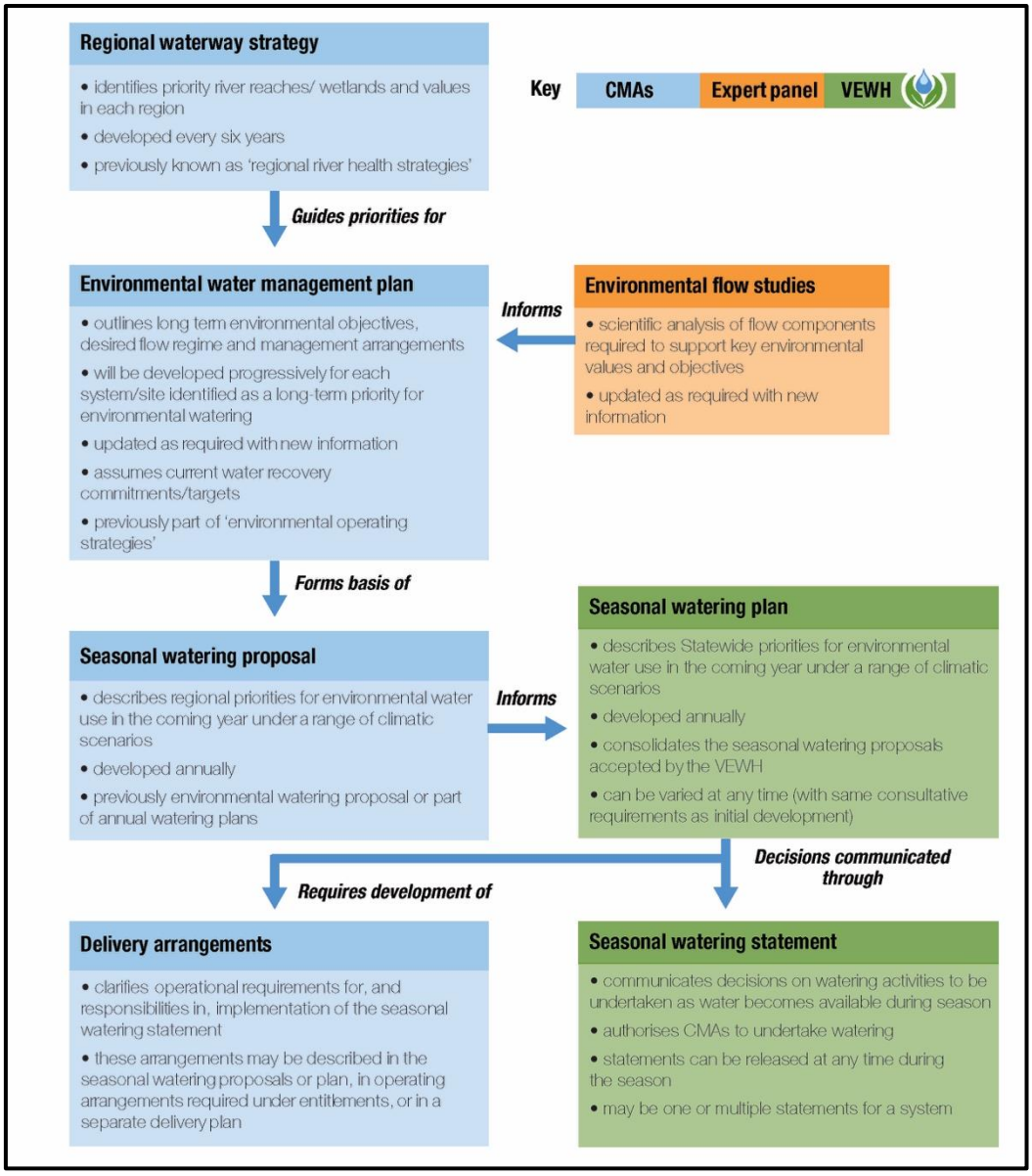

Figure 1. Planning framework for decisions about environmental water management in Victoria.

1.3. Purpose and scope

The Pig Swamp EWMP is a ten year management plan that describes the ecological values present, the long-term goal for the wetland and priority ecological objectives and the required watering regime to achieve these objectives. It is based on both scientific information and stakeholder consultation and will be used by the North Central CMA for annual environmental watering proposals. DELWP and the VEWH will also use the EWMP for short and longer-term environmental water planning (Department of Environment and Primary Industries [DEPI] 2014a).

The key purposes of the EWMP are to:

- identify the long-term objectives and water requirements for the wetland;
- provide a vehicle for community consultation, including for the long-term objectives and water requirements of the wetland;
- inform the development of future Seasonal Watering Proposals (SWPs) and seasonal watering plans; and

- inform Long-term Watering Plans that will be developed by the State under the Basin Plan Chapter 8 (DEPI 2014a).

The scope of this EWMP is the entirety of Pig Swamp, currently managed by Parks Victoria as a part of Gunbower National Park.

1.4. Development Process

Pig Swamp has an Environmental Watering Plan (EWP) that was prepared by the North Central CMA under the GMW Connections Project (formerly the Northern Victoria Irrigation Renewal Project). The EWP established the volume of mitigation water that GMW Connections Project was required to set aside to maintain the environmental values in Pig Swamp that had previously relied on irrigation outfalls. The EWP established ecological objectives and a watering regime for Pig Swamp. The Pig Swamp EWMP is based on work undertaken for, and presented in, the *Pig Swamp Environmental Watering Plan 2015*, and was developed in collaboration with key stakeholders including DELWP, PV, VEWH and GMW. Additional tasks were undertaken to develop the EWMP including:

- **Collation of flora and fauna records:** Species lists and status were updated with new records from relevant databases and surveys.
- **Collation of water quality data**
- **Community and stakeholder consultation**: Members of the original community and stakeholder group, where available, were consulted via telephone to provide input into the draft EWMP, particularly relating to the water management goal, ecological objectives and optimum watering regime. See Appendix 5 for further details.

The most recent technical information has been considered in the development of the Pig Swamp EWMP, including monitoring data, water delivery information and results of ecological investigations.

Information from the above tasks was analysed to provide justification and evidence for the following sections of the EWMP:

- **Water dependent values:** Environmental values were derived from the baseline flora and fauna surveys, historical reports, DELWP databases and community and stakeholder accounts. Terrestrial species that, due to large-scale clearing of woodland habitat throughout the catchment, are dependent on the vegetation surrounding the wetlands are also documented. Social values (cultural heritage, recreation and economic) are further described.
- **Ecological condition, condition trajectory and threats**: Available information was used to describe the current condition and water related threats to Pig Swamp. A "do-nothing" scenario is further considered to understand the condition trajectory if no action is undertaken.
- **Management objectives**: The water management goal and the ecological objectives for Pig Swamp are based on the water dependent values recorded for the wetland, the current condition and the condition trajectory. The objectives also align with the broader environmental outcomes proposed in the *Basin Plan draft Environmental Watering Strategy 2014*.
- **Managing risks:** The risks to achieving the ecological objectives for Pig Swamp are based on the best-available scientific and local knowledge. Management actions to mitigate each risk have been recommended and the residual risk (assuming full adoption of management action) has been evaluated.

- **Environmental water delivery infrastructure:** Current constraints to delivery of environmental water are identified and recommendations are made to improve future environmental water delivery.
- **Demonstrating outcomes**: A monitoring program is recommended to adaptively manage the delivery of environmental water and to demonstrate the outcomes against the ecological objectives.
- **Knowledge gaps and recommendations:** A number of knowledge gaps were identified during the process of developing the ecological objectives, management actions and risk analysis. Investigations to address the knowledge gaps are prioritised.

2. Site overview

2.1. Site location

Pig Swamp is a small, shallow freshwater marsh situated towards the southern end of Gunbower Forest in northern Victoria, 4 km northeast of Gunbower and 1.5 km southwest of the Murray River (Figure 2). Gunbower Forest lies between the townships of Torrumbarry and Koondrook and is bordered by the Murray River to the northeast and the Gunbower Creek to the southwest. Gunbower Forest is 19,450 ha in extent and forms part of the larger Gunbower-Perricoota-Koondrook forest complex that receives flooding from the Murray River.

Pig Swamp occupies approximately 50 ha within the Gunbower Forest (Northern Land Solutions 2011). The wetland has a full supply level (FSL) of 84.05 m AHD at which height the storage capacity in Pig Swamp is 213 ML (Northern Land Solutions 2011). The wetland floor has a slightly undulating surface with its lowest points at 83.40 m AHD north of the Straight Cut Channel, and approximately 83.60 m AHD to 83.80 m AHD south of the Straight Cut Channel. The maximum depth of surface water that could occur within Pig Swamp as a discrete wetland is therefore 0.65 m, but is more commonly from 0.2 m to 0.4 m. Refer to Appendix 2 for the contour plan prepared for Pig Swamp by Northern Land Solutions (2011).

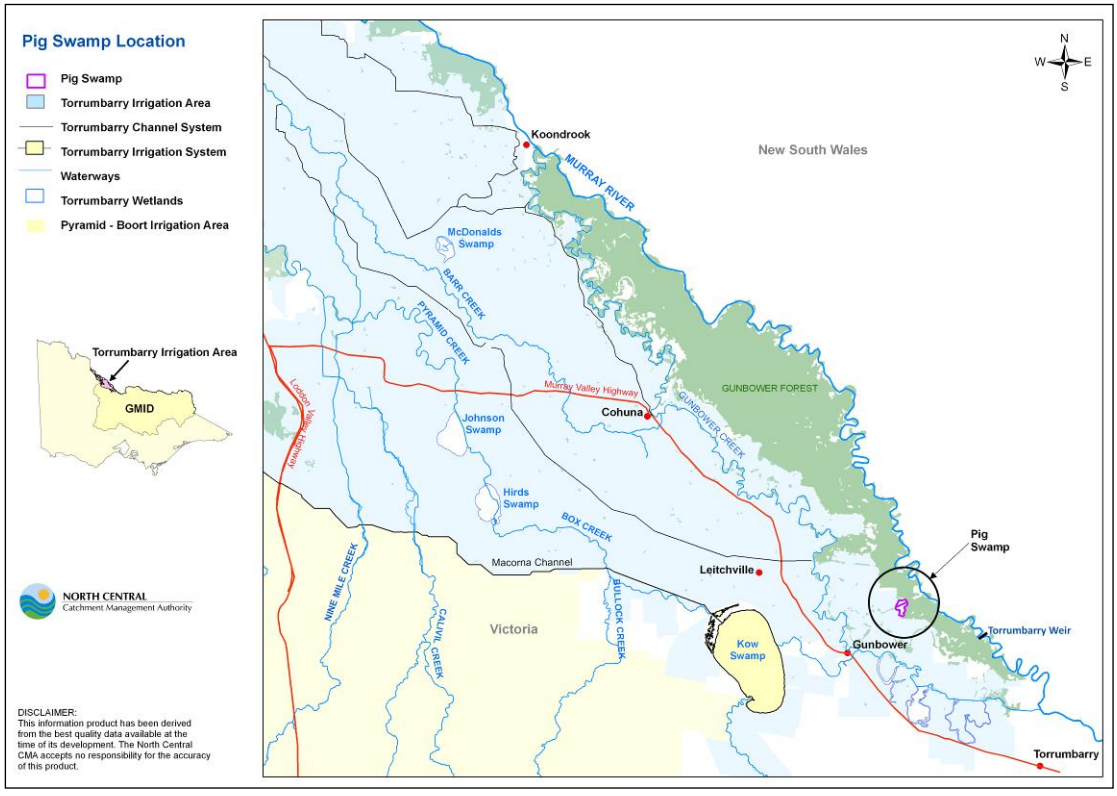

Figure 2. Location of Pig Swamp

2.2. Catchment setting

Climate

Gunbower Forest is situated within the grassland (warm/persistently dry) climatic zone of south-eastern Australia (Bureau of Meteorology 2016). The general climatic pattern is hot dry summers and cold winters. Maximum average temperatures range from 35.6°C in January to 16.5°C in July, with minimum average temperatures falling to 11.3°C in June. Rainfall, on average, occurs year

round with highest monthly median rainfall in June (41 mm) and lowest in February (15 mm). Annual average rainfall at nearby Echuca is 450 mm (Bureau of Meteorology 2011).

Hydro-physical characteristics

The extent of flooding within Gunbower Forest is determined by the height of the Murray River below Torrumbarry Weir. Torrumbarry Weir is adjacent to the upstream part of the forest. It creates a weir pool that maintains a high, stable water level to supply irrigation water to the Torrumbarry Irrigation Area. The Murray River at Torrumbarry Weir receives flows from downstream of Barmah-Millewa Forest, with discharges from both the Goulburn River upstream of Echuca and from the Campaspe River at Echuca (URS 2001 in North Central CMA 2010). A series of creeks and drainage lines in the southern end of Gunbower forest connect the Murray River to Pig Swamp during flood events. Figure 3 shows the location of Pig Swamp in the context of the terrain surrounding Murray River and Gunbower Creek.

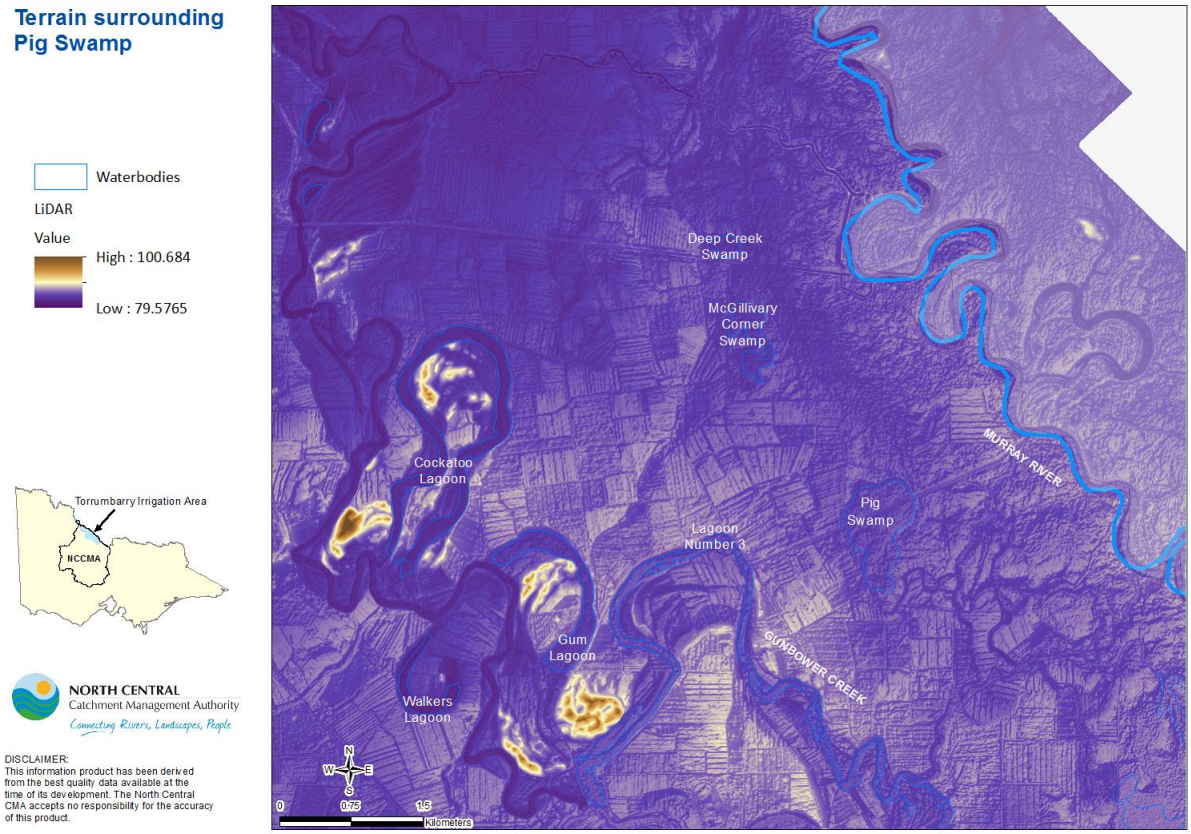

Figure 3. Terrain of Pig Swamp in the context of the Murray River Floodplain

2.3. Land status and management

Land use

Pig Swamp is located in Gunbower National Park, towards the southwest extent of the park. Irrigated farmland borders Pig Swamp on the southwest margin.

Land tenure

In 2009, the Victorian government endorsed (with amendments) the Victorian Environment Assessment Council (VEAC) recommendations for public land management. As of June 2010, Gunbower National Park (recommendation A4) comprises 8,892 hectares of Gunbower Forest, with

the remainder comprising Gunbower State Forest (recommendation C3) (VEAC 2009). The National Park immediately surrounding Pig Swamp is dominated by Grey and Black Box woodlands, which are listed as endangered vegetation communities within Victoria.

Pig Swamp is part of the Gunbower National Park under the National Park Act 1975 and is managed by Parks Victoria (PV). National parks are managed for the preservation and protection of the natural environment including wilderness areas and remote and natural areas (Victorian Government 1975).The agencies directly involved in environmental water management in Victoria are Catchment Management Authorities, the VEWH, DELWP and Water Corporations. Other agencies, such as public land managers, play an important role in facilitating the delivery of environmental watering outcomes. Table 1 describes the key stakeholders that are involved in the management of Pig Swamp.

Table 1. Roles and responsibilities for environmental water in Pig Swamp

Agency/group	Responsibilities/involvement
DELWP	- Manage the water allocation and entitlements framework - Develop state policy on water resource management and waterway management for approval by the Minister for Environment, Climate Change and Water - Develop state policy for the management of environmental water in regulated and unregulated systems - Act on behalf of the Minister for Environment, Climate Change and Water to maintain oversight of the VEWH and waterway managers (in their role as environmental water managers) - Legislative responsibilities for the management of flora and fauna - Approve EWMPs and endorse SWPs.
VEWH	- Make decisions about the most effective use of the Water Holdings, including use, trade and carryover - Authorise waterway managers to implement watering decisions - Liaise with other water holders to ensure coordinated use of all sources of environmental water - Publicly communicate environmental watering decisions and outcomes - Author of the State-wide Seasonal Watering Plan - Provide final endorsement of SWPs - Approve delivery of environmental water (Seasonal Watering Statement) and fund environmental water related monitoring.
Commonwealth Environmental Water Office (CEWO)	- Make decisions about the use of Commonwealth water holdings, including providing water to the VEWH for use in Victoria. - Liaise with the VEWH to ensure coordinated use of environmental water in Victoria - Report on management of Commonwealth water holdings.
Murray-Darling Basin Authority (MDBA)	- Implementation of the Murray-Darling Basin Plan - the Basin Plan sets legal limits on the amount of surface water and groundwater that can be taken from the Basin from 1 July 2019 onwards - Integration of Basin wide water resource management - Manager of The Living Murray water entitlements

Agency/group	Responsibilities/involvement
North Central CMA	- Waterway Manager - Identify regional priorities for environmental water management in regional waterway strategies - In consultation with the community assess water regime requirements of priority rivers and wetlands to identify environmental watering needs and implement works to use environmental water efficiently - Propose annual environmental watering actions to the VEWH and implement the VEWH environmental watering decisions - Provide critical input to manage other types of environmental water (passing flows management, above cap water) and report on environmental water management activities undertaken.
GMW	- Water Corporation – Storage Manager and Resource Manager - Work with the VEWH and waterway managers in planning for the delivery of environmental water to maximise environmental outcomes - Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental water - Ensure the provision of passing flows and compliance with management of diversion limits in unregulated and groundwater systems - Endorse SWP and facilitate on-ground delivery.
PV	- Land Manager - Implement the relevant components of EWMPs. - Operate, maintain and replace, as agreed, the infrastructure required to deliver environmental water, where the infrastructure is not part of the GMW irrigation delivery system. - Where agreed, participate in the periodic review of relevant EWMPs and endorse SWPs - Manage and report on other relevant catchment management and risk management actions required due to the implementation of environmental water.
Input, advice and interest in environmental watering	
Yorta Yorta Registered Aboriginal Party	- Traditional owners of the area encompassing Pig Swamp
Gunbower Operations and Advisory Group (GOAG) and Gunbower Community Reference Group (CRG)	- Stakeholder and community groups developed to provide advice on the best use of environmental water in Gunbower Forest and Gunbower Creek, including Pig Swamp - GOAG members are represented by GMW, DELWP, PV, VEWH, CEWO, VicForests, MDBA, Forestry Corporation NSW, Murray River Operations, and North Central CMA.

2.4. Wetland characteristics

Victoria's wetlands are classified according to their origin, water regime and habitat values. The classification scheme was developed by Corrick and Norman (1980) and was recently updated in 2013 to align with the Australian National Aquatic Ecosystem (ANAE) Classification.

The framework produces 37 wetland types based on three levels of classification. The first classification level distinguishes between naturally-occurring wetlands and human-made wetlands. The second classification level distinguishes between aquatic ecosystem habitats: palustrine, lacustrine and estuarine. The third classification level distinguishes wetland types on the basis of the following attributes: water regime, salinity, landscape context, soils and wetland vegetation (DEPI 2014b).

Pig Swamp is identified as a shallow freshwater marsh under both the pre-European and current classification using the Corrick and Norman system. Based on the updated classification system, Pig Swamp is classified as a naturally occurring temporary freshwater swamp (DEPI 2014b). An overview of the wetland characteristics of Pig Swamp is provided in Table 2.

Table 2. Wetland characteristics of Pig Swamp

Characteristics	Description	
Name	Pig Swamp	
Mapping ID (Corrick)	7726 662208	
Area (ha)	Wetland	56.5 hectares
Bioregion	Murray Fans	
Conservation status	Ramsar Site Listed in the Directory of Important Wetlands in Australia	
Land status	Crown Land (Gunbower National Park)	
Land manager	Parks Victoria	
Surrounding land use	East: private land (irrigated agriculture) West: National Park	
Water supply	• Natural: Dry Tree/Baggots Creek • Current: Torrumbarry Irrigation System – Straight Cut Channel • 300 EC • Capacity of 50-60 ML/day[1] (Straight Cut Channel)	
1788 wetland category (Corrick and Norman)	Category: Shallow freshwater marsh (<8 months duration, <0.5m depth) Sub-category: n/a	
1994 wetland category (Corrick and Norman)	Category: Shallow freshwater marsh Sub-categories: red gum, dead timber	
2013 Victorian wetland classification (DEPI 2014b)	*Wetland ID: 45345* *Aquatic System:* Palustrine *Salinity Regime:* Fresh *Water regime:* Periodically inundated- seasonal or episodic *Water Source – Tidal:* Non-tidal *Water Source – River:* Very high *Water Src – Groundwater:* Low *Source – Artificial:* Artificial *Wetland Origin:* Naturally occurring *Wetland Type:* Temporary freshwater swamps	
Wetland capacity	Full Supply Level: Variable: 84.05 mAHD; Volume: 213 ML	
Wetland depth at capacity	0.65 m maximum depth (North Central CMA 2015)	

2.5. Environmental water sources

The environmental water available for Pig Swamp is derived from a number of sources, described below and in Table 3. Water shares have two levels of reliability in Victoria:

- High-reliability water shares (HRWS), which is a legally recognised, secure entitlement to a defined share of water.
- Low reliability water shares (LRWS) which are water shares with a relatively low reliability of supply. Allocations are made to high-reliability water shares before low-reliability shares when there is limited availability (DEPI 2014c).

Water availability can vary from season to season according to climatic conditions, volumes held in storages and carryover entitlements.

[1] The current reported capacity of the channel is 30 ML/day as it is restricted by fallen trees, weeds and silt accumulation.

Bulk Entitlement (River Murray Flora and Fauna) Conversion Order 1999

The Victorian River Murray Flora and Fauna Bulk Entitlement provides 27,600 ML HRWS in the Murray System. It is held by the VEWH for the purpose of providing for flora and fauna needs. It has been used in a range of wetlands including Gunbower Forest (Living Murray Icon Site) and the Kerang Ramsar Wetlands. It can also be traded on the water market on an annual basis. The use of this water in Pig Swamp is not guaranteed and is at the discretion of the VEWH (VEWH 2012).

Commonwealth Water Holdings

Commonwealth environmental water holdings are the direct result of government purchases of entitlements and a substantial investment in more efficient water infrastructure in the Murray Darling Basin. As at 30 Nov 2015, the Commonwealth environmental water holdings totalled 3,883 ML for the Loddon River system and 344,660 ML for the Murray River system. The use of this water for wetlands in the North Central CMA region is not guaranteed and is at the discretion of the Commonwealth Environmental Water Office (CEWO 2015).

GMW Connections Project – Environmental Entitlement (Murray System)

The Goulburn-Murray Water Connections Project is an irrigation modernisation project that aims to improve the water delivery network across northern Victoria. While improving irrigation efficiency, the Connections Project will reduce outfall volumes to wetlands, including Pig Swamp. The project allows for 'mitigation water' to be delivered to wetlands to maintain ecological values put at risk by reduced outfall volumes. The *Pig Swamp Environmental Watering Plan 2015* determined that 170 ML of mitigation water needed to be set aside for Pig Swamp each year. More details on the justification for mitigation water and specific calculations for the mitigation volume for Pig Swamp are presented in NCCMA (2015a).

Table 3. Environmental water sources for Pig Swamp

Water entitlement	Volume	Flexibility of management	Conditions on availability and use	Responsible agency
Bulk Entitlement (River Murray – Flora and Fauna) Conservation Order 1999	28,750 ML (high reliability) 3,893 ML (low reliability) Carryover determined by VEWH	Fully flexible management	Can be used across multiple systems, within relevant trade protocols	VEWH
	40,000 ML (unregulated flows)	Flexible management in declared periods only	Only available for use during declared periods of unregulated flows on the Murray system	VEWH
Mitigation water (NVIRP stage 1)	170 ML for Pig Swamp	Can only be used in wetlands that have an approved Environmental Watering Plan with mitigation water recommended, such as Pig Swamp.		VEWH
Commonwealth Water Holdings	Determined by CEWO	Agreement is required with the CEWO	Can be used across multiple systems, within relevant trade protocols	CEWO (facilitated through VEWH)

2.6. Related agreements, legislation, policy, plans and activities

There are a range of international treaties, conventions and initiatives, as well as National and Victorian State Acts, policies and strategies that direct the management of wetlands within Victoria. Those that have particular relevance to the management of the environmental and cultural values at Pig Swamp are listed below. The function and major elements of each document are described in Appendix 1.

International treaties, conventions and initiatives:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979 – one species listed under this convention has been recorded at Pig Swamp.

Commonwealth legislation and policy:

- Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (Part IIA) – Pig Swamp is an area of cultural sensitivity.
- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) - one species listed under this Act has been recorded at Pig Swamp. Ramsar wetlands are recognised as a matter of national environmental significance under the EPBC Act.
- Water Act 2007 – to provide for the protection of ecological values at Pig Swamp through appropriate management of Murray-Darling Basin water resources.
- Basin Plan 2012 - The Basin Plan guides governments, regional authorities and communities to sustainably manage and use the waters of the Murray-Darling Basin.

Victorian legislation:

- Aboriginal Heritage Act 2006 – Pig Swamp is an area of cultural sensitivity.
- Catchment and Land Protection Act 1994 - governs the management of land surrounding Pig Swamp (e.g. pest plant and animal control).
- Water Act 1989 - provides a formal means for the integrated management of water in Victoria.
- National Parks Act 1975 – PV manages Pig Swamp in accordance with this Act
- Wildlife Act 1975 – PV manages Pig Swamp in accordance with this Act.
- Flora and Fauna Guarantee Act 1988 (FFG Act) – three species listed under this Act have been recorded at Pig Swamp.

National policies and strategies:

- The National Cultural Flows Research Project – this project is investigating indigenous water values and uses to form the basis for cultural flow water entitlements. These would be legally and beneficially owned by the Indigenous Nations and are of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous Nations. The cultural flows framework is under development but may influence Pig Swamp as it is an area of cultural sensitivity.

Victorian policy and strategies:

- Victorian threatened flora and fauna species (DELWP advisory lists) – six fauna species and two flora species on the DELWP advisory lists have been recorded at Pig Swamp.
- Victorian Waterway Management Strategy (VWMS) – this strategy outlines the direction for the Victorian Government's investment over an eight year period (beginning in 2012-13). The overarching management objective is to maintain or improve the environmental condition of waterways to support environmental, social, cultural and economic values (DEPI 2013a).

Regional strategies and plans:

- North Central Regional Catchment Strategy (RCS) (North Central CMA 2012) – this strategy (2013-2019) sets regional priorities for the management of natural assets, and sets overall direction for investment and coordination of effort by landholders, partner organisations and the wider community.

- North Central Waterway Strategy (NCWS) (North Central CMA 2014) – this regional strategy is an action out of the Victorian Waterway Management Strategy and provides the framework for managing rivers and wetlands with the community over the next eight years. It delivers key elements of the VWMS including developing work programs to maintain or improve the environmental condition of waterways in the North Central region.

3. Hydrology and system operations

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

3.1. Wetland hydrology, water management and delivery

3.1.1. Pre-regulation

Pig Swamp is situated relatively high on the Gunbower Forest floodplain and receives water during moderate to high Murray River flood events.

River water reaches the swamp via a network of creeks. Cameron's, Dry Tree and Baggots Creeks direct water across the southern end of Gunbower Forest into Pig Swamp and then into Upper Gunbower Creek.

Initial estimates were made that Pig Swamp would fill when flow in the Murray River downstream of Torrumbarry Weir exceeds 50,000 ML/day. This was recently validated when flows of 50,000 to 56,000 ML/day during December 2010 to January 2011 filled Pig Swamp. Modelled River Murray flow data for natural and current conditions (MSM-Bigmod data[2]; 1895 to 2009) showed that Pig Swamp would have filled on average every 1.2 years (83 in 100 years) under natural conditions (Figure 4 and Figure 5) (Bogenhuber and Campbell 2011). Under modelled actual conditions the events required to introduce water to Pig Swamp have declined to an average of one event every 2.71 years (Bogenhuber and Campbell 2011).

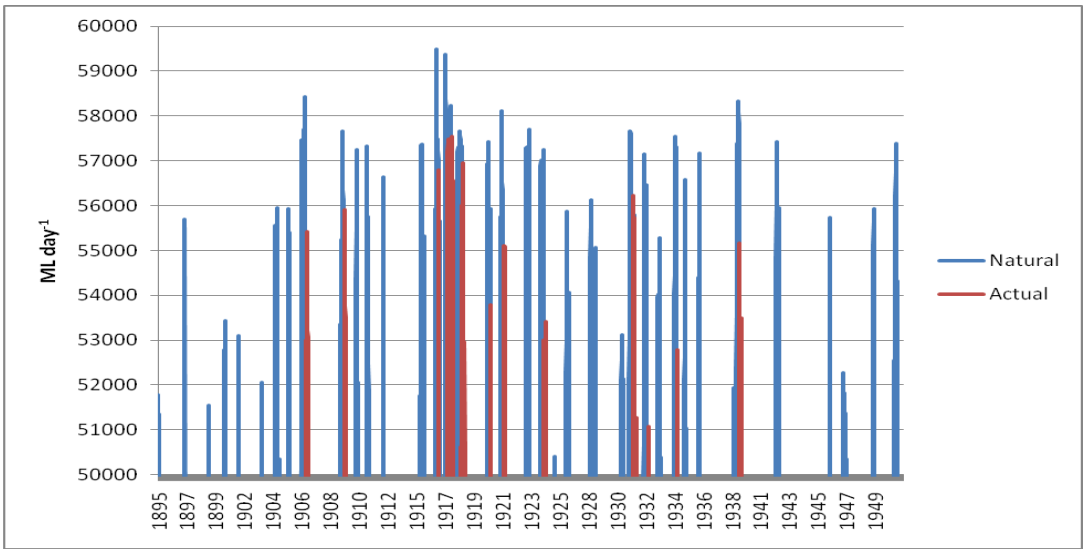

Figure 4. Murray River flows when Pig Swamp filled (1895 to 1951) (Source Andrew Keogh, MDBA)

[2] MSM-Bigmod is two computer based models that work together – output from MSM (Monthly Simulation Model) feeds into Bigmod (a daily simulation model).

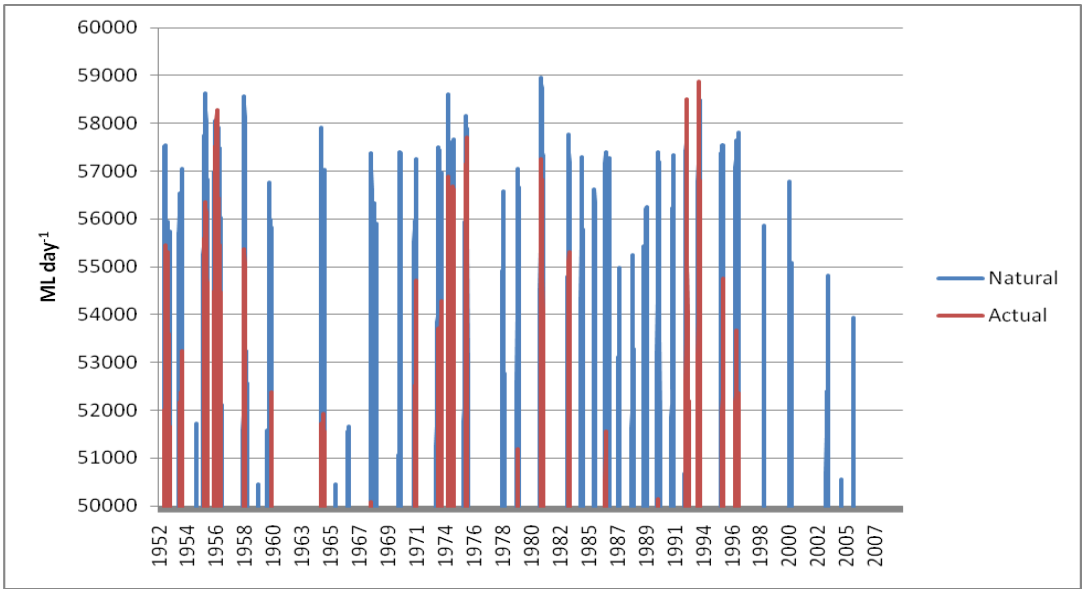

Figure 5. Murray River flows when Pig Swamp filled (1952 to 2009) (Source Andrew Keogh, MDBA)

The shallow depth of Pig Swamp (0.2 m to 0.4 m) results in water being retained for only a few months after inflows cease. The natural water regime at Pig Swamp supported the establishment of large widely spaced River Red Gums that could survive extended dry periods on the heavy floodplain clay soils.

3.1.2. Post-regulation

The natural water regime of Pig Swamp was altered during early European settlement as part of river regulation and the establishment of irrigated agriculture. The most significant change occurred during the 1870s when the Straight Cut Channel was constructed through the northern section of Pig Swamp (Figure 6). The channel initially transferred water from the Murray River to No. 3 Lagoon of Upper Gunbower Creek. Levee banks on the sides of this channel also interrupted the natural northerly flow of floodwater through Gunbower Forest and so the channel was frequently breached where it crossed Pig Swamp. Therefore, shortly after construction, a large in-channel earthen block was constructed at the entrance of the Straight Cut Channel, adjacent to the Murray River to prevent further uncontrolled flooding. This block has been in place for over 100 years.

To restore the natural flood flow path, the Straight Cut Channel was cut at three locations in the 1970s, where it crossed Pig Swamp. During the irrigation season, these breaches resulted in water spilling out of the channel into Pig Swamp. In the non-irrigation season (winter), the water level in the swamp drained down to a slightly lower level. Refer to Figure 6.

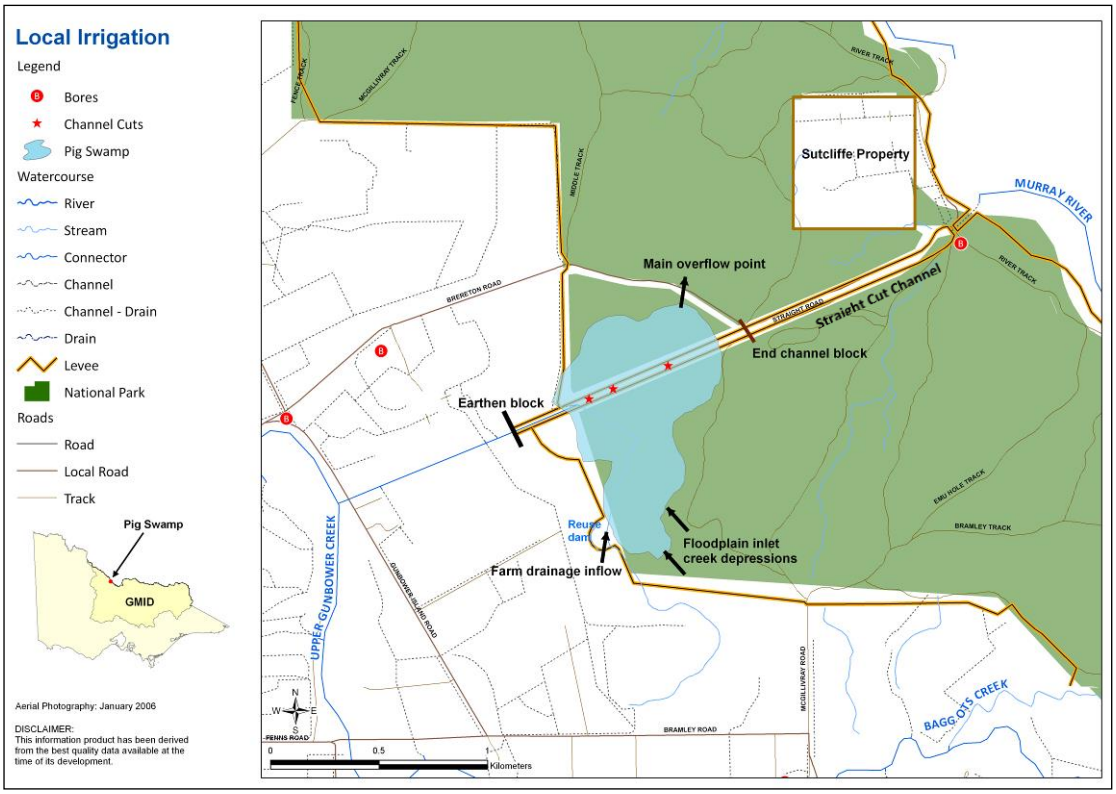

Figure 6. Pig Swamp local irrigation

Gunbower Creek, to the west of Pig Swamp, is operated as an irrigation supply channel. Where it passes Pig Swamp, at Upper Gunbower Lagoon, it is maintained at a level of approximately 84.0 m AHD during the irrigation season (August to May). Straight Cut Channel was used to deliver water from Gunbower Creek to irrigation customers at three service points (NVIRP 2010). The breaches in the channel where it crosses Pig Swamp allowed water to spread through the wetland, so that the wetland was persistently flooded during the irrigation season from the early 1970s for more than 30 years. This inundation drowned most of the original large River Red Gum and Black Box and encouraged the establishment of aquatic vegetation and riparian vegetation (e.g. Cumbungi) (O'Brien 2011). Outside of the irrigation season, water levels in the Upper Gunbower Creek were lowered, which partially drained Pig Swamp.

The requirement to supply irrigation water to the far end of Straight Cut Channel has been removed. The property that was supplied at the eastern end of the channel (Sutcliffe property - refer to Figure 6) was purchased by Water for Rivers in 2010. In 2007 the channel was blocked 200 m west of Pig Swamp (Figure 6) with compensation provided to the landowner. The block completely eliminated losses into the wetland with the result that the eastern section of the Straight Cut Channel and Pig Swamp completely dried out in 2007, and remained dry until the December 2010 natural flood event. River Red Gums regenerated into the base of Straight Cut Channel during the dry phase. A summary of the watering history of Pig Swamp over the last twenty years is presented in

Table 4.

Table 4. Pig Swamp wetting/drying events since 1995

Recommended watering regime	Watering History	Season									
		1995 - 1996	**1996 - 1997**	**1997 - 1998**	**1998 - 1999**	**1999 - 2000**	**2000 – 2001**	**2001 - 2002**	**2002 - 2003**	**2003 - 2004**	**2004 - 2005**
One event every year (i.e. wet and dry cycle every year) (duration of ~8mths)	Status[1]	W	W	W	W	W	W	W	W	W	W
	Water source[2]	C	C	C	C	C	C	C	C	C	C
		2005 - 2006	**2006 - 2007**	**2007 - 2008**	**2008 - 2009**	**2009 - 2010**	**2010 - 2011**	**2011 - 2012**	**2012 - 2013**	**2013 - 2014**	**2014 - 2015**
	Status[1]	W	W	D	D	D	W	D	D	D	D
	Water source[2]	C	C	-	-	-	I	-	-	-	-

[1] Water present / dry wetland
[2] Environmental water allocation / Flood mitigation / Unknown / Channel outfall / Surplus flows / Flood Inundation/Irrigation Tailwater

3.1.3. Soils

A hydrogeological study was undertaken at Pig Swamp in 2011 (Bartley Consulting 2011), including soil assessment. Two auger holes drilled at site DPI-A in February 2011 (Figure 7) found:

- Hole 1 (to 5.3 m depth) – 25 m from water edge. Thin organic layer over 4 m of medium to heavy clay, 1 m of clay loam and becoming silty clay and silt. Dry.
- Hole 2 (to 5.3 m depth) – 3 m from water edge. Thin organic layer over 4 m of medium to heavy clay, with clay loam to base. No silty material. Dry.

In both auger holes, the upper 1 – 2m of the profile was moist, the remainder of the profile was dry, and there was no water standing in the base of the holes after 48 hours. These observations are consistent with the Wrigley Dillon (2007) findings at Site 7 and Site 8 (Figure 7):

- Site 7 (to 2.2 m depth) far floodplain heavy soil – 150 mm friable loam over medium to heavy clay and medium clay, with poor to moderate to poor drainage.
- Site 8 (to 1.3 m depth) in wetland – 300 mm friable clay loam over light clay with moderate to poor drainage.

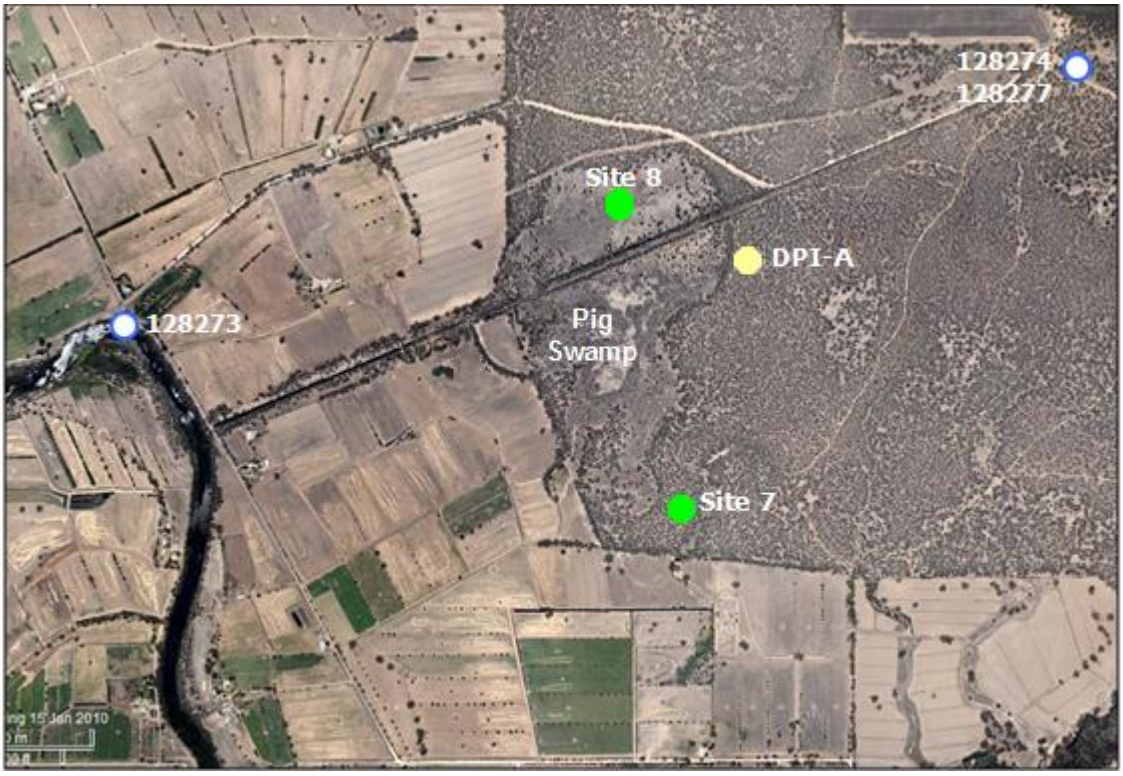

Figure 7. Soil and Groundwater Sites in vicinity of Pig Swamp

3.1.4. Groundwater/surface water interactions

The risk of watertable rise, water-logging and salinization from environmental watering was evaluated through a hydrogeological assessment at Pig Swamp (Bartley Consulting 2011). The Murray River floodplain is a complex area of former "prior stream" and "ancestral river" sediments (Pels, 1964), comprising channel, near floodplain and far floodplain deposits that overlay older riverine sediments. The present day Gunbower Creek and Murray River in the vicinity of Pig Swamp are within the area of these ancestral systems.

The principal aquifers are the outcropping Coonambidgal Formation and Shepparton Formation, and the underlying Calivil Formation and Renmark Group. The Coonambidgal and Shepparton Formation sediments are sandy clay and clay with variably connected layers of fine to coarse sand. They are approximately 100 m thick at the site[3] and overlie Calivil Formation and Renmark Group sediments.

Figure 7 shows the approximate location of soil and groundwater investigation sites in the vicinity of Pig Swamp. Bores not shown in Figure 7 are 12878 (located 7.4km south of Pig Swamp) and 87809 (located 7.9km southeast, near Torrumbarry). The depth of the bores investigated range between 9.5m and 23m deep.

Regional groundwater levels in the vicinity of Pig Swamp have been declining since the late 1990s, which corresponds with an extended period of below average rainfall (Figure 8). The drier period and lower irrigation amounts have meant less recharge to groundwater from rainfall, flooding, surface water bodies, or from irrigation accessions. The (regulated) river water level is consistently higher than groundwater level. Notably, during historic periods of extremely low or no flow, the river base was around the groundwater level, hence making it possible for discharge at those times.

[3]Bore 66514 – drilled in 1985 approximately 6 km west of the site.

The water table depth at bores 128274/128277 near the Murray River has ranged from 5 m to 10 m below ground surface since 1983, but near Gunbower Creek (bore 128273) it has been shallower (i.e. 2 m to 6 m deep) (Figure 8).

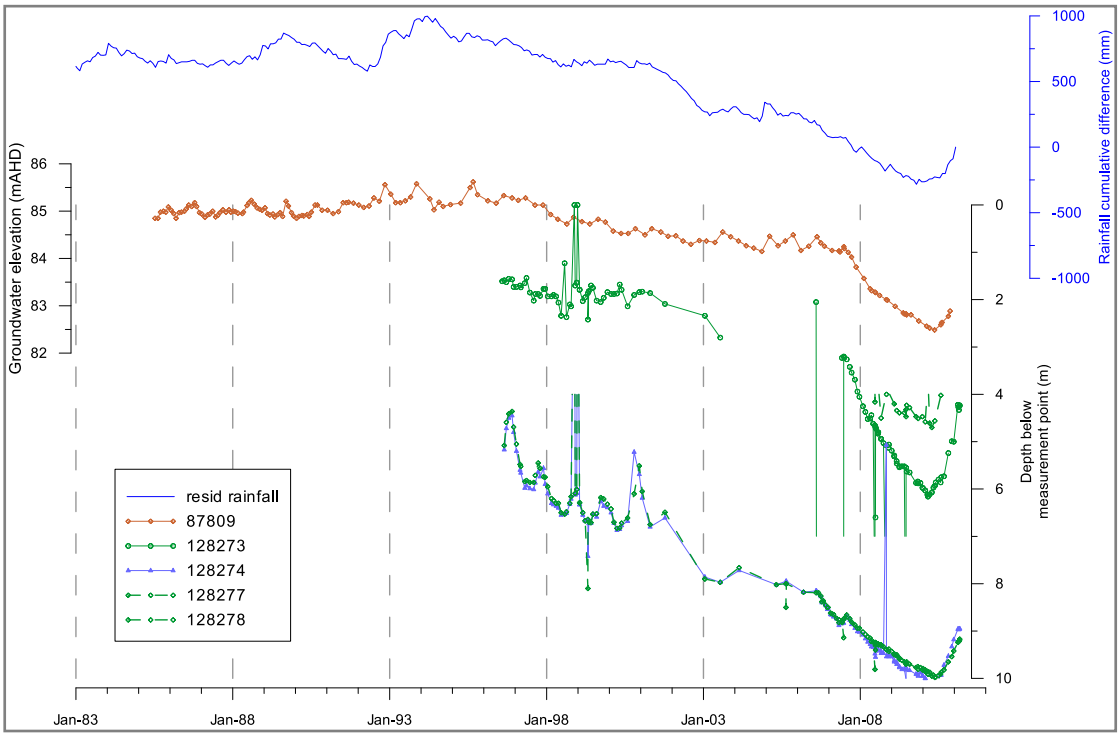

Figure 8. Groundwater Level – Bores Closest to Pig Swamp (1983 – 2012). No data was available for the period between 2013 and 2016) (Source: Victorian Water Measurement Information System)

Extrapolating the results of bore monitoring data suggests that when Pig Swamp held water, the water level would have been at least three metres above the local groundwater level. The soil conditions suggest that only a small amount of surface water could actually reach the water table. Most of the water would likely to be held within the soil profile and available for evapotranspiration.

In summary, based on the above data Bartley Consulting (2011) made the following conclusions about Pig Swamp:

- Pig Swamp is likely to have been a relatively minor source of groundwater recharge due to the shallow water depth (a limited driving head) and the underlying clay soils, with a recharge rate similar to other local areas that are underlain by mid and far floodplain soils that are intermittently flooded.
- If flooding occurs, the local groundwater would respond gradually beneath the floodplain, with no significant difference in groundwater level response beneath the site to elsewhere on the floodplain.
- The greatest likelihood of watertable rise to within the capillary fringe (in surrounding areas) is when there is inundation combined with high regional groundwater levels.
- The data indicates there is negligible risk of watertable rise from environmental watering. If water is introduced intermittently, some water is likely to slowly enter the subsurface; however, most is likely to be lost through evapotranspiration.
- The groundwater level is currently (greater than 5 m deep) below the soil capillary zone; therefore, there is no significant risk of adverse impact on the wetland or neighbouring land through watertable rise. This assumes inundation of the wetland is not permanent.

- Putting water into the wetland could increase the opportunity for salts to move down the soil profile; however, this movement would be limited by the medium to heavy clay soils.

3.1.5. Water Quality

No water quality data are available for Pig Swamp. Monthly water quality data for the Upper Gunbower Lagoon (source water) were available for the period 2012-2013. In general, water quality during that period was good, with almost neutral pH (median 7.1), low electrical conductivity (median 74 µs/cm; range 67-351 µs/cm), reasonable dissolved oxygen concentration (median 5.6 mg/L; range of 4.1-10.75 mg/L) and acceptable turbidity levels (21 NTU; range 10-55 NTU). Median total phosphorus (0.06 mg/L) slightly exceeded the EPA State Environmental Protection Policy (Waters of Victoria) guidelines for the Murray and Western Plains Bioregion (0.045 mg/L); median total nitrogen levels (0.51 mg/L) were below the guideline trigger value. Overall, source water quality from upper Gunbower Lagoon would not be expected to limit the development of diverse aquatic communities at Pig Swamp.

3.1.6. Environmental watering

The Northern Victoria Irrigation Renewal Project (NVIRP), now integrated into the GMW Connections Project, sought to upgrade ageing irrigation infrastructure across the Goulburn Murray Irrigation District (GMID) and to save water lost through leakage, seepage, evaporation and system inefficiencies (North Central CMA 2010). It was recognised that some of these 'losses' provided incidental benefits to environmental assets, and Pig Swamp was classified as a priority wetland that would be heavily impacted by the reduction in channel outfalls associated with increased efficiencies (SKM 2008). To mitigate these impacts, a volume of environmental water was calculated that could be used to sustain the existing ecological character of the wetland (North Central CMA 2010). In addition, other environmental water has been made available to use at the wetland. The *Pig Swamp Environmental Watering Plan* (North Central CMA, 2015) identified the values present at the site and an optimal watering regime was developed to maintain and improve the condition of the wetland. Pig Swamp was naturally flooded in 2010/11 but is yet to receive an environmental water allocation.

4. Values

4.1. Environmental values

4.1.1. Listings

Pig Swamp is part of a wetland of international and national significance, the Gunbower Forest Ramsar site, and listed on the Directory of Important Wetlands in Australia (Environment Australia 2001). It provides a diversity of habitats for aquatic and amphibious plants as well as habitat and food sources for birds, frogs and reptiles.

Table 5 details the legislation, agreement and conventions and listings that are relevant to Pig Swamp including one international listing (the Bonn Convention), one national listing (EPBC Act) and two Victorian State listings. A full list of flora and fauna recorded at Pig Swamp is shown in Appendix 3.

Table 5. Significance of Pig Swamp and its associated species

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	×
Republic of 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	✓
Victorian advisory lists	State	✓

4.1.2. Water-dependent fauna

Pig Swamp is shallow and has mostly been dry in the past decade. It is unlikely to be used as a breeding site for colonial nesting waterbirds (M Tranter [North Central CMA] 2011, pers. comm., 5 May), owing to the short inundation duration (typically less than four months). However, it could support breeding for other water-dependant birds including Azure Kingfisher, Australiasian Bittern and Clamorous Reed Warbler. Both Clamerous Reed Warbler and Australiasian Bittern use dense stands of reeds and rushes for foraging and breeding habitat. Anecdotally, ducks and hawks are also known to breed at the wetland. Because of the ephemeral water regime at Pig Swamp, it is unsuitable for populations of threatened fish species such as Murray Cod, Macquarie Perch and Murray Hardyhead. The Sedgy Riverine Forest/Tall Marsh/open water mosaic habitat, shallow bathymetry, ephemeral water regime, and absence of predatory fish at Pig Swamp provides conditions that support a diverse frog assemblage, with six frog species known to occur, including the Barking Marsh Frog. The listed Growling Grass Frog has also been recorded within a 5 km buffer of the site (GHD 2007; Bogenhuber and Campbell, 2011). Six listed fauna species have been recorded within Pig Swamp (DSE 2010a), three of which are water dependant (

Table 6 and Appendix 3).

Table 6. Significant water dependent fauna species recorded at Pig Swamp

Common name	Scientific name	Last record	International status	EPBC status	FFG status	Victorian status
Australasian Bittern	*Botaurus poiciloptilus*	1993	-	EN	L	e
Azure Kingfisher	*Alcedo azurea*	2011	-			nt
Clamorous Reed Warbler	*Acrocephalus stentoreus*	1993	B			

Key:
International Status: C = CAMBA, J = JAMBA, R = ROKAMBA, B=Bonn
EPBC: M = migratory species list, EN = Endangered
FFG Status: L = Listed as threatened, N = Nominated
DELWP Status: e = endangered, vu = vulnerable, nt = near threatened, dd = data deficient
Source: DELWP (2015a); DEPI (2013b)

4.1.1. Terrestrial fauna

Forty seven terrestrial bird species have been recorded at Pig Swamp, including the listed Brown Treecreeper (south-eastern ssp.) (*Climacteris picumnus victoriae*), Grey-crowned Babbler (*Pomatostomus temporalis temporalis*) and Hooded Robin (*Melanodryas cucullata cucullata*). Five terrestrial mammal species and two species of reptiles, including the listed Lace Monitor (*Varanus varius*) have also been recorded.

4.1.2. Vegetation mosaic and flora

DSE mapped four Ecological Vegetation Classes (EVCs) within and surrounding Pig Swamp (DSE 2011a, 2011b). However, ground validation of EVCs found no Lignum Swampy Woodland (Bogenhuber and Campbell, 2011). Presumably these areas have been cleared or modified, and/or this vegetation type has been lost due to changed hydrological conditions. Most of the swamp is covered by Sedgy Riverine Forest (refer to Appendix 4). The current EVCs recorded at Pig Swamp and their bioregional conservation status is presented in Table 7.

Table 7. Conservation status of EVCs at Pig Swamp

EVC no.	EVC name	Bioregional Conservation Status
103	Riverine Chenopod Woodland	Endangered
817	Sedgy Riverine Forest/Riverine Swamp Forest Complex	Depleted
821	Tall Marsh	Least Concern

Source: Bogenhuber and Campbell (2011)

The vegetation within Pig Swamp north of the Straight Cut Channel is different and less diverse than the area south of the channel. The northern section contains a large thick stand of Cumbungi (*Typha sp.)* that dominates the central section of the wetland (Plate 1). This Cumbungi is surrounded by a narrow band of River Red Gum and sedges (Plate 2). The Black Box woodland, which grows on the higher ground around Pig Swamp supports drier understorey species, particularly saltbush, and is rarely flooded (Plate 3).

The vegetation mosaic in the southern section of the wetland is more diverse than the northern section and is influenced by the subtle variations in elevation (Plate 4). The wetland floor is dominated by River Red Gum, sedges and water couch. The native sedge *Carex tereticaulis* is prominent, particularly towards the southern end. The adjoining Black Box areas along the eastern boundary support similar species to the northern section; however, the natural drainage lines that

enter the southeast section of the wetland support wetter understorey species. Nardoo was very prevalent after the 2010/11 floods and only a small number of Tangled Lignum (*Muehlenbeckia florulenta*) plants were observed (Bogenhuber and Campbell, 2011).

Plate 1: Tall Marsh, Pig Swamp North (DPI, March 2011)

Plate 2: River Red Gum, Pig Swamp North (MDFRC, March 2011)

Plate 3: Black Box woodland, Pig Swamp South (MDFRC, March 2011)

Plate 4: Aquatic vegetation, Pig Swamp South, (MDFRC, March 2011)

Native and threatened flora

A vegetation survey conducted at Pig Swamp in March 2011 recorded 63 native plant species, two of which are rare or threatened (Bogenhuber and Campbell 2011). The listed species are Einadia (*Einadia nutans subsp. linifolia*) and Two-spined Copperburr (*Sclerolaena uniflora*); neither of these are water-dependant. See Appendix 3 for the full species list (DSE 2010b).

Other significant species including Long Eryngium (*Eryngium paludosum*), Stiff Groundsel (*Senecio behrianus*), River Swamp Wallaby-grass (*Amphibromus fluitans*) and Winged Peppercress (*Lepidium monoplocoides*) have been recorded within five kilometres of Pig Swamp (GHD 2007, DSE 2010b, Bogenhuber and Campbell 2011) and are considered to be wetland/flow dependent (DNRE 2002 and VEAC 2008). The inundation tolerances of these species were considered when developing the desired watering regime for Pig Swamp (Section 6.4).

4.1.3. Wetland depletion and rarity

Pig Swamp classified as Shallow Freshwater Marsh under the old Corrick and Normal classification and Temporary Freshwater Marsh under new ANAE system. The rarity and significance of these wetland types in the North Central CMA region, Loddon River catchment and Murray Fans bioregion are discussed below.

Shallow freshwater marsh (Corrick and Norman Classification)

According to the Corrick and Norman classification, both the pre-European and 1994 classification of Pig Swamp was a shallow freshwater marsh. Shallow freshwater marshes are often degraded as a result of agricultural activities, including grazing or cropping, and have subsequently decreased in extent across the landscape. The area of shallow freshwater marshes across Victoria is estimated to have decreased by approximately 60% since European settlement (DNRE 1997). Although Pig Swamp represents only a small proportion of shallow freshwater marshes across Victoria, it accounts for approximately 5 per cent of the extent of this wetland type within the Murray Fans bioregion (Table 8). Pig Swamp is the only shallow freshwater marsh represented in the Gunbower Forest National Park (M Tscharke, [Parks Victoria] 2011, pers. comm., 2011).

Temporary freshwater swamps (Victorian Wetland Classification)

Pig Swamp represents less than 0.05% of temporary freshwater swamps in Victoria and contributes only a small proportion to the North Central CMA area, Loddon catchment and Murray Fans bioregion. (Table 8). A comparison of percentage reduction since European settlement could not be undertaken as the system does not include a comprehensive update of the WETLAND_1788 layer to meet the new wetland classification categories.

Table 8. Area, depletion and rarity of wetland classifications in the region

Region	Corrick and Norman classification Shallow freshwater marsh				Current classification Temporary freshwater swamps	
	Pre-European area (ha)	Current area (ha)	Reduction (%)	Pig Swamp contribution to current area (%)	Current area (ha)	Pig Swamp contribution to current area (%)
Victoria	125,942	54,537	57	0.1	103,559	0.05
North Central catchment	11,774	4,811	41	1.2	35,567	0.16
Loddon catchment	8,576	2,880	34	2.0	22,633	0.25
Murray Fans bioregion	3,141	1,074	34	5.3	41,719	0.13

4.1.4. Ecosystem function

'Ecosystem function' is a term used to describe the biological, geochemical and physical processes and components that occur within an ecosystem. These functions relate to the structural components of an ecosystem (e.g. vegetation, water, soil, atmosphere and biota) and how they interact with each other, both at a local (i.e. site specific) and regional (i.e. complex) scale. This includes processes that are essential for maintaining life such as storage, transport and nutrient cycling as well as the provision of resources that support biodiversity such as habitat, food and shelter.

Table 9 broadly shows the ecosystem functions provided by Pig Swamp from a local and regional perspective.

Table 9. Ecosystem function of Pig Swamp from a local and regional scale

Local ecosystem functions	Regional ecosystem functions
• **Convert matter to energy for uptake by biota** – substrates within the wetland (e.g. soil and woody debris) provide an area for primary producers such as biofilms and plants to grow on. These in turn provide food and energy for zooplankton, macroinvertebrates and higher order consumers. • **Provide shade and shelter for biota** - this includes amelioration of extremes in temperature, sunlight exposure and wind as well as protection from predators. The interrelationship of tree, shrub, forb and grass species with compatible geology, soil type, slope aspect, elevation, moisture availability and temperature range characteristics are the main ecosystem components supporting this function. • **Provision of water for consumption** - retention and storage of water for use by biota to enhance growth and development and to ensure survival and reproduction. • **Reproduction** - recruitment of new individuals requires sufficient shelter from predators, food for growth, resources for nest building and cues for breeding (i.e. water level changes, temperature, rainfall etc.). Adequate resources to support newly fledged individuals are also required, including shelter, food and provision of water for consumption. Plants also require specific germination and growth conditions (including flood cues, follow up flooding, drying etc.) to ensure successful recruitment.	• **Movement/ dispersal** - movement of individuals is linked to food web functions (see local ecosystem functions) and is a requirement for the life cycle of some species (i.e. migration). It also assists with maintaining genetic diversity within the landscape and reduces the risk of local species extinction. The movement of mobile species through the landscape further supports the dispersal of seeds/progapules in the landscape providing a source for colonisation. • **Cycle nutrients and store carbon** - important for essential ecological processes such as respiration and carbon sequestration etc. • **Population persistance** - a number of species require specific habitat requirements to breed. With a dramatic reduction in the area of temporary freshwater marsh in the landscape, the population of some species are ageing, which results in reduced fecundity and recruitment. • **Biological diversity** - the provision of a sufficient number and range of habitat types in the landscape supports a diversity of native species. This in turn assists to safeguard the region from the impacts of local catastrophic events (i.e. loss of habitat through fire and clearing) due to there being sufficient alternative habitats available. This supports the maintenance of genetic and species diversity in the region.
Note: The above ecosystem services are particularly important for species with low or restricted mobility.	

4.2. Social values

4.2.1. Cultural heritage

Evidence of Aboriginal occupation in Gunbower Forest includes scarred trees, earthen mounds, artefact scatters, shell middens and burial sites (SKM 2009). However, archaeological sites across the forest have been fragmented and in some cases damaged by past land use including stock grazing and timber harvesting. The majority of remaining scarred trees are box trees which are outside the area of forest managed for timber harvesting (Rhodes 1996).

Pig Swamp is within the Yorta Yorta Registered Aboriginal Party (RAP) native title area. Two scarred trees have been recorded within 5km of Pig Swamp and are registered with Aboriginal Affairs Victoria (AAV). No surveys have been conducted regarding European heritage at the site.

4.2.2. Recreation

Pig Swamp is a relatively unknown wetland for recreation within the Gunbower Forest area. The wetland has supported some duck hunting in the past. However hunting is no longer permitted because the site is now within a National Park.

4.3. Economic

While Pig Swamp does not provide any significant direct economic benefits, it is a component of Gunbower Forest which is a regionally significant tourism asset.

4.4. Conceptualisation of the site

Areas of Pig Swamp targeted by the watering regime (in the context of the surrounding landscape) are shown in Figure 9. These include the fringing River Red Gums, Sedgy Riverine Forest/Riverine Swamp Forest Complex, Tall Marsh and open water habitat within the swamp.

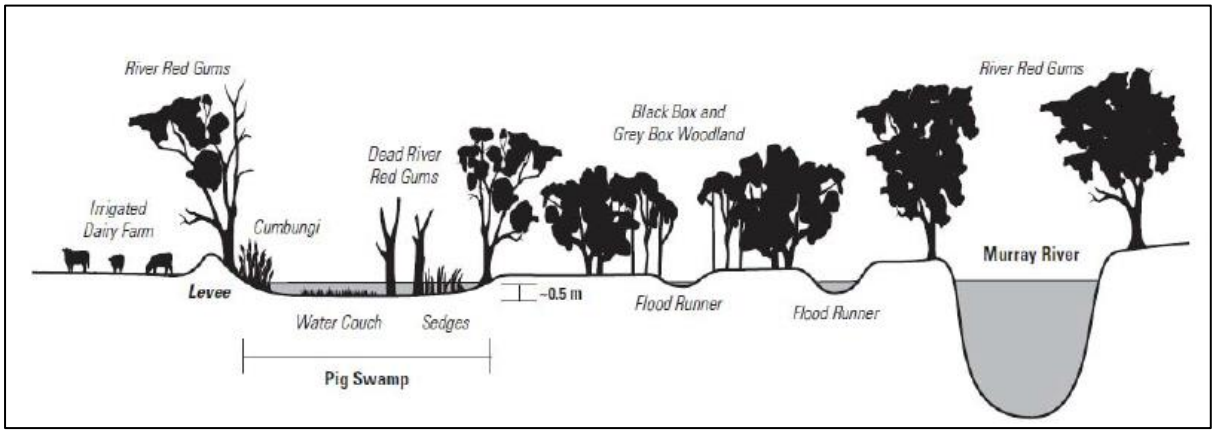

Figure 9. Schematic showing the location of Pig Swamp on the floodplain relative to the Murray River and other waterways and floodplain habitats (not to scale)

4.5. Significance

Pig Swamp meets three of the five Murray Darling Basin Plan criteria for identifying an environmental asset. It is part of the Gunbower Forest Ramsar Site, it supports several species listed under international conventions and it provides important habitat for frogs and waterbirds.

The dead River Red Gum trees and new recruits around the wetland fringe provide roosting, nesting and vantage points for birds, bats, reptiles and mammals. The frequent wetting and drying cycle of the wetland stimulates a highly productive environment, rich in nutrients, that can support aquatic and floodplain food webs. Although Pig Swamp has suffered from significant tree mortality since European settlement, it continues to support depleted and endangered vegetation communities and is one of the few River Red Gum and Black Box dominated swamps left in the North Central CMA region. Further, it is the only temporary freshwater marsh in Gunbower National Park. Appendices 6 and 7 detail assessment of Pig Swamp against the Murray Darling Basin Plan criteria for identifying an environmental asset, and the significance of ecosystem functions of Pig Swamp, respectively.

5. Ecological condition and threats

5.1. Context

Pig Swamp has been classified as a shallow freshwater marsh dominated by River Red Gum and dead timber both prior to and following European settlement (DSE 2009a and 2009b). Before European settlement, it contained mature, widely spaced River Red Gum (*Eucalyptus camaldulensis*) and was surrounded by Black Box (E. largiflorens). Pig Swamp naturally received floodwater from the south through a series of interconnecting creek lines and drainage depressions that flowed during Murray River flood events greater than 50,000 ML/day. Larger flood events resulted in more widespread sheet flooding that would have inundated the higher surrounding Black Box areas.

The cutting of the Straight Cut Channel at three locations in the 1970s resulted in near permanent inundation of Pig Swamp until 2007. That water regime caused the death of older trees scattered throughout the bed of the swamp and the establishment of younger River Red Gums on the swamp margins (Ecos Consulting, 2005). In 2007, an earthern block was placed in the straight-cut channel upstream of Pig Swamp and irrigation outfalls ceased, causing the swamp to dry out. Natural floods in the Murray River partially filled the wetland in December 2010; and filled and overflowed the wetland in January 2011 (O'Brien 2011). Pig Swamp was grazed by domestic stock until 2007 in the southern section, with stock removed from the northern section approximately 30 years ago (O'Brien 2011).

5.2. Current condition

Displacement of wetland vegetation communities

The altered water regime through much of the 20th century favoured Cumbungi, which has become abundant to the detriment of overall vegetation species diversity. Dense stands of Cumbungi have formed a thick organic peat layer across parts of the wetland. While Cumbungi provides valuable protection and nesting habitat for wetland birds and important frog habitat, they also form dense canopies of leaves which heavily shade the area beneath them, inhibiting the growth of other species.

A near-permanent water regime over the past century has resulted in the mortality of scattered River Red Gums throughout the wetland. The Straight Cut Channel is currently dominated by exotic species and several high threat weeds including African Boxthorn (*Lycium ferocissimum*), Sweet Briar (*Rosa rubiginosa*), Bridal Creeper (*Asparagus asparagoides*), Lippia (*Phyla canescens*) and Willow (*Salix* sp.).

Index of Wetland Condition

An Index of Wetland Condition (IWC) assessment has not been undertaken at Pig Swamp.

Tree condition

Vegetation surveys conducted in 2011 revealed that the majority of the River Red Gums on the northern side of Pig Swamp were in moderate to good health, while those on the southern side were in poor condition (Bogenhuber and Campbell, 2011). No subsequent tree condition assessments have been conducted.

Changes to fauna species diversity and composition

There have been few targeted fauna surveys at Pig Swamp; therefore, it is difficult to assess changes in fauna species diversity and composition over time. However, clearly the shift from a near permanent regime to a highly ephemeral wetland in 2007 would have resulted in the loss of any obligate aquatic species.

5.3. Condition trajectory – do nothing

As a complementary action to the RCS, the North Central CMA is developing the *North Central Climate Change Adaptation and Mitigation Plan* (North Central CMA, 2015b), which predicts the long term impacts of climate change under a range of scenarios. Although the scale of impacts (e.g. severity, timeframe) differs for each scenario, the following impacts are expected to occur across all scenarios:

- Reduced and more variable rainfall
- Decrease in winter rainfall
- Increased temperatures, and extreme heat
- Increased intensity of extreme rainfall
- Increased frequency and severity of bushfire and flood events

Under these predictions, Pig Swamp is likely to experience less natural rainfall over the winter period, higher spring and summer temperatures and increased evaporation during summer.

Although the water regime and vegetation communities have been significantly altered from its pre-European state, the wetland supports a reasonable diversity of water birds, high diversity frogs and fringing River Red Gums in moderate health.

Without environmental water, the water-dependent values that Pig Swamp currently supports would diminish. The wetland seedbank may become unviable, and there may be significant loss of habitat and refuge for water birds and frogs, reducing opportunities for breeding and recruitment in the landscape. The condition of existing River Red Gums may also decline and some trees may die.

6. Management objectives

6.1. Management goal

The long term management goal for Pig Swamp takes into account the environmental values the wetland supports, the current condition of those values and potential threats to those values. The management goal is the similar to that for the *Pig Swamp Environmental Watering Plan 2015*.

Pig Swamp Long-term Management Goal

To support flora and fauna that are typical of a shallow freshwater marsh, in particular providing habitat for frogs and waterbirds, while also improving the health and increasing the distribution of the current mosaic of plant communities.

6.2. Ecological objectives

Ecological objectives describe the intended outcomes of environmental water delivery. They contribute towards achieving the long term management goal. The ecological objectives for Pig Swamp are based on the key water-dependent values of the wetland. Where appropriate, these are expressed as the target condition or functionality for each key value, using one of the following trajectories:

- restore – recover a value that has been damaged, degraded or destroyed and return it to its original condition.
- rehabilitate – repair a value that has been damaged, degraded or destroyed but not to the extent of its original condition.
- maintain – maintain the current condition of a value.

Ecological objectives are presented as either primary objectives or secondary objectives. Primary objectives are related to the key values of Pig Swamp. Secondary objectives either support the primary objectives (e.g. invertebrates as a food source for waterbirds) or relate to values for which little baseline information is known (e.g. frogs). If the monitoring budget in future years is restricted it is anticipated that the North Central CMA will prioritise monitoring of primary objectives.

The ecological objectives for Pig Swamp and the justification for each are shown in Table 10.

Table 10. Ecological objectives and their justifications for Pig Swamp

Objective	Justification
1. Primary Objective – species	
1.1 Rehabilitate the health and distribution of Sedgy Riverine Forest/Tall Marsh/open water mosaic.	The Sedgy Riverine Forest/Tall Marsh/open water mosaic provides habitat for aquatic and amphibious plants as well as habitat and food sources for birds, frogs and invertebrates.
1.2 Rehabilitate the health and distribution of River Red Gums.	River Red Gums are the dominant tree species across the wetland and provide nesting, feeding and breeding habitat and refuge for a range of fauna. Fallen River Red Gum leaves also provide an important source of carbon to the wetland and can be transported to other parts of the floodplain and river channels during floods.
2. Secondary Objectives – species	
2.1 Establish a diverse native-dominated plant community and ensure species complete their lifecycle to maintain a viable seedbank	Establishing and/or maintaining a diverse native plant community will prevent the spread of exotic plant species and prevent the dominance of any one native species, e.g. *Typha* sp. Seed banks and rhizomes provide means of persistence for macrophytes in intermittent wetlands during dry periods.
3. Secondary Objectives – habitat	
3.1 Rehabilitate feeding and roosting habitat for waterbirds, including threatened species.	Linked to habitat objectives. Providing a mosaic of habitat types will increase the likelihood of maintaining waterbird populations such as the threatened Azure Kingfisher and the Australasian Bittern.
3.2 Provide habitat for frog populations when the wetland holds water.	Linked to habitat objectives. Providing a variety of habitat types (Sedgy Riverine Forest/Tall Marsh/open water mosaic) will increase the likelihood of maintaining frog communities, including populations of Barking Marsh Frog.
3.3 Ensure adequate biomass of macroinvertebrate functional feeding groups and zooplankton to support ecological processes and wetland foodwebs.	Linked to habitat objectives. Providing a mosaic of habitat types will increase the likelihood of maintaining an adequate biomass of a variety of invertebrate functional groups, which in turn facilitate ecological processes such as nutrient and carbon cycling and are an important food source for other fauna.
4. Secondary Objective - Process	
4.1 Restore connectivity between river, floodplain and wetland.	Connectivity between rivers and floodplains facilitates dispersal and movement of plant propagules, micro and macroinvertebrates, fish, frogs and turtles, as well as contributing to nutrient and carbon cycling.

6.3. Hydrological requirements

A series of hydrological requirements based on the ecological objectives described in Section 6.2 have been developed for Pig Swamp. The information provided in Table 11 is a summary of this information.

Table 11. Hydrological requirements for Pig Swamp

Ecological Objectives	Water management area	Hydrological Objectives										
		Recommended number of events in 10 years			Tolerable interval between events once wetland is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth (m)*
		Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
1. Primary objectives												
1.1 Rehabilitate the health and distribution of Sedgy Riverine Forest/Tall Marsh/open water mosaic.	Bed/fringe	3	6	10	1-6	24	36	4	5-6	11	Spring	0.2-1m; alternate between FSL and 75% FSL.
1.2 Rehabilitate the health and distribution of River Red Gums.	Bed/fringe	2	3-6	7	6	18-30	54	2	4	18	Spring/Summer	Not critical
2. Secondary Objectives – species												
2.1 Establish a diverse native-dominated plant community and ensure species complete their lifecycle to maintain a viable seedbank	Bed/fringe	3	6	10	1-6	24	36	4	5-6	11	Spring	0.2-1m; alternate between FSL and 75% FSL.
3 Secondary Objectives – habitat												
3.1 Rehabilitate feeding and roosting habitat for waterbirds, including threatened species.	Bed/fringe	3	6	10	1-6	24	36	4	5-6	11	Spring	0.2-1m; alternate between FSL and 75% FSL.
3.2 Provide habitat for frog populations when the wetland holds water.	Bed/fringe	2	4	8	Unknown - prefer ephemeral or semi-permanent water bodies but will retreat to permanent water bodies in dry conditions			3	3-6	12	Spring through to Autumn	Variable
3.3 Ensure adequate biomass of macroinvertebrate functional feeding groups and zooplankton to support ecological processes and wetland foodwebs.	Bed	3	4	8	Variable depending on species			3	3-6	-	Spring through to Autumn	Variable
4. **Secondary Objectives - processes**												
4.1 Restore connectivity between river, floodplain and wetland.	Floodplain and	During times of 'natural' flood/ localised rainfall, provide additional environmental water if necessary and where possible to reach full supply level or extend flooding duration and ensure all wetland components are inundated.										

Ecological Objectives	Water management area	Hydrological Objectives										
		Recommended number of events in 10 years			Tolerable interval between events once wetland is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth (m)*
		Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
	Wetland											
Source: Fitzsimons et al. 2011, Roberts and Marston 2011, Rogers and Ralph 2011, Bogenhuber and Campbell, 2011												

6.4. Watering regime

The wetland watering regime for Pig Swamp has been derived from the ecological objectives and hydrological requirements described in Section 6.2 and 6.3, and considers the requirements and tolerances of characteristic species in each objective. The watering regime is framed using the seasonally adaptive approach, which describes an optimal regime 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.

Minimum watering regime

Fringe and wetland target years (3 events in 10 years): Inundate wetland three in ten years to FSL (84.05 m AHD). Pig Swamp should not be allowed to dry for more than three consecutive years. Ideally, fill in winter/spring and maintain full for three to six months. To achieve this during times of 'natural' flood/localised rainfall, provide environmental water if necessary and where possible to inundate Pig Swamp to full supply level or above and ensure all wetland components are inundated. The wetland is shallow and unlikely to retain water for 12 months, therefore drying is likely (and desirable) within six months. The wetland should be completely dried for at least 3 to 6 months between most filling events.

Optimum watering regime

Fringe and wetland target years (6 events in 10 years): Inundate wetland six in ten years. Approximately half the events should inundate the wetland to FSL (84.05 m AHD); other events should only fill to 75% FSL (83.8 m AHD). Ideally, fill in winter/spring and maintain full for three to six months. Variability is desirable in all components of the watering regime e.g. timing, frequency, duration, extent and depth. Variability in flood extent and depth will assist in maintaining a mosaic of open water, Tall Marsh and Sedgy Riverine Forest and avoid a 'fringe' effect, particularly of River Red Gums. Seasonal variability (e.g. variability in timing of flows) is also desirable as it will allow for the germination and recruitment of seasonal plant species, thus maintaining and increasing overall biodiversity. Allow 'natural' floods to inundate Pig Swamp and if possible, maintain flood level or extend duration with environmental water. The wetland is shallow and unlikely to retain water for 12 months, therefore drying is likely (and desirable) within six months. The wetland should be completely dried for at least 3 to 6 months between most filling events.

Maximum watering regime

Fringe and wetland target years (8 events in 10 years): Inundate the wetland no more than eight in ten years. Ideally, fill in winter/spring and maintain full for three to six months. Approximately half the events should inundate the wetland to FSL (84.05 m AHD); other events should only fill to 75% FSL (83.8 m AHD). To achieve this during times of 'natural' flood/localised rainfall, provide environmental water if necessary and where possible to inundate Pig Swamp to full supply level or above and ensure all wetland components are inundated**.** The wetland is shallow and unlikely to retain water for 12 months, therefore drying is likely (and desirable) within six months. The wetland should be completely dried for 3 to 6 months at least once every five years, and preferably more often.

The volume required to fill Pig Swamp to 84.05 m AHD from dry would be approximately 421 ML (North Central CMA, 2015). Additional water would be required to maintain the wetland at this level in years where sustained flooding is required.

7. Risk Assessment

A qualitative risk assessment has been undertaken for Pig Swamp to assign the level of long-term risk associated with:

- delivering environmental water; and
- achieving set ecological objectives (i.e. non-flow related factors that may inhibit the ability to achieve objective)

The level of risk is determined by the likelihood of a threat occurring and the severity of the impact of that threat (Table 12).

Table 12. Risk Matrix

		Severity		
		Major	Moderate	Minor
Likelihood	Probable	High	High	Moderate
	Possible	High	Moderate	Low
	Improbable	Moderate	Low	Low

The results from the Pig Swamp risk assessment presented in Table 13 are adapted from the *Pig Swamp Environmental Watering Plan 2015*. Management measures relevant for the moderate to high level risks are recommended and the residual risk after those measures are implemented is estimated using the same risk matrix. Please note that short-term operational risks (e.g. environmental releases causes flooding of private land) are assessed as part of the development of the *Gunbower Seasonal Watering Proposal* which includes Pig Swamp.

Table 13. Possible risks and mitigation measures associated with environmental water delivery to Pig Swamp

Risk No.	Threat	Outcome	Relevant objective	Likelihood	Severity	Risk rating	Management Measure	Residual Risk rating
1	**Threats from environmental water**							
1.1	Poor water quality (i.e. temperature fluctuations, blackwater events, high turbidity, Blue-Green Algae, salinity and nutrient levels)	• Reduced primary production (turbid water), limiting food resources for aquatic invertebrates and waterbirds. • Encroachment of vegetation that thrives under high nutrient conditions. • Excessive algal growth • Potential fish kills	All	Possible	Moderate	Moderate	• Monitor quality of source water used to deliver environmental flows and delay or defer delivery if quality is poor. • Monitor groundwater levels, salinity and nutrient inputs in conjunction with a regular water quality monitoring program. • Adaptively manage water regime and delivery. Environmental water could be used to provide 'freshening' flows.	Low
1.2	Introducing and promoting invasive aquatic and terrestrial species	• Competition with native species; potential decline in health and distribution of Sedgy Riverine Forest/Tall Marsh mosaic.	All	Possible	Major	High	• Target control of source populations of Willows in the Straight Cut Channel, which have potential to spread into Pig Swamp via water delivery. • African Boxthorn and Bridal Creeper in the Straight Cut Channel also require control. • Monitoring and weed control (e.g. spraying).	Moderate
2	**Threats to achieving ecological objectives**							
2.1	No supply point re-instated to the wetland	• Desired water regime not achieved • Provision of environmental water not possible	All	Possible	Major	High	• Upgrade the Straight Cut Channel to ensure environmental and mitigation water delivery is possible. • Rectified through the Gunbower SDL offsets project	Low
2.2	Water is only available at times other than preferred winter/spring (e.g. autumn)	• Failure to achieve identified objectives and water management goal • Promotion of excessive *Typha* growth if water is delivered over summer.	All	Possible	Major	High	• Adaptively manage water regime and delivery of environmental water to assist the achievement of desired goal i.e. fill a portion of the wetland in autumn to minimise the water required to fill it in winter/spring.	Moderate

Risk No.	Threat	Outcome	Relevant objective	Likelihood	Severity	Risk rating	Management Measure	Residual Risk rating
2.3	Encroachment or dominance of native flora species	• Monoculture of *Typha* sp. • Loss in species diversity • Habitat loss (i.e. open water) • Watering events prove unproductive for waterbirds and frogs	1.1, 2.1 3.1	Probable	Major	High	• The recommended watering regime has been developed with consideration of preferred growing periods and conditions for dominant native species (*Typha spp*). Allowing the wetland to periodically dry out and not maintain water in the wetland over consecutive summers aims to manage these species. • Active management (spraying, slashing, crash grazing etc.) • Regular monitoring and adaptive management of water regime.	Moderate
2.4	Loss of standing timber habitat	• Dead River Red Gums are unstable and falling over, with limited regeneration to replace the dead trees. • Reduced availability of nesting and roosting habitat for birds, bats, mammals.	1.2, 3.1	Probable	Moderate	High	• The recommended watering regime has been developed to provide appropriate hydrological requirements for growth and recruitment of River Red Gums. • Regular monitoring of tree health and condition will be undertaken to inform adaptive management of the wetland. • Residual risk rating is low in consideration that an appropriate watering regime will assist in recruitment of River Red Gums.	Low
2.5	Introduced species – fish	• European Carp and *Gambusia* possibly move into Pig Swamp during inundation events, as they are likely to be present in the irrigation system. A high abundance of these species may limit the growth of aquatic plants, predate on frogs (food sources for waterbirds) and reduce water quality. However they may also provide a source of food for piscivorous waterbirds.	1.1, 2.1, 3.2, 3.3	Possible	Moderate	Moderate	• Annual drying (as per recommended regime) will manage populations and prevent increases over time. • Development of a Gunbower Carp Management Plan will inform carp control options. • Investigate Carp screen option to prevent large carp entering the wetland during filling events.	Low

Risk No.	Threat	Outcome	Relevant objective	Likelihood	Severity	Risk rating	Management Measure	Residual Risk rating
2.6	Introduced species – foxes	• Foxes have been observed (and previously targeted by hunters) at Pig Swamp. Impacts include predation of juvenile waterbirds, reptiles and mammals.	3.1	Probable	Moderate	High	• Fox control program required • Residual risk reduced to reflect water and target fox control management	Moderate
2.7	Introduced species – rabbits	• Herbivory of emergent vegetation as well as recruited understorey and overstorey (i.e. River Red Gums) impacts on the health and extent of native vegetation. The presence of warrens may also disrupt sites of cultural heritage and impact on soil structure.	1.1, 1.2, 2.1	Possible	Moderate	Moderate	• Rabbit control program required • Active revegetation (including use of plant guards) may be required in heavily impacted areas • Residual risk reduced to reflect active management	Low
2.8	Lack of seedbank viability of species not currently present	• Monoculture of *Typha* sp. • Emergence of unexpected native or exotic species • Restricted regeneration of native wetland plants • Lower species diversity	All	Possible	Moderate	Moderate	• The recommended watering regime has been developed with consideration of hydrological requirements to enable plants to complete their life cycles, which includes contribution to the seed bank. • Monitoring of exotic species (particularly in the straight cut channel), adaptive management and weed control as required. • Fluctuation of water levels will be required to support River Red Gum germination. Consider seeding if necessary.	Low
2.9	Fire	• Habitat and resource loss (e.g. standing timber) • Water quality may deteriorate.	All	Possible	Major	High	• Active management, monitoring (e.g. IWC) and adaptive management.	Moderate
2.10	Chytrid fungus	Chytrid fungus is an infectious amphibian disease that impairs osmoregulation of most species. Although there has been no testing for the disease at Pig Swamp, it is considered widespread in Victoria. Mortality rates of up to 100% are common, with adults more vulnerable than tadpoles.	3.2	Possible	Moderate	Moderate	• Undertake zoospore counts to identify presence of disease- N.B. the disease is not as prevalent in semi-arid regions (vivacity linked to wet and cold conditions). • No change to residual risk due to limited control measures available.	Moderate

8. Environmental water delivery infrastructure

Pig Swamp has previously received water from the Straight Cut Channel via a series of cuts in the banks of the channel (Figure 10). The Straight Cut Channel from the Gunbower Creek to the wetland is currently uncommitted Crown Land.

As of 2015, the Straight Cut Channel is operated to deliver water to the two remaining service points west of Pig Swamp. In 2007, GMW constructed an earthen embankment to block the Straight Cut Channel west of Pig Swamp as a drought/water savings measure (Figure 10). Therefore, no water can now be delivered to Pig Swamp.

Currently, two options for environmental water delivery are being investigated:

- Option one - delivery using the western section of the Straight Cut Channel from the Upper Gunbower Lagoon.
- Option two - delivery using the eastern section of the Straight Cut Channel, pumped from the Murray River. This is the preferred option and is being investigated as part of North Central CMAs Gunbower Forest Sustainable Diversion Limits Program.

8.1. Proposed changes to existing infrastructure

The Stage 1 GMW Connections Project works program includes delivering an automated backbone for the water distribution system, rationalising spur channels, connecting farm water supply to the backbone and upgrading metering on up to 50% of customer supply points in the GMID. The GMW Connections Project is investigating options to move the current two service points on the Straight Cut Channel (west of the earthen block) to the backbone. The section of the channel east of the earthen bank is likely to remain untouched (M Paganini [GMW Connections Project] 2011, pers. comm., 8 June).

The GMW Connections Project is responsible for "retain(ing) infrastructure and improving where practicable, where it will be required for delivering environmental water…." (NVIRP 2010). A review of the infrastructure requirements and supply arrangements will be needed to enable the delivery of environmental water to Pig Swamp.

The GMW Connections Project has developed a register of infrastructure that is/could be used to deliver environmental water to waterways and wetlands (NVIRP 2011). Pig Swamp has now been added to this register.

8.1. Infrastructure constraints

Under both options, Straight Cut Channel is the conduit for delivering environmental water to Pig Swamp. Depending on the option, either the eastern or western section will need to be retained. Under option one, additional works will be needed to bypass or remove the earthen block that currently prevents water being delivered directly to the wetland. A small regulator structure in the form of a gated pipe outlet from the Straight Cut Channel into Pig Swamp is also required.

Under option two, two regulators would be required on the eastern section of the Straight Cut Channel to control water delivery to both Pig Swamp and to target flood dependent vegetation within upper Gunbower Forest. Water being delivered to the upper forest will need to pass across Brereton road; the point along the channel where this regulator would be situated, and whether water will be delivered under the road via a culvert, or via flooding over the road is currently being investigated.

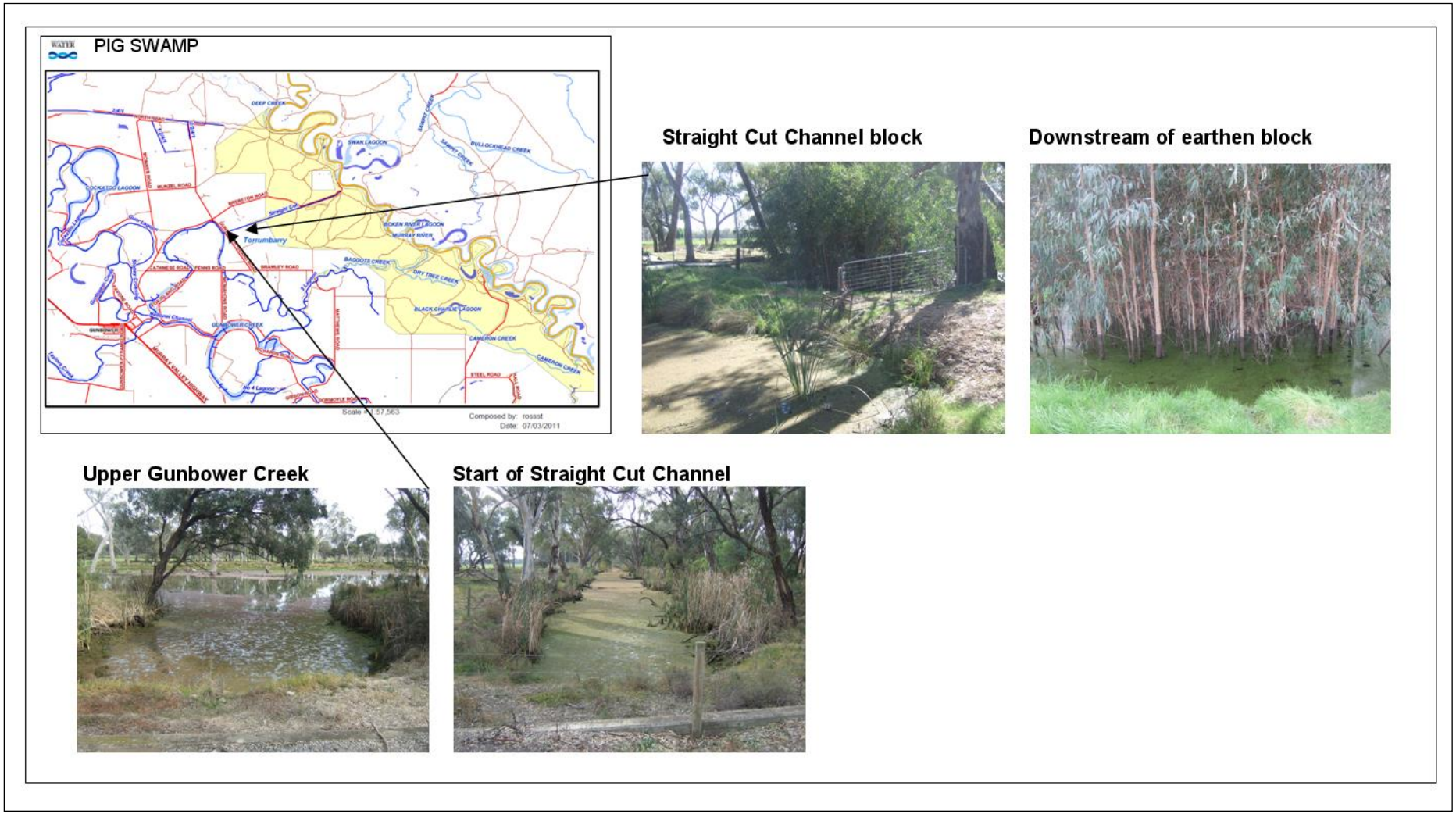

Figure 10. Infrastructure at Pig Swamp

8.2. Operation constraints

Under option one, the supply of water from the Straight Cut Channel to Pig Swamp is restricted by the operating level in the Upper Gunbower Lagoon. The Upper Gunbower Lagoon FSL ranges between 83.9-84.0 m AHD. GMW has indicated that delivery to Pig Swamp from the Straight Cut Channel is restricted to 84.0 m AHD (R Stanton [GMW] 2011, pers. comm., 1 July). For this reason, watering from Upper Gunbower Lagoon is not the preferred option.

It is recommended that a delivery rate of 42 ML/day is provided. This has been calculated based on the modelled volume required to fill from dry (North Central CMA, 2015) and the depth at FSL. Note that (1) the modelled volume has not yet been verified as Pig Swamp has not yet received environmental water and (2) under option one (gravity fed); the rate of fill would slow markedly as the wetland fills.

Optimal delivery rate	= (volume required to fill to FSL from dry / target depth) x maximum rate of fill
	= (421 / 50) x 5
	= 42.1 ML day

8.3. Infrastructure recommendations

The following recommendations require investigation to improve water management in the Upper Gunbower Forest. Recommendations applicable to both options are:

- Restore the capacity of the Straight Cut Channel by removing debris, vegetation and sediment.
- The Straight Cut Channel is an impediment to flood flows, preventing overbank flows from moving through the Gunbower Forest. The channel also acts as a barrier between the northern and southern parts of Pig Swamp. The removal of this channel from the recommended delivery point to Pig Swamp needs to be investigated. Consideration could also be given to breaching the channel in such a way as to establish 'islands' of channel bank which would provide the desired habitat and some protection from predation (e.g. turtle eggs from foxes).

Specific recommended works for option one are:

- Remove the earthen block (200 m west of the wetland).
- Construct a pipe and outlet structure at the wetland entry point in the Straight Cut Channel to allow water to be delivered into the wetland.
- Construct a structure in the channel on the east side of Pig Swamp to prevent water from filling the full length of the channel.

Specific recommended works for option two are:

- Install two regulators on the Straight Cut Channel; one to control water delivery to Pig Swamp and the other control watering of target flood dependant vegetation within upper Gunbower Forest.

9. Complementary actions

Implementation of the recommended watering regime for Pig Swamp will generate benefits to the environmental values of the wetland. Some objectives require complementary actions in order to be realised. These are directly related to the risk section, i.e. risk of not achieving objectives (Table 14).

Table 14. Complementary actions to enhance the benefits of environmental watering

Activity	Rationale
Typha spp. management	This species have been advantaged by altered hydrology in the wetland and has previously formed large mono-specific patches throughout the wetland. Dominance by Cumbungi reduces species diversity and loss of important habitat for wetland species (e.g. open water, Sedgy Riverine Forest/Riverine Swamp Forest Complex). Active management such as spraying, mowing and slashing, in conjunction with an appropriate watering regime, will assist in controlling the extent of this species.
Exotic flora control	Thirty two percent of species recorded at Pig Swamp are exotic, and have the potential to disturb the function of native vegetation through displacement and competition. The Straight Cut Channel in particular is dominated by exotic species (see 5.2 and Appendix 4). Exotic plants also impact on primary production within a system, which in turn feeds into all other food web interactions that take place within a system. Weed control such as manual removal and chemical application should target high threat terrestrial and amphibious weeds.
Fox control	Foxes are commonly observed at Pig Swamp. Impacts include predation on juvenile waterbirds, turtles, mammals and terrestrial birds. Fox control measures include baiting and interactive fox drives, and should be intensified during wet phases, particularly if bird breeding occurs.
Protection of turtle nests	Turtle nests are often predated upon by foxes. Mesh may be used to protect turtles nests in some cases.
Rabbit control	The presence of rabbits inhibits recruitment of native vegetation. Rabbit control measures include baiting, warren fumigation or destruction, and interactive education activities such as rabbit buster.

10. Demonstrating outcomes

Monitoring programs enable water managers to justify the application of environmental water by demonstrating that environmental outcomes are being achieved. Monitoring is undertaken to help determine the success of managed watering events, and to inform adaptive management of Pig Swamp.

Two types of monitoring are recommended to assess the effectiveness of the proposed water regime on objectives and to facilitate adaptive management:

- Intervention monitoring
- Long-term condition monitoring

It is essential that monitoring results are analysed regularly to develop an understanding of changes occurring at the wetland so that water managers can manage accordingly.

10.1. Intervention monitoring

Intervention monitoring will assess the responses of key environmental values to the changes in the water regime (intervention) and indicate whether ecological objectives are being achieved. Intervention monitoring may include monitoring of water quality, vegetation and biota (i.e. native waterbirds).

Monitoring the response to a watering event will be important to provide feedback on how the system is responding and whether any amendments need to be made to the operational management or determine if any risk management actions need to be enacted.

Required intervention monitoring

Pig Swamp is yet to receive environmental water, and therefore has no existing intervention monitoring program. A proposed intervention monitoring program relating to each objective is shown in Table 15.

Table 15. Required intervention monitoring for the implementation of the Pig Swamp EWMP

Ecological objective		Monitoring question	When	Method
1.1	Rehabilitate the health and distribution of Sedgy Riverine Forest/Tall Marsh/open water mosaic	Is the watering regime improving the health and distribution of the Sedgy Riverine Forest/Tall Marsh/open water mosaic?	Before and after environmental watering or natural event.	Photo point and rapid condition assessment monitoring
1.2	Rehabilitate the health and distribution of River Red Gums.	What frequency and duration of inundation do River Red Gums at Pig Swamp require to ensure they are in good condition?	Every 2 years during long dry periods	Photo point and rapid condition assessment monitoring
1.2	Rehabilitate the health and distribution of River Red Gums.	Is the health of mature River Red Gums changing after flooding? Are River Red Gum trees recruiting after flooding?	Before and approx. one year after environmental watering or natural event. Ongoing monitoring will determine the long-term survivorship of recruits.	Photo point and rapid condition assessment monitoring
2.1	Establish a diverse native-dominated plant community and ensure species complete their lifecycle to maintain a viable seedbank	Does the water regime allow establishment of a native dominated plant community and viable seed bank?	Before environmental watering and during the first year after environmental watering or natural event	Photo point and rapid condition assessment monitoring
3.1	Rehabilitate feeding and roosting habitat for waterbirds, including threatened species.	Are waterbirds using the wetland for feeding and successful breeding when it is inundated?	Throughout watering event	Visual monitoring as well as the use of monitoring cameras in key areas of the wetland (i.e. in trees over water) Water height monitoring
3.2	Provide habitat for frog populations when the wetland holds water.	How many species of frogs are present and breeding at Pig Swamp in response to the watering regime?	Throughout watering event	Call-back and visual surveys
3.3	Ensure adequate biomass of macroinvertebrate functional feeding groups and zooplankton to support ecological processes and wetland foodwebs.	Does Pig Swamp support a desired range and abundance of macroinvertebrate functional groups when it is inundated by environmental water?	Twice during a watering event; at least one month after inundation, and during drawdown.	Quantitative macroinvertebrate surveys; zooplankton trawls
Risk		**Monitoring question**	**When**	**Method**
1.2	Poor surface water quality	Are water quality parameters maintained at acceptable levels during watering events?	Monthly during a watering event; coinciding with photo point monitoring	Measurement of electrical conductivity, pH, turbidity, dissolved oxygen, temperature
2.2	Encroachment or dominance of native flora species	Is the watering regime causing excessive growth of *Typha*	Monthly during watering event	Photo point monitoring

		spp.	1 to 3 months after the end of wetting cycle	Comparison of aerial imagery[1] to 2011 mapping (Bogenhuber and Campbell, 2011)
2.4	Introduced species – fish	Are large numbers of introduced fish (Carp, *Gambusia*) entering the wetland during inundation?	Once during a watering event	Fyke nets, bait traps, backpack electrofishing
2.9	Chytrid fungus	Are frogs being affected by Chytrid fungus?	Once during a watering event	Swabbing for Chytrid Fungus
[1]Subject to availability of regularly updated imagery.				

10.2. Long term monitoring

Long-term condition monitoring aims to provide information on whether the watering regime (and other factors) is causing a change in, or maintaining, the overall condition of the wetland (trend over time). Table 16 details monitoring required to demonstrate changes in condition over time specifically focusing on the long-term outcomes of the Pig Swamp EWMP.

It should be noted that condition monitoring is recommended to be conducted in conjunction with intervention monitoring to comprehensively evaluate any changes to Pig Swamp.

Table 16. Required long-term condition monitoring for Pig Swamp

Ecological Objective	**Method**	**When**
Maintain health and distribution of Sedgy Riverine Forest/Tall Marsh/open water mosaic. Maintain health and distribution of River Red Gums. Maintain health of the fringing Riverine Chenopod Woodland Establish a diverse and resilient native-dominated plant community that prevents the spread of exotic plant species and prevents the dominance of any one native species, e.g. Typha sp. Return Pig Swamp to a wet/dry cycle.	Comprehensive vegetation condition surveys including tree health, IWC, EVC condition, species presence and abundance and weediness	Ideally annually with no more than two years between surveys
Risks	**Method**	**When**
Groundwater intrusion or discharge to low-lying surrounding area resulting from elevated groundwater levels.	Review groundwater-related aspects of the site, including environmental risks and impact of adopted watering regime. Subject to data availability, this should include an appraisal of the movement of the wetting front and salt, impacts on surrounding groundwater levels and neighbouring land, and a water budget that includes estimates of accessions to groundwater. See Table 17 for further details.	At least every 7 years or sooner if regional groundwater levels rise.

11. Knowledge gaps and recommendations

The Pig Swamp EWMP has been developed using the best available information. However, a number of information and knowledge gaps exist which may impact on recommendations and/or information presented in the EWMP. These are summarised below with priority status in Table 17.

Table 17. Knowledge gaps and recommendations for Pig Swamp

Knowledge Gap	Objective/ Risk	Recommendation	Who	Priority
Objectives				
Increase knowledge on the fauna using Pig Swamp for habitat, feeding and breeding, particularly frogs, waterbirds and listed species.	3.1, 3.2	Undertake comprehensive frog and waterbirds surveys when Pig Swamp is in a wet phase.	CMA or consultant on behalf of CMA	High
Risks				
Poor water quality (i.e. temperature fluctuations, blackwater events, high turbidity, salinity and nutrient levels).	1.2	Currently there is no water quality data available for Pig Swamp. Monitoring of surface water is recommended to ensure no detrimental impacts from implementation of the water regime.	CMA or consultant on behalf of CMA	Moderate
Groundwater intrusion or discharge to low-lying surrounding area resulting from elevated groundwater levels.	1.3	Continued monitoring and evaluation of groundwater levels. Install data loggers within the wetland and in selected groundwater bores, to provide data before watering and throughout the wetting and drying cycle at the site. Establishing a surface water level gauge, and use volume rating tables to assist recording level and volume, to verify the surface water data logger readings. Regular liaison with neighbouring landholders to understand their water use and irrigation practices, and how these change over time. Installation of shallow and deep (to approximately 10 m and 20 m) groundwater monitoring bores, at two locations adjacent the site Assessing the watertable depth and soil and salinity profile beneath the lowest part of the site floor.	CMA or consultant on behalf of CMA	Moderate
Constraints				
Determine the future operation of the Straight Cut Channel and modification required (including ownership and maintenance) to enable the delivery of environmental water to the wetland.	All	Investigate infrastructure arrangements	CMA/GMW	High

Determine the implications of works on the straight cut channel banks regarding disturbance to habitat. The Straight Cut Channel has been in place since the 1870s and as such, has become a well-established component of the Pig Swamp habitat. Reptiles, Grey-crowned Babblers and the possible occurrence of Stiff Groundsel should be especially considered.	All	Undertake comprehensive flora and fauna surveys along the straight cut channel prior to works to optimise works locations and mitigate impacts.	CMA/GMW/ consultant on behalf of CMA	High

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13. Abbreviations and acronyms

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
CEWO	Commonwealth Environmental Water Office
CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
DEPI	Department of Environment and Primary Industries (Now an amalgamation DELWP in 2015)
DPI	Department of Primary Industries (Now an amalgamation DELWP in 2015)
DSE	Department of Sustainability and Environment (Now DELWP in 2015)
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Cth)
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
EWP	Environmental Watering Plan
FFG	Flora and Fauna Guarantee Act 1988 (Vic)
FSL	Full supply level
GIS	Geographical Information System
GMW	Goulburn Murray Water
GMWCP	Goulburn Murray Water Connections Project
HRWS	High Reliability Water Share
JAMBA	Japan-Australia Migratory Bird Agreement
LRWS	Low Reliability Water Share
MDBA	Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC)
ML	Megalitre (one million litres)
ML/d	Megalitres per day
NCWS	North Central Waterway Strategy
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RCS	Regional Catchment Strategy
SWP	Seasonal Watering Proposal
VEWH	Victorian Environmental Water Holder
VWMS	Victorian Waterway Management Strategy

Appendix 1. 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".

World Heritage Sites

Heritage includes places, values, traditions, events and experiences that capture where we've come from, where we are now and gives context to where we are headed as a community. The World Heritage Convention aims to promote cooperation among nations to protect heritage from around the world that is of such outstanding universal value that its conservation is important for current and future generations. It is intended that, unlike the seven wonders of the ancient world, properties on the World Heritage List will be conserved for all time (DEWHA 2008a).

East Asian-Australasian Flyway Sites

Australia provides critical non-breeding habitat for millions of migratory waterbirds each year. Migratory waterbirds include species such as plovers, sandpipers, stints and curlews. The corridor through which these waterbirds migrate is known as the East Asian-Australasian Flyway.

To ensure their conservation, the Australian Government has fostered international cooperation through the recently launched East Asian-Australasian Flyway Partnership. Under the Flyway Partnership, the site network for shorebirds has been combined into a single network, referred to as the East Asian–Australasian Flyway Site Network.

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); and
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

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 1999 (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.

Nationally Important Wetlands

Victoria has a number of waterways of National importance as described in A Directory of Important Wetlands in Australia (Environment Australia, 2001).There are 159 wetlands in Victoria listed in the Directory.

Living Murray Icon Sites

The Living Murray was established in 2002 in response to evidence that the health of the River Murray system is in decline. The Living Murray's first stage focuses on improving the environment at six 'icon sites' along the River:

- Barmah-Millewa Forest;
- Gunbower-Koondrook-Perricoota Forest;
- Hattah Lakes;
- Chowilla Floodplain and Lindsay-Wallpolla Islands;
- Lower Lakes, Coorong and Murray Mouth; and
- River Murray Channel.

The sites were chosen for their high ecological value—most are listed as internationally significant wetlands under the Ramsar convention—and also their cultural significance to Indigenous people and the broader community (MDBC, 2006).

HEVAE

Through National Water Initiative (NWI) commitments, a toolkit for identifying high ecological value aquatic ecosystems (HEVAE) has been developed so that national consistency may be applied. Five core criteria are used to develop HEVAE sites across a range of scales and ecosystems:

- Diversity
- Distinctiveness
- Vital habitat
- Naturalness
- Representativeness.

The HEVAE toolkit is saved at http://www.environment.gov.au/resource/aquatic-ecosystems-toolkit-module-3-guidelines-identifying-high-ecological-value-aquatic

National Heritage Sites

The National Heritage List has been established to list places of outstanding heritage significance to Australia. It includes natural, historic and Indigenous places that are of outstanding national heritage value to the Australian nation (DEWHA 2008).

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 2. Contour Map and Capacity Table

Capacity Summary for Pig Swamp

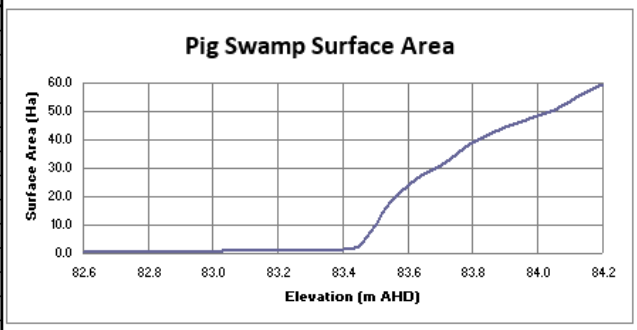
MAy 2011

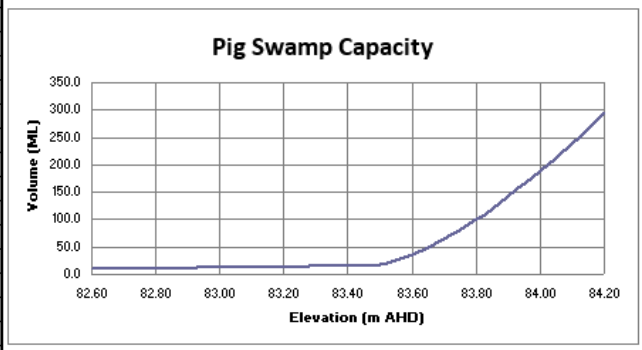
Produced by Wes Pye (Northern Land Solutions, Swan Hill)

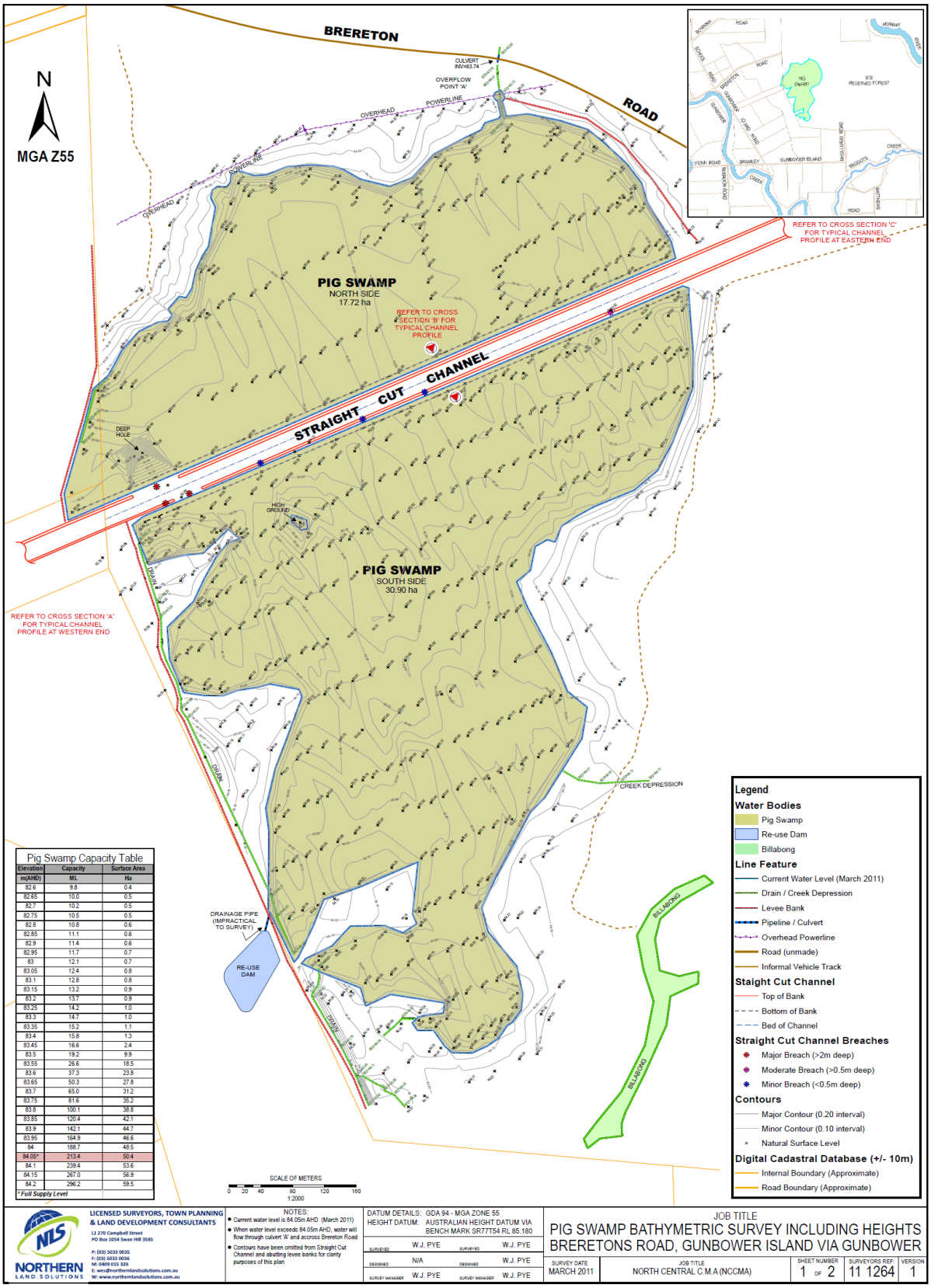
DATUM DETAILS: GDA 94 - MGA ZONE 55
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM VIA
BENCH MARK SR77T54 RL 85.180
Water level is 84.05m AHD (March 2011), when water level exceeds 84.05m AHD, water will flow through culvert 'A' and accross Brereton Road

Base Level (AHD) 82.6
FSL (AHD) 84.05 (Estimate)

Elevation	Capacity	Surface Area
m(AHD)	ML	Ha
82.60	9.8	0.4
82.65	10.0	0.5
82.70	10.2	0.5
82.75	10.5	0.5
82.80	10.8	0.6
82.85	11.1	0.6
82.90	11.4	0.6
82.95	11.7	0.7
83.00	12.1	0.7
83.05	12.4	0.8
83.10	12.8	0.8
83.15	13.2	0.9
83.20	13.7	0.9
83.25	14.2	1.0
83.30	14.7	1.0
83.35	15.2	1.1
83.40	15.8	1.3
83.45	16.6	2.4
83.50	19.2	9.9
83.55	26.6	18.5
83.60	37.3	23.8
83.65	50.3	27.8
83.70	65.0	31.2
83.75	81.6	35.2
83.80	100.1	38.8
83.85	120.4	42.1
83.90	142.1	44.7
83.95	164.9	46.6
84.00	188.7	48.5
84.05	213.4	50.4
84.10	239.4	53.6
84.15	267.0	56.9
84.20	296.2	59.5






BRERETON
ROAD
N
MGA Z55
CULVERT INV=83.74
OVERFLOW POINT 'A'
OVERHEAD POWERLINE
REFER TO CROSS SECTION 'C' FOR TYPICAL CHANNEL PROFILE AT EASTERN END
PIG SWAMP
NORTH SIDE
17.72 ha
REFER TO CROSS SECTION 'B' FOR TYPICAL CHANNEL PROFILE
STRAIGHT CUT CHANNEL
DEEP HOLE
HIGH GROUND
PIG SWAMP
SOUTH SIDE
30.90 ha
REFER TO CROSS SECTION 'A' FOR TYPICAL CHANNEL PROFILE AT WESTERN END
DRAIN
CREEK DEPRESSION
DRAINAGE PIPE (IMPRACTICAL TO SURVEY)
RE-USE DAM
BILLABONG
SCALE OF METERS
0 20 40 80 120 160
1:2000
Pig Swamp Capacity Table
Elevation m(AHD) | Capacity ML | Surface Area Ha
82.6 9.8 0.4
82.65 10.0 0.5
82.7 10.2 0.5
82.75 10.5 0.5
82.8 10.8 0.6
82.85 11.1 0.6
82.9 11.4 0.6
82.95 11.7 0.7
83 12.1 0.7
83.05 12.4 0.8
83.1 12.8 0.8
83.15 13.2 0.9
83.2 13.7 0.9
83.25 14.2 1.0
83.3 14.7 1.0
83.35 15.2 1.1
83.4 15.8 1.3
83.45 16.6 2.4
83.5 19.2 9.9
83.55 26.6 18.5
83.6 37.3 23.8
83.65 50.3 27.8
83.7 65.0 31.2
83.75 81.6 35.2
83.8 100.1 38.8
83.85 120.4 42.1
83.9 142.1 44.7
83.95 164.9 46.6
84 188.7 48.5
84.05* 213.4 50.4
84.1 239.4 53.6
84.15 267.0 56.9
84.2 296.2 59.5
* Full Supply Level
Legend
Water Bodies
Pig Swamp
Re-use Dam
Billabong
Line Feature
Current Water Level (March 2011)
Drain / Creek Depression
Levee Bank
Pipeline / Culvert
Overhead Powerline
Road (unmade)
Informal Vehicle Track
Staight Cut Channel
Top of Bank
Bottom of Bank
Bed of Channel
Straight Cut Channel Breaches
Major Breach (>2m deep)
Moderate Breach (>0.5m deep)
Minor Breach (<0.5m deep)
Contours
Major Contour (0.20 interval)
Minor Contour (0.10 interval)
Natural Surface Level
Digital Cadastral Database (+/- 10m)
Internal Boundary (Approximate)
Road Boundary (Approximate)
NORTHERN LAND SOLUTIONS
LICENSED SURVEYORS, TOWN PLANNING & LAND DEVELOPMENT CONSULTANTS
L1 270 Campbell Street
PO Box 1054 Swan Hill 3585
P: (03) 5033 0035
F: (03) 5033 0036
M: 0409 015 326
E: wes@northernlandsolutions.com.au
W: www.northernlandsolutions.com.au
NOTES:
Current water level is 84.05m AHD (March 2011)
When water level exceeds 84.05m AHD, water will flow through culvert 'A' and accross Brereton Road
Contours have been omitted from Straight Cut Channel and abutting levee banks for clarity purposes of this plan
DATUM DETAILS: GDA 94 - MGA ZONE 55
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM VIA BENCH MARK SR77154 RL 85.180
SURVEYED W.J. PYE
DESIGNED N/A
SURVEY MANAGER W.J. PYE
JOB TITLE
PIG SWAMP BATHYMETRIC SURVEY INCLUDING HEIGHTS BRERETONS ROAD, GUNBOWER ISLAND VIA GUNBOWER
SURVEY DATE MARCH 2011
JOB TITLE NORTH CENTRAL C.M.A (NCCMA)
SHEET NUMBER 1 OF 2
SURVEYORS REF. 11 1264
VERSION 1

Appendix 3. Species lists

Table 18. Fauna species recorded within 1km buffer zone of Pig Swamp.

Common name	Scientific name	Date of last record	Source
Amphibians			
Barking Marsh Frog	*Limnodynastes fletcheri*	2011	Bogenhuber & Campbell (2011)
Common Froglet	*Crinia signifera*	2007	DELWP (2015)
Peron's Tree Frog	*Litoria peronii*	2007	DELWP (2015)
Plains Froglet	*Crinia parinsignifera*	2007	DELWP (2015)
Pobblebonk Frog	*Limnodynastes dumerilii dumerilii*	2007	DELWP (2015)
Spotted Marsh	*Limnodynastes tasmaniensis*	1982	DELWP (2015)
Mammals			
Black Wallaby	*Wallabia bicolor*	2007	DELWP (2015)
Common Brushtail Possum	*Trichosurus vulpecula*	2007	DELWP (2015)
Common Ringtail Possum	*Pseudocheirus peregrinus*	2007	DELWP (2015)
Eastern Grey Kangaroo	*Macropus giganteus*	2007	DELWP (2015)
European Rabbit	*Oryctolagus cuniculus*	2007	DELWP (2015)
Red Fox	*Vulpes vulpes*	2007	DELWP (2015)
Yellow-footed Antechinus	*Antechinus flavipes*	2007	DELWP (2015)
Platypus	*Ornithorhynchus anatinus*	2007	DELWP (2015)
Water Rat	*Hydromys chrysogaster*	2007	DELWP (2015)
Reptiles			
Lace Monitor	***Varanus varius***	**1998**	**DELWP (2015)**
Skinks	*fam. Scincidae gen. Egernia*	2007	DELWP (2015)
Water-dependent birds			
Australasian Bittern	***Botaurus poiciloptilus***	**1993**	**DELWP (2015)**
Australian Shelduck	*Tadorna tadornoides*	1993	DELWP (2015)
Australian White Ibis	*Threskiornis molucca*	1993	DELWP (2015)
Azure Kingfisher	***Alcedo azurea***	**2011**	**Bogenhuber & Campbell (2011)**
Clamorous Reed Warbler	***Acrocephalus stentoreus***	**1993**	**DELWP (2015)**
Dusky Moorhen	*Gallinula tenebrosa*	2007	DELWP (2015)
Eurasian Coot	*Fulica atra*	1993	DELWP (2015)
Grey Teal	*Anas gracilis*	2007	DELWP (2015)
Little Pied Cormorant	*Microcarbo melanoleucos*	2007	DELWP (2015)
Pacific Black Duck	*Anas superciliosa*	2007	DELWP (2015)
Purple Swamphen	*Porphyrio porphyrio*	2007	DELWP (2015)
Sacred Kingfisher	*Todiramphus sanctus*	1993	DELWP (2015)
Swamp Harrier	*Circus approximans*	1993	DELWP (2015)
White-necked Heron	*Ardea pacifica*	2007	DELWP (2015)
Terrestrial birds			
Australian Magpie	*Gymnorhina tibicen*	2007	DELWP (2015)
Australian Raven	*Corvus coronoides*	2007	DELWP (2015)
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	2007	DELWP (2015)
Brown Treecreeper (south-eastern ssp.)	***Climacteris picumnus victoriae***	**2007**	**DELWP (2015)**
Brown-headed Honeyeater	*Melithreptus brevirostris*	2007	DELWP (2015)
Common Bronzewing	*Phaps chalcoptera*	2007	DELWP (2015)
Crested Pigeon	*Ocyphaps lophotes*	2007	DELWP (2015)

Common name	Scientific name	Date of last record	Source
Crested Shrike-tit	*Falcunculus frontatus*	2007	DELWP (2015)
Dusky Woodswallow	*Artamus cyanopterus*	2007	DELWP (2015)
European Goldfinch	*Carduelis carduelis*	2007	DELWP (2015)
Galah	*Eolophus roseicapilla*	2007	DELWP (2015)
Grey Fantail	*Rhipidura albiscarpa*	2007	DELWP (2015)
Grey Shrike-thrush	*Colluricincla harmonica*	2007	DELWP (2015)
Grey-crowned Babbler	***Pomatostomus temporalis temporalis***	**2011**	**EWP (2015)**
Hooded Robin	***Melanodryas cucullata cucullata***	**2007**	**DELWP (2015)**
Jacky Winter	*Microeca fascinans*	2007	DELWP (2015)
Laughing Kookaburra	*Dacelo novaeguineae*	2007	DELWP (2015)
Little Corella	*Cacatua sanguinea*	2007	DELWP (2015)
Little Grassbird	*Megalurus gramineus*	1993	DELWP (2015)
Little Raven	*Corvus mellori*	2007	DELWP (2015)
Magpie-lark	*Grallina cyanoleuca*	2007	DELWP (2015)
Masked Lapwing	*Vanellus miles*	2007	DELWP (2015)
Noisy Miner	*Manorina melanocephala*	2007	DELWP (2015)
Pallid Cuckoo	*Cuculus pallidus*	1993	DELWP (2015)
Peaceful Dove	*Geopelia striata*	2007	DELWP (2015)
Pied Butcherbird	*Cracticus nigrogularis*	2007	DELWP (2015)
Red-browed Finch	*Neochmia temporalis*	2007	DELWP (2015)
Red-rumped Parrot	*Psephotus haematonotus*	2007	DELWP (2015)
Restless Flycatcher	*Myiagra inquieta*	2007	DELWP (2015)
Southern Boobook	*Ninox novaeseelandiae*	2007	DELWP (2015)
Straw-necked Ibis	*Threskiornis spinicollis*	2007	DELWP (2015)
Striated Pardalote	*Pardalotus striatus*	2007	DELWP (2015)
Sulphur-crested Cockatoo	*Cacatua galerita*	2007	DELWP (2015)
Superb Fairy-wren	*Malurus cyaneus*	2007	DELWP (2015)
Tawny Frogmouth	*Podargus strigoides*	2007	DELWP (2015)
Wedge-tailed Eagle	*Aquila audax*	2007	DELWP (2015)
Weebill	*Smicrornis brevirostris*	2007	DELWP (2015)
Welcome Swallow	*Petrochelidon neoxena*	2007	DELWP (2015)
Western Gerygone	*Gerygone fusca*	1993	DELWP (2015)
Whistling Kite	*Haliastur sphenurus*	2007	DELWP (2015)
White-browed Babbler	*Pomatostomus superciliosus*	2007	DELWP (2015)
White-browed Scrubwren	*Sericornis frontalis*	2007	DELWP (2015)
White-plumed Honeyeater	*Lichenostomus penicillatus*	2007	DELWP (2015)
White-throated Treecreeper	*Cormobates leucophaeus*	2007	DELWP (2015)
White-winged Chough	*Corcorax melanorhamphos*	2007	DELWP (2015)
Willie Wagtail	*Rhipidura leucophrys*	2007	DELWP (2015)
Yellow Rosella	*Platycercus elegans flaveolus*	2007	DELWP (2015)

Table 19. Flora species recorded within 1km buffer zone of Pig Swamp.

Common name	Scientific name	Date of last record	Source
Water-dependent species			
Clove-strip	*Ludwigia peploides subsp. montevidensis*	2011	Bogenhuber & Campbell (2011)
Club-sedge	*Schoenoplectus sp.*	2011	Bogenhuber & Campbell (2011)
Common Blown-grass	*Lachnagrostis filiformis*	2011	Bogenhuber & Campbell (2011)
Common Nardoo	*Marsilea drummondii*	2011	Bogenhuber & Campbell (2011)
Common Sneezeweed	*Centipeda cunninghamii*	2011	Bogenhuber & Campbell (2011)
Common Spike-sedge	*Eleocharis acuta^*	2011	Bogenhuber & Campbell (2011)
Common Wallaby-grass	*Austrodanthonia caespitosa*	2011	Bogenhuber & Campbell (2011)
Cumbungi	*Typha spp.*	2011	Bogenhuber & Campbell (2011)
Duckweed	*Lemna sp.*	2011	Bogenhuber & Campbell (2011)
Finger Rush	*Juncus subsecundus*	2011	Bogenhuber & Campbell (2011)
Lesser Joyweed	*Alternanthera denticulata*	2011	Bogenhuber & Campbell (2011)
Narrow-leaf Dock	*Rumex tenax*	2011	Bogenhuber & Campbell (2011)
Pale Knotweed	*Persicaria lapathifolia*	2011	Bogenhuber & Campbell (2011)
Poison Pratia	*Pratia concolor*	2011	Bogenhuber & Campbell (2011)
Poong'ort	*Carex tereticaulis*	2011	Bogenhuber & Campbell (2011)
Raspwort	*Haloragis sp.*	2011	Bogenhuber & Campbell (2011)
River Bluebell	*Wahlenbergia fluminalis*	2011	Bogenhuber & Campbell (2011)
River Red Gum	*Eucalyptus camaldulensis*	2011	Bogenhuber & Campbell (2011)
Slender Knotweed	*Persicaria decipiens*	2011	Bogenhuber & Campbell (2011)
Small Loosestrife	*Lythrum hyssopifolia*	2011	Bogenhuber & Campbell (2011)
Small Spike-sedge	*Eleocharis pusilla*	2011	Bogenhuber & Campbell (2011)
Star Fruit	*Damasonium minus*	2011	Bogenhuber & Campbell (2011)
Tall Fireweed	*Senecio runcinifolius*	2011	Bogenhuber & Campbell (2011)
Tall Spike-sedge	*Eleocharis sphacelata*	2011	Bogenhuber & Campbell (2011)
Tangled Lignum	*Muehlenbeckia florulenta*	2011	Bogenhuber & Campbell (2011)
Water Ribbons	*Triglochin procera*	2011	Bogenhuber & Campbell (2011)
Woodland Swamp-daisy	*Brachyscome paludicola*	2011	Bogenhuber & Campbell (2011)
Terrestrial species			
Annual Cudweed	*Euchiton sphaericus*	2011	Bogenhuber & Campbell (2011)
Berry Saltbush	*Atriplex semibaccata*	2011	Bogenhuber & Campbell (2011)
Black Box	*Eucalyptus largiflorens*	2011	Bogenhuber & Campbell (2011)
Bristly Wallaby-grass	*Austrodanthonia setacea*	2011	Bogenhuber & Campbell (2011)
Cherry Ballart	*Exocarpus cupressiformis*	2011	Bogenhuber & Campbell (2011)
Clammy Goosefoot	*Chenopodium pumilio*	2011	Bogenhuber & Campbell (2011)
Common Cotula	*Cotula australis*	2011	Bogenhuber & Campbell (2011)
Common Wheat-grass	*Elymus scaber*	2011	Bogenhuber & Campbell (2011)
Cotton Fireweed	*Senecio quadridentatus*	2011	Bogenhuber & Campbell (2011)
Einadia	*Einadia nutans*	2011	Bogenhuber & Campbell (2011)
Einadia	***Einadia nutans subsp. linifolia***	**2011**	**Bogenhuber & Campbell (2011)**
Gold-dust Wattle	*Acacia acinacea*	2011	Bogenhuber & Campbell (2011)
Golden Everlasting	*Xerochrysum bracteatum*	2011	Bogenhuber & Campbell (2011)
Grey Germander	*Teucrium racemosum*	2011	Bogenhuber & Campbell (2011)
Kangaroo Grass	*Themeda triandra*	2011	Bogenhuber & Campbell (2011)
Lax Goosefoot	*Einadia trigonos subsp. trigonos*	2011	Bogenhuber & Campbell (2011)
Mallow	*Malva sp.*	2011	Bogenhuber & Campbell (2011)
Nettle	*Urtica sp.*	2011	Bogenhuber & Campbell (2011)

Common name	Scientific name	Date of last record	Source
New Holland Daisy	*Vittadinia sp.*	2011	Bogenhuber & Campbell (2011)
Nightshade	*Solanum sp.*	2011	Bogenhuber & Campbell (2011)
Plantain	*Plantago sp.*	2011	Bogenhuber & Campbell (2011)
Prickly Saltwort	*Salsola tragus*	2011	Bogenhuber & Campbell (2011)
Rough Spear-grass	*Austrostipa scabra*	2011	Bogenhuber & Campbell (2011)
Ruby Saltbush	*Enchylaena tomentosa*	2011	Bogenhuber & Campbell (2011)
Short-leaf Bluebush	*Maireana brevifolia*	2011	Bogenhuber & Campbell (2011)
Sorrel	*Oxalis sp.*	2011	Bogenhuber & Campbell (2011)
Sprawling Saltbush	*Atriplex suberecta*	2011	Bogenhuber & Campbell (2011)
Spreading Goodenia	*Goodenia heteromera*	2011	Bogenhuber & Campbell (2011)
Two-spined Copperburr	***Sclerolaena uniflora***	**2011**	**Bogenhuber & Campbell (2011)**
	Senecio sp.	2011	Bogenhuber & Campbell (2011)
	Senecio sp. 1315	2011	Bogenhuber & Campbell (2011)
Exotic water dependant species			
Drain Flat-sedge	*Cyperus eragrostis*	2011	Bogenhuber & Campbell (2011)
Paspalum	*Paspalum dilatatum*	2011	Bogenhuber & Campbell (2011)
Water Couch	*Paspalum distichum*	2011	Bogenhuber & Campbell (2011)
Exotic terrestrial species			
African Box-thorn	*Lycium ferocissimum*	2011	Bogenhuber & Campbell (2011)
Barley-grass	*Hordeum sp.*	2011	Bogenhuber & Campbell (2011)
Bathurst Burr	*Xanthium spinosum*	2011	Bogenhuber & Campbell (2011)
Black Nightshade	*Solanum nigrum*	2011	Bogenhuber & Campbell (2011)
Blackberry	*Rubus fruticosus spp. agg.*	2010	DELWP (2015)
Bridal Creeper	*Asparagus asparagoides*	2011	Bogenhuber & Campbell (2011)
Cat's Ear	*Hypochaeris radicata*	2011	Bogenhuber & Campbell (2011)
Chicory	*Cichorium intybus*	2011	Bogenhuber & Campbell (2011)
Cleavers	*Galium aparine*	2011	Bogenhuber & Campbell (2011)
Clover	*Trifolium sp.*	2011	Bogenhuber & Campbell (2011)
Common Heliotrope	*Heliotropium europaeum*	2011	Bogenhuber & Campbell (2011)
Common Peppercress	*Lepidium africanum*	2011	Bogenhuber & Campbell (2011)
Curled Dock	*Rumex crispus*	2011	Bogenhuber & Campbell (2011)
Fleabane	*Conyza sp.*	2011	Bogenhuber & Campbell (2011)
Ox-tongue	*Helminthotheca echioides*	2011	Bogenhuber & Campbell (2011)
Prickly Lettuce	*Lactuca serriola*	2011	Bogenhuber & Campbell (2011)
Prostrate Knotweed	*Polygonum aviculare*	2011	Bogenhuber & Campbell (2011)
Sand-spurrey	*Spergularia rubra*	2011	Bogenhuber & Campbell (2011)
Scotch Thistle	*Onopordum acanthium subsp. acanthium*	2011	Bogenhuber & Campbell (2011)
Spear Thistle	*Cirsium vulgare*	2011	Bogenhuber & Campbell (2011)
Sweet Briar	*Rosa rubiginosa*	2011	Bogenhuber & Campbell (2011)
Verbena	*Verbena litoralis*	2011	Bogenhuber & Campbell (2011)
Wild Oats	*Avena fatua*	2011	Bogenhuber & Campbell (2011)
Willow	*Salix sp.*	2011	Bogenhuber & Campbell (2011)

Appendix 4. Ecological Vegetation Class Mapping

Appendix 5. Community and stakeholder engagement

Consultation was undertaken for the Environmental Watering Plan in 2010, which captured information provided by members of the community, interest groups and agency stakeholders. Building on this, consultation was undertaken for the *Pig Swamp EWMP* in 2016 to confirm ecological values and objectives, and discuss emerging threats and any proposed changes to the watering regime. As the EWP was written prior to the floods, the consultation in 2016 focused on changes that were observed at the wetland during the floods and in the years since.

Consultation involved phone interviews, with each person available who was originally consulted during the EWP development process.

Below is a summary of the discussions and information that was received as part of the original consultation for the EWP. Comments were compiled so that they are not referred back to individuals.

Pre European Settlement Condition

- The water levels in the Murray River would have fluctuated more, prior to the construction of the storages and river regulation. This changing water level would have influenced the flooding on Gunbower Island.
- Pig Swamp is situated high on the Gunbower Island floodplain; therefore it naturally flooded infrequently and only held water for short periods, about 2 – 3 months.
- During minor floods, water would have feed out of the Murray River through the creeks and drainage lines like Baggots and Upper Gunbower Creeks.
- In a major Murray River flood, water would have flooded more broadly over the higher Black Box areas surrounding Pig Swamp.
- Pig Swamp naturally contained large widely spaced red gums through the main drainage depression.
- The area around Pig Swamp was dominated by Black Box trees which indicates it only flooded occasionally.
- Originally the area contained much larger more widely spaced trees. Large “Bull Gums” (term that refers to big old trees) would occupy an area and prevent other trees and vegetation from establishing. The bush had a more open appearance.
- During big floods water naturally broke out of the Murray River upstream of Pig Swamp and flowed through Dry Tree Lagoon and Dry Tree Creek, then on through to Baggots Creek which fed Pig Swamp as well as Upper Gunbower Creek and the lagoon system. Floodwater would then flow northwards inundating areas further downstream.
- Upstream of Torrumbarry, the Cameron’s Creek system would flood and feed water into Dry Tree Creek and Baggots Creek.
- Swan Lagoon over the Murray River in NSW carried floodwater across into the NSW forest and then flowed northwards entering Cow and Calf creeks.
- Pre-European settlement the creek systems around Gunbower were deeper and narrower and would rise and fall more quickly in line with the levels in the Murray River. Over time these creeks have silted up.
- Floodwater could also break out of the Murray River during a major floods closer to Pig Swamp (around “Masters House” area) and create shallow sheet flooding through the bush around Pig Swamp.
- In wet years, Mahers Creek (which is) out on the Patho Plains would feed water across into the Upper Gunbower Creek System. This water possibly entered the Gunbower system, prior to the Murray River flooding.
- Aboriginal people would have utilised the southern end of Gunbower Island and associated wetlands including Pigs Swamp.

- Aboriginal people possibly utilised the higher areas of Gunbower Island such as Pig Swamp during a major flood event and then moved north utilising the lower wetlands as water levels receded.
- There is not much evidence of Aboriginal occupation in the Pig Swamp area in the form of scar trees and cooking mounds.

Changed Management

- Early European settlers changed floodwater distribution as they established farms.
- Levees were constructed to protect farms and houses which changed the flood patterns across the southern end of Gunbower Island which influenced the flooding through Pig Swamp.
- Many trees were cut down and utilised by paddle steamers travelling along the Murray River." Masters Landing" east of Pig Swamp was a paddle steamer port and these boats were utilised up until the 1940s.
- Large numbers of trees on the southern end of Gunbower Island were cut for fence posts. Unwanted or lower value trees were ring-barked.
- The Straight Cut Channel was constructed very early in the development of the irrigation supply system - it was built in the 1870s. It was constructed by approximately 200 men with shovels and wheel barrows. It was designed to deliver irrigation water pumped from the Murray River to the Upper Gunbower Creek. This was a huge engineering task as the channel was dug down possibly 6 to 8 feet below the natural ground level.
- The significant Murray River flood in the 1870s forced large quantities of water up the Straight Cut Channel causing flooding problems in the Upper Gunbower Creek system. Shortly afterwards a large earthen bank was built across the entrance of the Straight Cut Channel to prevent further uncontrolled flooding. This block has been in place for over 100 years.
- The Straight Cut Channel irrigation system proved to be too small. A larger irrigation system was established over time.
- Irrigation syndicates on Baggots Creek were establish very early and may have pre-dated the Straight Cut Channel.
- Baggots Creek was also used as an early irrigation supply system. Water would be pumped across from the Murray River, through Baggots Creek into the Upper Gunbower Creek. Sandbags were used to block the top section of the Upper Gunbower Creek near the Straight Cut Channel. This elevated the water allowing farmers upstream to irrigate then water was allowed the flow on and supply landholders further downstream.
- The Cohuna Irrigation Trust established a larger irrigation supply system downstream of the Straight Cut Channel at the old "Head Works" or "Flume" around 1886 and eventually this was replaced by the construction of the Torrumbarry Weir in 1923.The original weir lasted about 90 years and supplied an extensive irrigation area and allowed water to be gravitated through the Gunbower Creek and Lagoons.
- Large floods in the late 1800 and early 1900s (possibly 1909) broke through the banks on the Straight Cut Channel causing them to leak irrigation water into the swamp. Other major flood events occurred during the 1950s, 1970s and 1990s.
- Much of the water flowing down the Murray River is distributed out on the floodplain. In a flood over 29ft 6inches at Echuca, for every 1 foot rise at Echuca results in only a 1 inch rise in the Murray River at Gunbower.
- Some of the breaches and leaks through the banks of the Straight Cut Channel are likely to be near the deeper sections or flood runner through the swamp.
- The Torrumbarry Weir created elevated water levels in the Upper Gunbower Creek System and this allowed water to flow back along the Straight Cut Channel to supply the landholder adjacent to the Murray River. The Straight Cut Channel was utilised to supply this farm, as water in the Murray River (downstream of Torrumbarry Weir) would need to be lifted 22 –

28 feet which was very expensive. The landholder pumped irrigation water from the east end of the Straight Cut Channel onto the farm.

- The Straight Cut Channel has altered the natural flooding of Pig Swamp by delivering irrigation water into it for over 100 years, maintaining it almost permanently full.
- The Straight Cut Channel was built through the Pig Swamp depression and continuously leaked into both the north and south sections.
- Possibly up to 1000 ML/yr was lost out of the irrigation supply system that flooded out of the Straight Cut Channel into Pig Swamp.
- The banks of the Straight Cut Channel were mechanically excavated to allow flood water to flow northwards during the floods in the 1970s.
- In a major flood event, water would flow through the area around Pig Swamp about 1- 2 feet deep, then flow northwards into the Deep Creek system. This would create flood problems in the Cohuna area.
- Brereton Road flooded in the lowest section, adjacent to Pig Swamp.
- There was a bridge on Gunbower Island Road where the Straight Cut Channel connected to the Upper Gunbower Creek. Historically during a major Murray River flood, water would enter via the breaches in the Straight Cut Channel and flow strongly up the channel into the Upper Gunbower Creek. This assisted in flushing the Upper Gunbower Creek. This bridge was replaced with a 2 ft pipe in the 1960s which greatly restricts flood flows between the channel and the creek.
- The water levels in Pig Swamp were mostly determined by the height of the water in the Straight Cut Channel, which was influenced by the water in the Upper Gunbower Creek. When the water levels rose in the irrigation supply system this resulted in additional water spilling into Pig Swamp.
- The normal summer full supply level of Pig Swamp is lower than indicated on the map. The swamp edge is below the surrounding Black Box tree line as these trees do not tolerate continuous summer watering.
- During winter in non-irrigation season the Gunbower Creek system was lowered. This lowered the water level in the Straight Cut Channel and eliminated flows into Pig Swamp. Water could drain back out of Pig Swamp, via the Straight Cut Channel into the Upper Gunbower Creek, leaving ponded water in the deeper depression towards the centre of the swamp. The area inundated in Pig Swamp reduced to 510 acres on each side of Straight Cut Channel.
- During wet winters, the water levels in Pig Swamp where partially maintained due to rainfall and cooler temperatures.
- The southern section of Pig Swamp has been historically grazed by cattle for the past 100 years. The area would carry about 25 head for most of the year, and then the stock was moved off and grazed the adjoining farm. The grazing licence was cancelled around 2006/07 and there has been no cattle grazing since.
- The Black Box vegetation was originally sparse and Pig Swamp could be seen from the Murray River. The thick regeneration has occurred over more recent decades resulting in a denser stand of smaller trees.
- The permanent inundation due to the operation of the Straight Cut Channel probably drowned and killed the original scattered large River Red Gums within the swamp.
- Permanent inundation also killed the low lying Black Box vegetation and encouraged River Red Gums and aquatic plants to establish.
- Timber was cut out of Pig Swamp in the 1970s for the Kraft factory. This took place during the irrigation season as it was too wet most winters. Therefore the water levels in Pig Swamp (and Upper Gunbower Creek) may have been operated slightly lower.
- Grazing appeared to keep the vegetation open in Pig Swamp - it reduced Cumbungi dominance and the fire risk.

- Grazing did occur historically in the northern section of Pig Swamp although there has been no grazing in the north section of Pig Swamp for the past 30 years due to the cancellation of the licence.
- Grazing didn't appear to harm the southern section of Pig Swamp.
- Cattle grazing through the southern section of Gunbower Island bared out the vegetation, and with associated pugging, made it more difficult to drive through.
- Goulbourn Murray Water (GMW) was under increased pressure to save water during the recent drought.
- Water has been recently permanently sold off the irrigation farm at the end of the Straight Cut Channel (adjacent to Murray River). This resulted in GMW not being required to supply water via the Straight Cut Channel. Only a small stock and domestic licence of approximately 10ML exists on the farm today.
- As part of water savings measures, GMW constructed an earthen bank in the Straight Cut Channel in 2007 about 300m upstream of Pig Swamp. This prevented irrigation water flowing further down the channel and spilling into Pig Swamp.
- Pig Swamp received slightly less water during the recent drought years and the swamp dried out completely after the Straight Cut Channel was blocked in 2007.
- Two landholders west of Pig Swamp continue to have their irrigation water supplied through the Straight Cut Channel.
- Little irrigation drainage historically entered Pig Swamp as irrigation farmers throughout the area did not have access to good drainage systems and consequently were very careful when irrigating, producing minimal irrigation runoff.
- There is a small agricultural catchment that drains water into Pig Swamp. This comprises of approximately 20ha of annual pasture and 20ha of permanent pasture.
- Drainage off farms into Pig Swamp was probably slightly higher in earlier years. However, this is insignificant now as most farmers have improved their irrigation practices and installed reuse systems.
- The agricultural land around Pig Swamp is very productive.
- During wet years, some of the drainage from surrounding agricultural land enters depressions and creek lines on farmland and does not penetrate through to the forest.
- Some of the catchment runoff south of Pig Swamp flows into Emu Hole and does not reach Pig Swamp.
- Historically irrigated permanent or summer pasture surrounded Pig Swamp (intensive irrigation). However, the recent drought resulted in much less watering. Most of the permanent water rights have been maintained adjacent to Pig Swamp with only one small area where the water has been sold off.
- Salinity does not affect the south end of Gunbower Island. Groundwater levels are very low and the Murray River provides important drainage. The large areas of forest use up additional water and lower the water table which protects the area from salinity.
- The groundwater levels in the bore adjacent to the Upper Gunbower Creek (50m away) are lower than the bed of the creek. This indicates very little seepage or leakage from the creek. Currently the groundwater levels are 15-16ft below ground level.
- The heavy clay soils in the base of Pig Swamp are very tight and hold water with minimal leakage. Some refer to these soils as a "blue plug".
- Historically the watertables were high across some of the farmland around Pig Swamp; however, they did not cause salinity and they drop down very low under the forest.
- The upper or western section of the Straight Cut Channel has had the silt recently removed to improve water movement along the channel. A lot of tree regeneration has occurred in the silt that has been deposited adjacent to the channel banks.
- Pig Swamp has recently been naturally flooded from the Murray River during the December 2010 event and more recently the January 2011 flood event. These are not considered major Murray River flood events.

- There are minimal weeds through Pig Swamp except for scattered African Boxthorns and Scotch Thistles.
- The total area of Pig Swamp is estimated to be approximately 160 acres with 100 acres south of the channel and 60 acres north of the channel.
- The deeper sections in Pig Swamp were the drainage lines which could be up to 4 feet deep when the wetland was flooded.
- The normal water level in Pig Swamp during the irrigation season is less than 18 inches deep (knee deep).
- There have been no fires in the south end of the Swamp over the past 30 -40 yrs and possibly 2 fires in the northern section over the same period of time.
- Fires didn't appear to do much damage. Cumbungi burnt and a few large dead trees were lost and the fires easily distinguished when they reached the surrounding Black Box areas.
- Fire risk to Pig Swamp and Gunbower Forest increases due to visiting campers.

Environmental & Other Values

- Pig Swamp was a valuable and productive wetland, particularly for waterbirds.
- Pig Swamp consistently supported good numbers of waterbirds, particularly ducks, and was a popular duck shooting swamp.
- Pig Swamp has been degraded by keeping it permanently full, reducing its environmental value.
- There are numerous opportunities for waterbirds throughout the Gunbower Creek and associated wetland system without the need to artificially supply Pig Swamp.
- Pig Swamp is not as valuable as the Upper Gunbower Creek system. Ducks and coots were common however it does not support a healthy variety of wildlife.
- Lignum has established sparsely, mostly around the south end and where drainage creeks enter Pig Swamp around the south eastern side.
- Pig Swamp is an important wetland and always held water supporting good numbers of waterbirds particularly ducks. It was popular with hunters.
- Other birds included ibis, dab chicks, hawks and various waders.
- Pig Swamp at times supported hundreds of ducks, mostly Grey Teal and Black Ducks.
- Pig Swamp was an important breeding area for waterbirds, particularly ducks and hawks.
- Common birds that utilised Pig Swamp included ducks, ibis, kingfishers, hawks, mudlarks and jays.
- The swamp supported very high numbers of Red Bellied Black Snakes and Brown Snakes in the surrounding Black Box areas.
- The southern section of Pig Swamp was more diverse and environmentally significant.
- The northern end of Pig Swamp was dominated by Cumbungi and not as significant.
- There are only a small number of Aboriginal scar trees and cooking mounds in the Pig Swamp area.
- River Red Gum trees have encroached into the swamp due to the artificial water and several of these regenerated trees have died during the recent dry periods.
- River Red Gums have also established very thickly in the bed of the Straight Cut Channel after the channel was blocked a few years ago.
- Water Couch (*Paspalum distichum*) grew prolifically in Pig Swamp, particularly south of the channel and provided good cattle feed.
- Paraquata or Reed Sweetgrass (tall aquatic grass) was another water plant that grew well and provided summer feed for livestock. This plant was possibly introduced to the area to increase productivity. *(Editors note: Reed Sweet Grass, Glyceria maxima, is an introduced weed. It has not been "officially" recorded for Pig Swamp).*
- Paraquata grows in shallow water particularly around the edge of swamps and creeks.
- Paraquata grew adjacent to both sides adjacent to the Straight Cut Channel. It also extended into the southern section of Pig Swamp.

- In the southern section of Pig Swamp, Cumbungi established around the edges in places and did not persist in the deeper water.
- There was no Phragmites (Common Reed) in Pig Swamp and very few weeds with the exception of few scattered African Boxthorns.
- Pig Swamp supports good numbers of kangaroos when it dries up.
- Pig Swamp is well known by duck and fox hunters.
- The wetter River Red Gum sections of Gunbower Island grow more understorey reeds, rushes and grasses than the Black Box areas. Much higher stocking rates were achieved amongst the River Red Gum vegetation were rushes were common.
- Approximately 700 head of cattle were grazed in the southern half of Gunbower Island, most grazed the wetter River Red Gum areas.
- Black Box vegetation naturally has less understorey growth than River Red Gum areas and often looks much barer, even with no cattle grazing.
- Carp did significant damage to the understorey vegetation on Gunbower Island when they entered during a large Murray River flood.
- Carp have damaged the Upper Gunbower Creek system.
- Duck hunters visit the swamp but there is normally no camping. The presence of grazing cattle and associated licence has probably discouraged camping.

Suggested Future Management

- A pipe and structure could be placed in the current block in the Straight Cut Channel to allow water to be intentionally delivered into the swamp. Another structure should be placed in the channel on the east side of Pig Swamp to prevent water from filling the full length of the channel.
- If no water was delivered into Pig Swamp via the Straight Cut Channel then the swamp would only fill only occasionally, during very large floods. This might be as infrequent as once every 10 to 15 years.
- There may be long periods when Pig Swamp does not flood naturally. Floods large enough to fill the swamp occurred in 1956, 1974, 1993 and 2010, with long dry spells in between.
- Water could be delivered via the Straight Cut Channel into Pig Swamp every season if there was sufficient water available.
- In future, Pig Swamp could receive some environmental water from the Straight Cut Channel. It might suit to deliver about once every 3 or 4 years.
- Pig Swamp has been artificially managed for over 100 years and should be allowed to revert back to its original condition. The vegetation may take 100 years to adjust back with reduced flooding. It should be expected that some of the regenerated River Red Gums will die if water is delivered less frequently into Pig Swamp.
- Maintaining permanent irrigation water through many of the Gunbower creeks and wetlands has caused them to degrade. Some of these wetlands should be allowed to fill and dry out, returning them to a more natural watering cycle.
- The Cameron's Creek, One Tree Creek and Baggots Creek system could be opened up to allow natural flooding of the south end of Gunbower Island, including Pig Swamp. This option would require some minor topping up of the levees to protect adjacent farmland.
- The Upper Gunbower Creek System that delivers water through the Straight Cut Channel is very stagnant and should receive some through flow or flushing occasionally.
- Pipes through Dormoyle's Bank at the commencement of the Upper Gunbower Creek could be opened and allow the 10 – 11km of creek to receive a freshening flow. This water would then return back into the Gunbower Creek. Flows could be split between the Gunbower Creek and Upper Gunbower Creek allowing water to flow down both systems.
- Pig Swamp needs to be occasionally grazed to manage the vegetation and reduce the fuel loads and associated fire risk.

- Light grazing of the forest and Pig Swamp is preferable as the licence requires weeds to be controlled. Government agencies do not have the man power or funding to manage weeds across big areas of Crown Land.

A summary of additional comments from the 2016 phone consultations are below:

- Red gums (8ft high) have regenerated on the south side of the Straight Cut Channel, following the wet years about 2 years ago (2013/14)
- The sedges have died from the long dry spell
- A lot of kangaroos graze in the swamp during the dry times.
- There are a few foxes, but not in huge numbers
- Many weeds in the swamp have died
- Pig Swamp needs water soon; has been very dry for a long time.
- The pipe that flows through the western end ("Straight Cut Bridge") needs to upgraded to increase capacity.
- There are lots of saplings growing in the Straight Cut Channel; these will need to be removed if water is to be delivered via the Straight Cut Channel.
- In dry times Pig Swamp has large fuel loads (because of dense Cumbungi) and used to be occasionally burned (although, not as a management activity).
- There may be an option to return carbon rich water to the Murray River via the Straight Cut Channel instead of allowing it to evaporate.
- Box trees occur right up to the edge of Pig swamp and need to be considered when flooding Pig Swamp to full capacity.
- Because the Straight Cut Channel is higher than Pig swamp, there may be an option to create a track in along the banks and a hide/viewing area for education and tourism purposes.

Appendix 6. Assessment against the Murray Darling Basin Plan Criteria for Identifying an Environmental Asset

Table 20. Pig Swamp assessed against the Murray Darling Basin Plan criteria for identifying an environmental asset

Item	Criteria	Meets criteria	Justification
Criterion 1: The water-dependent ecosystem is formally recognised in international agreements or, with environmental watering, is capable of supporting species listed in those agreements			
1	Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it is:		
	(a) a declared Ramsar wetland; or	✓	Part of the Gunbower Ramsar Site
	(b) with environmental watering, capable of supporting a species listed in or under the JAMBA, CAMBA, ROKAMBA or the Bonn Convention.	✓	Refer to Table 6, Pig Swamp has supported species listed under the Bonn Convention; notably, with environmental watering, is capable of supporting several species listed under these conventions
Criterion 2: The water-dependent ecosystem is natural or near-natural, rare or unique			
2	Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it:		
	(a) represents a natural or near-natural example of a particular type of water-dependent ecosystem as evidenced by a relative lack of post-1788 human induced hydrologic disturbance or adverse impacts on ecological character; or	X	
	(b) represents the only example of a particular type of water-dependent ecosystem in the Murray-Darling Basin; or	X	
	(c) represents a rare example of a particular type of water-dependent ecosystem in the Murray-Darling Basin.	X	
Criterion 3: The water-dependent ecosystem provides vital habitat			
3	Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it:		
	(a) provides vital habitat, including: (i) a refuge for native water-dependent biota during dry spells and drought; or	X	
	(ii) pathways for the dispersal, migration and movements of native water-dependent biota; or	X	
	(iii) important feeding, breeding and nursery sites for native water-	✓	Pig Swamp provides important feeding and breeding habitat for frogs, as well as feeding

Item	Criteria	Meets criteria	Justification
	dependent biota; or		habitat for waterbirds
	(b) is essential for maintaining, and preventing declines of, native water-dependent biota.	✓	Pig Swamp provides important habitat for water dependent fauna in the area, particularly red gums, frogs and waterbirds.
Criterion 4: Water-dependent ecosystems that support Commonwealth, State or Territory listed threatened species or communities			
4	Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it:		
	(a) supports a listed threatened ecological community or listed threatened species; or Note: See the definitions of ***listed threatened ecological community*** and ***listed threatened species*** in section 1.07. (Listed under the EPBC Act 1999)	✓	Pig Swamp provides habitat for the Australasian Bittern
	(b) supports water-dependent ecosystems treated as threatened or endangered (however described) under State or Territory law; or	✓	Pig Swamp supports one endangered EVC within the Murray Fans Bioregion.
	(c) supports one or more native water-dependent species treated as threatened or endangered (however described) under State or Territory law.	✓	Pig Swamp supports water-dependant two state listed fauna species.
Criterion 5: The water-dependent ecosystem supports, or with environmental watering is capable of supporting, significant biodiversity			
5	Assessment indicator: A water-dependent ecosystem is an environmental asset that requires environmental watering if it supports, or with environmental watering is capable of supporting, significant biological diversity. This includes a water-dependent ecosystem that:		
	(a) supports, or with environmental watering is capable of supporting, significant numbers of individuals of native water-dependent species; or	~	This is likely (e.g. for frogs species), but needs to be confirmed following environmental watering
	(b) supports, or with environmental watering is capable of supporting, significant levels of native biodiversity at the genus or family taxonomic level, or at the ecological community level.	~	This is likely, but needs to be confirmed following environmental watering

Appendix 7. Criteria and assessment indicators for Pig Swamp ecosystem functions

Item	Criteria	Meets criteria	Description for Pig Swamp
Criterion 1: The ecosystem function supports the creation and maintenance of vital habitats and populations			
1	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides vital habitat including:		
	(a) a refugium for native water-dependent biota during dry periods and drought; or	X	
	(b) pathways for the dispersal, migration and movement of native water-dependent biota; or	X	
	(c) a diversity of important feeding, breeding and nursery sites for native water-dependent biota; or	✓	Pig Swamp provides diverse habitats that support a range of waterbird and frogs.
	(d) a diversity of aquatic environments including pools, rifle and run environments; or	X	
	(e) a vital habitat that is essential for preventing the decline of native water-dependent biota.	X	
Criterion 2: The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment			
2	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides for the transportation and dilution of nutrients, organic matter and sediment, including:		
	(a) pathways for the dispersal and movement of organic and inorganic sediment, delivery to downstream reaches and to the ocean, and to and from the floodplain; or	✓	During natural flood, or a top up to increase flooding extent, Pig Swamp provides a potential pathway to and from the Murray River and the Gunbower forest floodplain.
	(b) the dilution of carbon and nutrients from the floodplain to the river systems.	X	
Criterion 3: The ecosystem function provides connections along a watercourse (longitudinal connections)			
3	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides connections along a watercourse or to the ocean, including longitudinal connections:		
	(a) for dispersal and re-colonisation of native water-dependent communities; or	X	
	(b) for migration to fulfil requirements of life history stages; or	X	
	(c) For in-stream primary production.	X	

Item	Criteria	Meets criteria	Description for Pig Swamp
Criterion 4: The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections)			
4	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides connections across floodplains, adjacent wetlands and billabongs, including:		
	(a) lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities; or	X	
	(b) lateral connections for off-stream primary production.	X	