OPTIONS REVIEW:

Investigation of alternative options to control *Phragmites* at Reedy Lake

April 2013

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Addendum

This investigation was commissioned by the Corangamite Catchment Management Authority based on an understanding that *Phragmites australis* was the main reed species colonising Reedy Lake. Towards the completion of this investigation into *Phragmites* control options, new information was presented that *Typha* reeds also colonise substantial areas of the lake. Due to the scope of the original assessment, this report focuses solely on *Phragmites* control options. However this addendum has been added to identify potential implications for the management recommendations given the presence of *Typha.*

Both *Phragmites* and *Typha* share a number of similar characteristics in that they are both potentially invasive, robust, emergent macrophytes with a substantial below-ground rhizome. There are sufficient structural similarities between the two species to suggest that control methods proposed for *Phragmites* are likely to work, in broad terms, for *Typha* too. However, there are a number of differences that may affect the priority and timing of control methods, including the following:

- *Phragmites* responds better to fluctuating water levels, whereas *Typha* 'prefers' stable waters, especially with summer inundation. This will be important should a more variable water regime be imposed (*Typha* may reduce, however *Phragmites* may increase).

- *Phragmites* has a suite of single emergent stems from which branch the array of leaves, whereas the above-ground component of *Typha* consists almost entirely of leaves that form a sheath up from the rhizomes. This structural difference may be important should cutting/slashing be used to reduce biomass, as *Phragmites* will likely be easier to slash than *Typha*.

- Although still salt tolerant, *Typha* is likely to be more sensitive to salt than *Phragmites*. As a result, tidal flushing and saline groundwater intrusion (during drying events) may have a greater impact on *Typha* extent than that expected for *Phragmites.*

- *Typha* forms noxious masses of decaying matter on the lake bed sediments, likely a result of it growing in permanent water, whereas biomass accumulations could well be smaller for *Phagmites* when it grows in systems with alternating wet and dry cycles. This difference has implications for the development of foul water should *Typha* be killed on a large scale.

The main recommendation from this report is to conduct a trial or series of trials involving a combination of implementing a 1 in 4 year drying regime, *Phragmites* cutting (boat based and/or dryland slashing/mowing), and tidal flushing. The drying regime is important for a suite of flow-ecology objectives, the tidal flush is primarily to mitigate against potential contaminant release, and as *Phragmites* is salt tolerant then cutting is deemed necessary to have any significant impact on *Phragmites* extent.

Given that *Typha* prefers stable water levels, and is expected to be less salt tolerant than *Phragmites*, then it is likely that implementing the 1 in 4 year drying regime, and the tidal flushing, may have a significant impact on *Typha* extent (without the need for cutting).

It is now recommended that the first components of a trial in reed control methods in Reedy Lake be a tidal flush and implementation of the 1 in 4 year drying regime, in conjunction with the concurrent reed monitoring program. Cutting/slashing options could then be considered in the next 5 – 10 years if reed extents have not been sufficiently reduced. Tidal flushing is the preferred method of re-introducing saline water into the wetland, as it is a more natural (wetland has experienced this in the past) and gradual processes of saline intrusion than any direct applications of salt on the wetland, and has benefits for contaminant mitigation.

Despite general similarities*, Phragmites* and *Typha* are different species, in different plant families, and with different hydrological optima, as well as likely having different tolerances to salt and with different responses to nutrients. Further investigations should include a review of *Typha* specific control methods, which may differ from the range of methods used for *Phragmites* control.

Summary

Reedy Lake is part of the Lake Connewarre Complex, and an important wetland within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site. Prior to European settlement, Reedy Lake was most likely a variable system that experienced periods of drying and hypersalinity (Dr Jessica Reeves, pers. comm. March 2013). The hydraulics of the system have been altered with several interventions since settlement, significantly changing the water regime of the wetland, and transitioning it to a permanent freshwater lake.

The overarching environmental objective for Reedy Lake is to maintain the diversity and populations of waterbirds, fish and other fauna dependent on the site and its plant communities (CCMA Watering Plan, 2012). It is likely that the altered hydrological and salinity conditions in Reedy Lake have markedly changed the wetland's vegetation. In particular, the increasing abundance of *Phragmites australis* has been identified as an important threat to this high-level environmental objective.

As part of the proposed environmental flow recommendations for the Lower Barwon system, Lloyd *et al.* (2012) recommend a 10 year period of annual summer drying for Reedy Lake to assist with *Phragmites* control. It was envisaged that the combination of drier conditions and a related increase in salinity would inhibit the growth and spread of *Phragmites*. It was proposed that once the reeds were controlled, the longer term watering regime for Reedy Lake would involve summer drying one year in four, to provide an optimal water regime to maintain and support the current flora and fauna (with reduced dominance of *Phragmites*).

Annual drying of the lake over an initial 10 year period for *Phragmites* control has significant implications for other social and economic values of the lake, and has recently be identified as high risk for exposure of acid sulfate soils and heavy metal mobilisation, particularly of arsenic and chromium (Alluvium 2013). With this new information in mind, the purpose of the current investigation was to assess a range of alternative control options to reduce the density and area of *Phragmites australis* in the vegetation mosaic of Reedy Lake.

The problem faced by those who manage Reedy Lake is that it provides an ideal growing environment for *Phragmites australis*, being relatively shallow, nutrient rich, and with variable micro-topography that provides a wide range of slightly different water regimes for the plant. *Phragmites*, although a native species, is often invasive, is tolerant of a wide range of flooding-wetting regimes and of relatively high salt concentrations, and is difficult to kill due to its clonal growth pattern and extensive horizontal networks of underground stems, or rhizomes.

A wide range of possible control options were considered in this project, including using altered water regimes, tidal flushing, mechanical control, and chemical and biological control. Several options were not appropriate for Reedy Lake due to the particular characteristics of the site, e.g. its Ramsar listing (chemical use over water not desirable), presence of contaminants in the lake bed sediments (major disturbance not desirable), and nearby residential development (major disturbance not desirable).

A remaining shortlisted set of options were then reviewed in further detail according to a range of scenarios (5, 10 and 20 year time frames). Each scenario was compared with a suite of management sub-objectives developed specifically for this investigation, in order to assess the relative benefits of each option.

Annual summer drying for an initial 10 year period as proposed by Lloyd *et al.* (2012) poses significant risks for contaminant release from the lake bed sediments (Alluvium 2013), may not impact significantly on *Phragmites* extent, and is therefore not recommended for *Phragmites* control.

Less regular drying (1 in 4 yrs) will assist in achieving a range of desired flow-ecology objectives, but is unlikely to be effective in *Phragmites* reduction. Ultimately, *Phragmites* reduction is unlikely to be achieved with changes to water regime alone. If a substantial reduction in *Phragmites* is required to achieve management objectives for Reedy Lake, mechanical intervention will be required. There is still a risk of contaminant release associated with less regular drying, however with appropriate monitoring in place, there is opportunity to assess the nature of the risk after the first drying event/s.

Based on consideration of the scenario assessment, the preferred option for *Phragmites* control that achieves the best outcomes for a range of objectives is the combination of ***less regular drying (1 in 4 years), cutting (boat based and/or dryland slashing/mowing) and tidal flushing***. Cutting / slashing should result in a rapid

reduction in *Phragmites* biomass and extent (pending a trial of the logistics). Boat based cutting creates less disturbance of the lake bed, and involves cutting under the water or raising the water level post-cut. Dryland slashing / mowing and herbicide application (if used) can be undertaken at the channel margins, and may be able to expanded in from the margins of the lake during a drying event, pending a trial to assess disturbance to the soil and risk of contaminant release (from tractor slashing). The changed flow regime will assist with meeting other flow-ecology objectives, and tidal flushing will assist with mitigating the risk of contaminant release posed by the drying events.

The benefits of this combined option (1 in 4 yr drying, cutting/slashing and flushing) do come with a significant cost associated with cutting/slashing and the upgrades to infrastructure that may be required to introduce effective tidal flushing. It is also likely that *Phragmites* will continue to grow back after cutting, given that environmental conditions within Reedy Lake are broadly well suited to the growth and spread of reeds, and hence the long term control of *Phragmites* will be a difficult task and will require a program of ongoing management intervention.

It is recommended that a trial program commence over the next 5 years that includes implementing the 1 in 4 year drying regime, and testing the feasibility, effectiveness and costs of boat based cutting, dryland slashing/mowing, and tidal flushing.

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1 Introduction

1.1 Project context

Reedy Lake is part of the Lake Connewarre Complex, within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site. More specifically, it is an important component of the Lower Barwon wetlands group on the Bellarine Peninsula.

Prior to European settlement, Reedy Lake was most likely a variable system that experienced periods of drying and hypersalinity (Dr Jessica Reeves, pers. comm. March 2013). The hydraulics of the system have been altered with several interventions since settlement, significantly changing the water regime of the wetland, and transitioning it to a permanent freshwater lake, with the exception of occasional drying events for Carp control (approximately every 7 – 10 years).

In preparation for the establishment of an environmental flow entitlement for the Barwon River, Lloyd *et al.* (2012) reviewed flow-ecology relationships and a range of scenarios for the Lower Barwon wetlands, and developed environmental flow recommendations to meet a suite of objectives for the Lake Complex. In developing these recommendations, Lloyd *et al.* (2012) noted that changes to the hydrology of Reedy Lake since 1970 (including summer flooding) have resulted in conditions highly favourable for *Phragmites australis*. The expansion of these reeds across Reedy Lake has reduced the extent of other aquatic plant communities and degraded fauna habitat, and is considered by Lloyd *et al.* (2012) to threaten the habitat value of the lake as a whole.

This threat formed the basis of an initial recommended watering regime by Lloyd *et al.* (2012) for Reedy Lake that included annual summer drying over an initial ten-year period. It was envisaged that the combination of drier conditions and a related increase in salinity would inhibit the growth and spread of *Phragmites*. Lloyd *et al.* (2012) then recommend that once reeds had been controlled by this initial intervention, a watering regime for Reedy Lake that balances the water requirements of all flora and fauna should include summer drying one year in four.

Annual drying of the lake over the initial 10 year period for *Phragmites* control has significant implications for other social and economic values, and has recently been identified as high risk for exposure of acid sulfate soils and heavy metal mobilisation, particularly arsenic and chromium (Alluvium 2013). With this in mind, alternative control options are also being considered to reduce the density and dominance of *Phragmites australis* in the vegetation mosaic.

1.2 Objectives

The overarching environmental objective for Reedy Lake is to maintain the diversity and populations of waterbirds, fish and other fauna dependent on the site and its plant communities (CCMA Watering Plan, 2012). As the increasing abundance of *Phragmites* has been identified by Lloyd *et al.* (2012) as a key threat, water management aims to limit the encroachment of reeds into open water habitat to promote native fish and waterbird breeding, and increase feeding potential.

The purpose of this investigation was to examine a range of alternative *Phragmites* control options to determine their appropriateness and feasibility for Reedy Lake. *Phragmites* control options are explored largely as an alternative or supplementary approach to drying for the initial 10 year period. However, options for the longer term management of the lake are also being considered.

1.3 Approach

The scope of this investigation was limited to a desktop assessment using existing literature and available knowledge of the system. Two project team workshops were conducted as part of the process, at which several members of the Reedy Lake Steering Committee attended (Table 1).

The first workshop (26th Nov 2012) was focused on identifying all possible control options, discussing the team's experience with other reed-control programs in similar types of wetlands, and identifying a shortlist of feasible options for Reedy Lake. In the second workshop (25th Jan 2013) the benefits of shortlisted options were considered, and combinations of options, over 5, 10 and 20 year scenarios were examined in order to identify a preferred option/s based on consideration of benefit and cost/feasibility.

Outcomes of the literature review and workshop discussions are documented in this report.

Table 1. Project workshop participants

	Workshop 1 ***Phragmites* control options**	**Workshop 2** **Options assessment**
Alluvium project team	Ross Hardie Elisa Zavadil Paul Boon (Dodo Environmental) Damian Magner (Catchment Capable)	Ross Hardie Elisa Zavadil Paul Boon (Dodo Environmental) Damian Magner (Catchment Capable)
Corangamite Catchment Management Authority	Jayden Woolley	Jayden Woolley
Department of Sustainability and Environment	Phil Mitchell	Phil Mitchell
Victorian Environmental Water Holder		Bridie Velik-Lord
Parks Victoria		Stuart Wilsher

2 Background

2.1 Site description

Lloyd *et al.* (2012) provide an extensive description of Reedy Lake from European settlement to present time, as well as an overview of the ecosystem dynamics including geomorphic processes, vegetation, waterbirds and fish. Exerts of background information relevant to this investigation are summarised here and in the following sub-sections (from Lloyd *et al.* (2012) unless otherwise indicated).

Reedy Lake is a shallow freshwater sub-circular basin of 550 ha bordered by a higher terrestrial landscape on the west, north and eastern sides (Figure 1 Figure 2). It is located to the north-east of the lower Barwon River and is connected to Lake Connewarre on the southern side, where it forms part of the Lower Barwon wetlands group, within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site. The lake has a small local catchment of 27 km^2 and receives its water almost entirely from the Barwon River. The Barwon River flows from north-west to south-east on the southern margins of Reedy Lake, and discharges to the tidal, open water environment of Lake Connewarre. The river is separated from Reedy Lake by a natural levee.

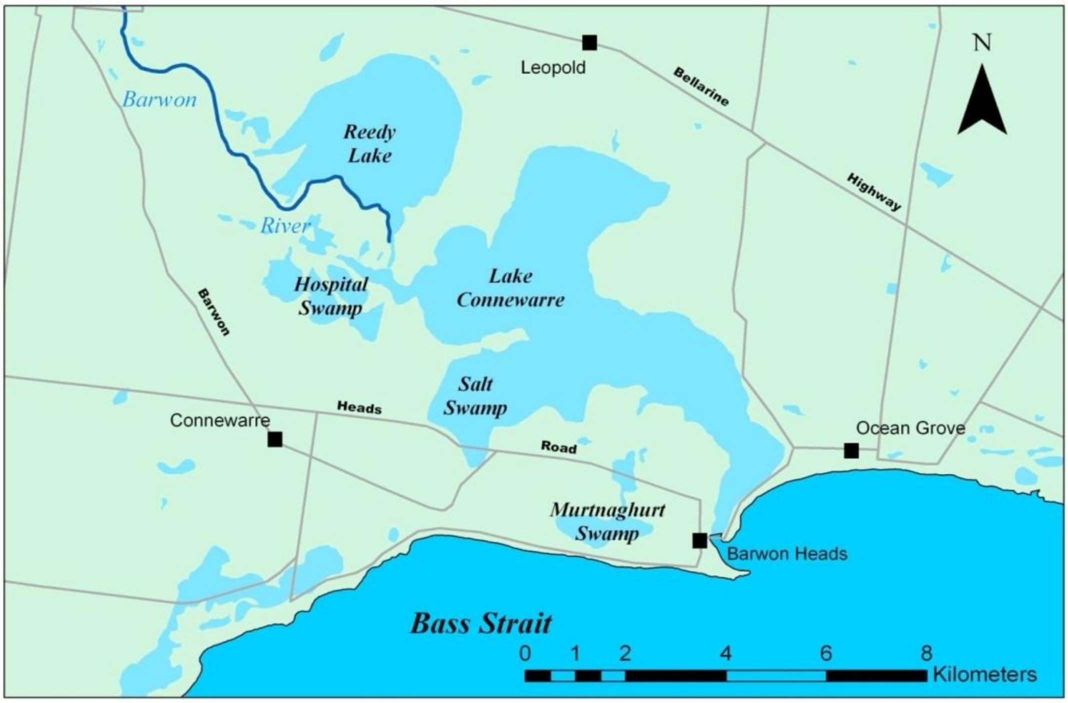

Figure 1. *Reedy Lake in the Lower Barwon wetland region (courtesy of CCMA)*

Figure 2. *View across Reedy Lake, showing extensive areas of Phragmites in the background and areas of open water, with swans, in the foreground*

2.2 Land use change

The site has seen a series of agricultural and industrial developments since the early 1800s, when the area was opened up to sheep grazing and associated industry (wool scour, tannery). During the 1850's gold rush vast tracts of land upstream were cleared for mining, and tailings from the mining operations flowed through the catchment and into the Barwon River and its lower wetlands. These tailings have proven a large source of toxic, heavy-metal contaminants, as discussed below. During the first half of the 20th century recreational shooting became common in the area (Dahlhaus *et al.* 2007). The Connewarre complex more generally has been slowly infilling over time, due to ongoing inputs of sediment from the catchment (Victorian Saltmarsh Study 2011). These sediments have brought with them a chronic nutrient load, resulting in nutrient enrichment and eutrophication of the wetland complex (Victorian Saltmarsh Study 2011).

A detailed history of land use changes for the Lower Barwon region is documented by Lloyd *et al.* (2012) based on work by Dr Erica Nathan (in Dahlhaus *et al.* 2007), and key periods are noted for reference in Table 2.

Table 2. Periods of landuse change in the Lower Barwon region (after Lloyd *et al.*. 2012)

Period	Events
Pre settlement	Aboriginal land management – light harvesting of the lakes natural resources and mosaic burning of the surrounding country.
1830 – mid 1850s	Early pastoral runs and first breakwater established.
Mid 1850s - 1890	Agricultural subdivision, gold mining waste begins, extensive riverfront industries, two major flood events, dredging, commercial shooting of wildfowl.
1890 - 1950	Agricultural decline, tourism, harbour trust management (lower breakwater), gold mining waste ends, Geelong sewerage schemes, river stabilisation works.
1950 - 1980	Growth of Geelong and Bellarine Peninsula, State Rivers and Water Supply Commission lower breakwater works, early conservation management, cement quarry discharge, erosion of lower Barwon, recreational lobby, high rainfall of early 1950s.
1980 - present	Ramsar wetland listing, Parks Victoria management, Hospital Swamp project, cessation of grazing and irrigation licences, estuarine studies, residential pressure.

High concentrations of chromium have been found in the Reedy Lake sediments (by the RMIT and Ballarat University sediment core pilot study). This element is most likely to have been a by-product from a local tannery. High levels of arsenic and mercury are also present, these are likely to have been a result of gold mining and refining in the catchment during the gold rush. Lead has also been found in the sediments, this is most likely associated with lead-shot from the game reserve and from use of lead at the wool scour (Grundell *et al.* 2012). The nickel found in the sediments is likely to have originated from the local volcanic rocks (Fabris *et al.* 2006).

2.3 Lake and water management

Prior to European settlement, Reedy Lake was most likely a variable system that experienced periods of drying and hypersalinity (Dr Jessica Reeves, pers. comm. March 2013). The river was originally estuarine upstream of the lake, and the lake would have received a combination of saline and freshwater inflows, depending on the contribution of high tides and river levels.

Prior to modifications, the spill of water from the river to Reedy Lake was controlled by the natural levee of the river bank. Water would have spilled onto the wetland several times a year in response to flood events and winter and spring freshes. On the basis of seasonality in regional climatic patterns, it is believed that the wetland flooded most often in winter and spring, and then dried out over summer and autumn. Inflows regularly exceeded the lake's capacity and discharged to Lake Connewarre to the south. The sill between the wetland and Lake Connewarre allowed saline estuarine water to enter the wetland during high tides.

The hydrology and hydraulics of the system has been altered with several interventions since settlement, significantly changing the water regime of the wetland, which is now a freshwater system. Lloyd *et al.* (2012) document a detailed history of lake and flow regime modifications, a summary of which is provided in Table 3.

Table 3. Reedy Lake past modifications (after Lloyd *et al.* 2012)

Period	Events
1898	A weir (the lower breakwater) was constructed where the Barwon River discharges to Lake Connewarre to raise the river level upstream and prevent the incursion of saline estuary water. The weir raised the level adjacent to Reedy Lake and presumably promoted inflow events.
1906	Reedy lake was described as drying out only in very prolonged dry weather. The water level in the Barwon River was 0.3 m higher than the lake, so that water could easily be diverted into the lake.
1950s	The lower breakwater was replaced (by SRWSC) with a floating gate structure at a lower level to manage the higher rainfall that was occurring at the time and the high flows that were expected to result from the Corangamite Drainage Scheme. The new structure held the Barwon River at 0.3 m below the lake.
1953	A channel was cut between the Barwon River regulator and Reedy Lake to aid inflows. Water entering the lake rapidly drained to the estuary.
1960s	Competing interests emerged during the dry years of the 1960s, particularly 1960, 1961 and the drought period of 1967-68. Irrigators required a high Reedy lake water level to provide water for irrigation, while graziers sought a low summer level to allow dairy cattle grazing. Field and Game sought to retain water in Reedy Lake in summer over a minimum of two thirds of the wetland area to provide habitat for waterfowl. The inlet structure was sabotaged on several occasions including in 1967 when the lake was dry and farmers sought to fill the lake. The typical water regime in the 1960s has been described as flooding in the central lake 3 to 4 times per year, with water retained between floods and mostly dry by February (prior to duck hunting season). Management objectives for Reedy Lake changes after 1961 when the Wildlife reserves Investigation Committee recommended the area as one of the new State Wildlife Reserves. There was concern that waterbird numbers has been declining over the previous 50 years and that the lowering of the river level by the new lower breakwater had adversely impacted Reedy Lake. The lake came under the management of the Division of Fisheries and Wildlife, however much of the on-ground management work (fencing, revegetation) was undertaken by the Field and Game Association.
1967-68	In order to maintain water levels in the 1967-68 drought, the bank at the outlet was raised to 0.7 – 0.8 m AHD. These arrangements increased the wetlands volume, depth, area and permanence.
1970	The outlet was modified by construction of an embankment across the natural outlet drain with a spillway height of around 0.7m AHD. The effect of the embankment was however to prevent tidal water egress.
1973	A report was prepared on the effects of grazing in Reedy lake.
1974 (circa)	A new larger capacity inlet and channel was constructed (the current structure).
1983	All grazing and irrigation licences were terminated by 1983.
1995	Until the 1990s, Barwon River flows were supplemented by brackish water discharged to the Moorabool River from a dewatered quarry. This maintained the weir pool upstream of the lower breakwater an increased the frequency of spill events form the river to Reedy lake. In 1995 Field and Game drained the lake by cutting a new outlet.
1996	In 1995/96 the lake was drained to eradicate the carp population that had developed and facilitate works on the drainage flow path. The flow path from the lake to the Barwon River below the Lower Breakwater was excavated to a depth of approximately 0.1 m AHD, allowing the wetland to be drained when lake levels permit. The drop board regulator on the outlet channel was constructed at this time. A major management objective has since been to dry Reedy Lake every 6 to 7 years for Carp control.
1997	The regulator from the Barwon River was upgraded by closing two of the box culverts and replacing the flap gate on the third with a penstock regulator and fish screen.
2005-2006	The lake was dried out and the channel from the inlet structure to the lake bed was excavated to 0.1 m AHD and cleared of vegetation. Accumulated sediment and vegetation was also cleared form the outlet channel, to a depth of 0.1 m AHD. The inlet fish screen was replaced with a sloping screen to minimise clogging, single penstock removed and all culverts re-opened. Groundwater monitoring bores were also installed.

2.4 Groundwater

Groundwater salinity varies considerably across the lower Barwon River and estuary complex. In the Reedy lake sediments, groundwater EC varies from 15 – 25 mS/cm, whereas at the northern and western edges of the lake it is consistently a little higher. Salinities of groundwater in the shallow geological units surrounding Reedy Lake and Hospital Swamps (Newer Volcanics, Fyansford Formation and Quaternary sediments) generally range from 20 to 60 mS/cm (Dr Matthew Currell, pers. comm., March 2013). By way of comparison, seawater has an EC of about 52 mS/cm, so the groundwater underneath the wetlands complex is roughly between one-quarter and one-half seawater salinity. The source of salt in the groundwater may be partly oceanic, but it is also likely that evapotranspiration is a major control on groundwater salinity (Currell *et al.* 2012).

The salt and water environment in Reedy Lake is understood to have been largely stable since the 1970's when the last modifications to the hydraulics of the system were completed. However, this has not been confirmed with monitoring data as groundwater monitoring in the region did not commence till 2006 (Dr Matthew Currell, pers. comm., March 2013).

2.5 Geology and sediment

The geology of the sediments underlying the Lower Barwon is of the Holocene epoch. The wetland sediments are fine-grained, being dominantly clay-, silt- and fine sand-sized. Significant sediment deposition is episodic, occurring only when turbid river water enters the wetlands during high flow events. The bed sediments can be re-suspended, causing turbid water conditions, episodically in association with periods of high wind velocity. The events also generate waves, which can erode exposed shorelines. Bed sediments are also subject to the ongoing process of mixing by organisms (bioturbation by animal burrowing). In its current configuration, Reedy Lake receives only a small percentage of the Barwon River sediment load, with most of it being transferred to Lake Connewarre (Lloyd *et al.* 2012).

High concentrations of arsenic and chromium have been reported for the Reedy Lake bed sediments, and there is a significant risk of acid sulfate soils being present as well (Alluvium 2013). Exposure of acid sulfate soils to air (e.g. during drying of wetlands) provides a high risk for mobilising these contaminants into the water column as well, of course, of lowering the pH of the water and sediments, with possible adverse ecological outcomes.

2.6 Ecosystem

Reedy Lake is now a freshwater wetland containing diverse aquatic habitats and supporting 16 native fish species. These habitats include open water, reed beds, and submerged aquatic plant beds. Vegetation mapping available from the interactive mapsite of the Department of Sustainability and Environment shows four main vegetation communities in the wetland: i) EVC 300 Reed Swamp; ii) EVC 899 Plains Freshwater Sedge Wetland; iii) EVC 898 Cane grass-Lignum Halophytic Herbland, and iv) a fringe of EVC 9 Coastal Saltmarsh Aggregate. Of these, the reed beds are the dominant vegetation type.

Reedy Lake has been recognised as an area of significant wetland vegetation since European settlement. Lake salinities declined after the installation an embankment on the outlet around 1970, which excluded saline estuary water from the lake. Submerged aquatic plants increased in response so that by 1979 the lake supported approximately 25% open water, 25% submerged aquatics and 50% reeds. Despite the arrival of carp around 1979, the lake vegetation retained this general structure until 1990 (Lloyd *et al.* 2012).

Extensive changes in vegetation in the seasonally waterlogged periphery of Reedy Lake occurred between 1983 and 2010 corresponding with the removal of stock. The extent of *Phragmites australis* and *Typha orientalis* in Reedy Lake has fluctuated dramatically (Lloyd *et al.* 2012) between 1983 and 2010, with carp strongly indicated as a dominant influence (along with removal of stock). Carp were introduced in 1979 and when in high abundance, reduce the variety of plant communities present in the lake and change the physical and chemical character of the water column (Ecological and Associates 2012). Carp are benthivorous fish that feed in and on the sediments to a depth of about 12 cm into the soil. They resuspend sediments and in doing so likely reduce visibility for visual-feeding fish. Carp can destroy existing vegetation and, in particular, soft bodied and young, recolonising plants. Carp also alter prey availability for non-benthic predators (Driver *et al.* 2005).

Modifications to Reedy Lake have contributed to an increase in the depth and permanence of water and reduced salinity, making conditions more favourable for *Phragmites australis* growth than existed in pre-European times. *Phragmites* grows well in areas that are subject to spring and summer inundation to a depth of 0.2 to 1.0 m, and an increase in wetland depth and permanence would have expanded the available habitat. *Typha* reeds are now also a dominant component of the wetland vegetation mosaic.

The diversity and populations of birds supported by habitats within Reedy Lake have generally declined, relative to other wetlands in the complex. The foraging conditions in Reedy Lake that in the past attracted large populations of waterbirds, particularly waders, have over the last forty years occurred less frequently. Habitat destruction by Carp is considered to be one of the primary factors in this decline, as significant recovery in bird numbers has been observed after Carp control (drying) events (Ian McLachlan, Field and Game Association, pers. comm. March 2013).

Fish diversity is high with Reedy Lake having 16 native fish species. The vast majority of the fish species prefer either open water or areas of dense submerged aquatic vegetation. The fish are important for their conservation value, value in fisheries (eels), and as food for waterbirds. Many of the fish species require or utilise aquatic vegetation beds as critical habitat. Fish require a water regime that supports aquatic vegetation and open water habitats at key stages of their biology such as feeding and growth, spawning of eggs and recruitment of juveniles. The lake has had a semi-permanent water regime in the past with long periods of inundation which has proved ideal conditions for the species present.

2.7 Watering regimes

The water regime of the most recent past as described by Lloyd *et al.* (2012), has seen the lake at a high level in winter/spring (0.7m AHD), drying to average 0.4m by late summer, and refilling in response to autumn breaks, usually April/May (Table 4).

Table 4. Reedy Lake water regime in the recent past (Lloyd *et al.* 2012)

Season	Typical hydrological environment
Winter/spring	High (**0.7 m** AHD)
Late summer	Drying to average **0.4 m**
Autumn	Refilling in response to autumn breaks, usually April/May

To support a trajectory of change towards the vegetation types recorded in 1983, Lloyd *et al.* (2012) proposed the water regimes summarised in Table 5. Lloyd et al. (2012) also proposed a 10 year period of annual summer drying be implemented for *Phragmites* control prior to this longer term water regime (of 1 in 4 year drying).

Table 5. Future water regime for Reedy Lake (modified from (Lloyd *et al.* 2012))

Scenario	Typical hydrological environment	Hydrological objective	Frequency
Wettest 25% of years	High flows in the Barwon with multiple overbank flow events in winter, spring and summer	Maintain high lake level (at or near **0.8 m AHD**) throughout the year.	1 year in 4
Typical (interquartile) years	Moderate flows in the Barwon with frequent freshes and overbank flow events in winter and spring	Allow wetland to fill in winter and spring to **0.8 m AHD**. Gradually reduce water levels to **0.3 m** at an approximate rate of 7 cm per week, starting December 1. Restart drawdown following overbank flows in summer, if any.	2 years in 4
Driest 25% of years	Low flows in the Barwon with infrequent freshes	Allow wetland to fill in winter Gradually reduce water levels to **0.0 m** at an approximate rate of 7 cm per week, starting November 1. Restart drawdown following overbank flows in summer, if any.	1 year in 4

3 Characteristics of *Phragmites australis*

Understanding the physiology and growth patterns of *Phragmites australis* is an important background context to understanding the strengths and limitations of various control options that might be implemented in Reedy Lake. Much of the following background is summarised from Norris *et al.* (2002) and supplemented with additional references and information discussed in the project workshops.

Phragmites australis is a tall perennial wetland grass with strong, leathery horizontal shoots growing on or beneath the ground surface (rhizomes). Its vertical stalks range in height from 1.5 – 3 m. *Phragmites* commonly inhabits riparian areas, brackish and freshwater marsh, river banks and lake shores. The species is especially common in disturbed or polluted soils, ditches and dredged areas. Ideal growing conditions include nutrient rich soils, shallow water levels and variable micro-topography, such as the environment of Reedy Lake where *Phragmites* dominants the vegetation mosaic (Figure 3). Nutrient rich soils allow plants to put more energy into creating above ground biomass.

Figure 3. *Example image of Reed extent across Reedy Lake (2002), much of which is Phragmites australis or Typha. Open water in this image appears as the dark grey-black areas.*

Phragmites can spread from a portion of a rhizome or from seeds. In wetland environments, *Phragmites* expansion is likely to be mostly or entirely by rhizome expansion, and this type of spread is known as clonal growth. This growth form is very common in wetland plants (Hatton *et al.* 2008). New stems grow each spring and rhizomes spread horizontally in all directions during the growing season (spring – summer). The stems transport oxygen to the rhizomes, which sustains plant growth over large areas. In autumn the food reserves move from the leaves and stems to the rhizome system, and the plants become dormant over winter.

Because of its high growth rate, *Phragmites* quickly becomes established in a wetland, and then the accumulation of dead leaves and stems, as well as the pervasive rhizome system, prohibits the growth of other competing plant species, resulting in a wetland monoculture. The aggressive nature of *Phragmites* is directly related to the near-unique combination of powerful, adaptive features. It produces abundant wind dispersed seeds, which makes it an outstanding colonizing species in disturbed wetland areas. Rhizomes and stolons provide additional sources of propagules which can allow the plant to spread rapidly.

Phragmites has high growth and transpiration rates, translating to rapid growth and the ability to modify marginal habitats by providing oxygen to the rhizosphere and altering ambient soil moisture in ways that favour the expansion of *Phragmites* (Ailstock 2000). Rhizomes (and hence the surrounding sediments) become anoxic when the plant is 'drowned' (e.g. stem cut and submerged: see Boon 2006). The rhizome will attempt to 'shut off' sections to reduce the extent of impact and protect other parts of the cloned plant system. The ability of *Phragmites* to aerate its rhizosphere is crucial to its ability to colonise wetlands and to grow into relatively (at least 1 m, sometimes 2 m) of standing water. It also accounts, in part, for why *Phragmites* has one of the widest hydrological niches among wetland plants (e.g. see Rogers and Ralph 2011).

Importantly, *Phragmites* is also quite salt-tolerant (Bailey *et al.* 2003; Morris *et al.* 2008), growing in salinities ranging from about 15 – 27 g / L (~23–42 dS / m; based on a conversion factor of 0.64) (e.g. Lissner and Schierup 1997; Adams and Bate 1999; Talley and Levin 2001).

Phragmites australis is found worldwide in moist soil habitats especially those of tidal and non tidal wetlands, with a range of genotypes. A major cause for the spread of *Phragmites* is an increase in anthropogenic habitat manipulation, providing optimal growing conditions.

4 *Phragmites australis* control options

There is a range of *Phragmites australis* control options associated with each of the following categories:

1. Watering regime
2. Mechanical – major disturbance
3. Mechanical – moderate disturbance
4. Chemical
5. Biological.

Details of these options are provided in the following sections.

4.1 Water regime

There are several options for manipulating the watering regime to assist with *Phragmites* control. Drying the lake is part of the current flow recommendations. We note that deeper flooding and tidal flushing may also be options to assist with *Phragmites* control, particularly in combination with mechanical intervention.

Drying

Drying over the summer months (as proposed in the ecological flow recommendations of Lloyd *et al.* 2011) may have some influence on *Phragmites* extent in high lying areas if saline groundwater is present and the sediments dry out completely. Variable water depths caused by episodic drying, however, provides a fluctuating water regime and thus broadly favourable conditions for *Phragmites* (Rogers and Ralph 2011) so it may also have the opposite effect and actually encourage the further growth of reeds into different parts of Reedy Lake.

Flooding

Rhizomes are flood tolerant. Extended inundation > 30cm deep may assist to limit the expansion of an existing clone (Norris *et al.* 2002), however has not been shown to significantly reduce existing reed extents. There is also the practical problem that this depth of inundation is difficult to achieve when there is substantial above ground biomass (1-2 m high) in a shallow lake bed (such as Reedy Lake). Flooding the existing Phragmites stands in Reedy Lake would require increasing the water level > 30 cm above the top of the current biomass, i.e. increasing flow depth in the order of 2 – 2.5 m. This would have implications for extensive inundation of the floodplain, likely impacting roads and infrastructure, residential and industrial property, and the broader lake ecosystem. Other reeds that prefer stable water environments may also increase in extent as a result (e.g. Typha). Flooding (at more natural high lake levels) is likely to be more appropriate when used with cutting to 'drown' cut sections of the aerial parts of the reed bed.

Tidal flushing

Tidal flushing can increase salinity and assist in preventing *Phragmites* from becoming established (Norris *et al.* 2002). It is, however, thought to be unlikely to have a significant impact on existing stands because of the high salt-tolerance of many strains of *Phragmites* (Bailey *et al.* 2003; Morris *et al.* 2008). At the very least, it would require a detailed investigation into salinity thresholds for the *Phragmites* clones that grow in Reedy Lake and a comparable study into the salinity regimes that are likely to result from improved tidal flushing. Neither set of information is currently available, but could be obtained with additional studies. A better understanding of the relationship between water table height, groundwater salinity and reed extent is also required in order to more accurately determine the controls on reed destruction.

Salt dosing

Salt dosing refers to direct and concentrated application of salt or saline water (e.g. seawater) onto parts of the wetland, via aerial spraying / depositing. As with a tidal flush, salt dosing is unlikely to have any substantial impact on salt tolerant *Phragmites*. Furthermore, the ecosystem risks associated with direct and concentrated application of salt onto parts of the wetland are uncertain, including impacts on other vegetation and aquatic species and residence time of the salt. There may also be implications for noxious masses of decaying matter if large areas of *Typha* (the other dominant reed in Reedy Lake) are killed. Tidal flushing is the preferred method of re-introducing saline water into the wetland, as it is a more natural (wetland has experienced this in the past) and gradual processes of saline intrusion than any direct applications of salt on the wetland. The gradual dispersal of saline water via a flush also has benefits for contaminant mitigation.

4.2 Mechanical control - major disturbance

There are several mechanical options that involve a major disturbance to the treatment area, where the whole area of interest must be dried and then worked over. This includes ploughing/disking (which chops the rhizome into pieces too small to be viable), bulldozing (which exposes rhizomes to thorough drying out) and dredging (which causes a complete removal of rhizomes, followed by flooding of area to >1.5m to avoid regrowth). These interventions cause major disturbance to other plants and biota, and there is also a high likelihood that this disturbance simply re-creates the micro-topography that is ideal for *Phragmites* to re-colonise. Major disturbance to the soil may also mobilise contaminants.

As a Ramsar listed wetland, and with significant concerns for acid sulfate soils and heavy metal contaminants (Alluvium 2013), mechanical control options that require major disturbance to the soils and ecosystem are not considered appropriate for Reedy Lake.

4.3 Mechanical control - moderate disturbance

Mechanical options that involve a more moderate disturbance to the environment (limited disturbance of lake bed sediments and other plants and biota) involve approaches aimed at reducing above ground biomass. These approaches can be combined with manipulation of the watering regime (e.g. flooding) and herbicide application to adversely affect the rhizomes for a longer term result.

Seasonal dry land slashing / mowing

Annual summer mowing / slashing of *Phragmites* can assist with reducing biomass and increasing the available sunlight to competing plant species. However, spring mowing has been shown to produce shorter but more dense stands of *Phragmites* within the same growing season (Norris *et al.* 2002). Mowing may be beneficial for reducing biomass around the edges of Reedy Lake, and will likely be more effective when combined with use of a herbicide.

Boat based cutting and drowning of reeds

Boat based cutting involves cutting the stems below the water level, or cutting and raising the water level to submerge the top of the stems by 30 – 40 cm. The high water level must be maintained to allow shoot bases to become flooded, resulting in plants rotting below the surface (Norris *et al.* 2002). A second cut in the same growing season is likely to produce better results (Norris *et al.* 2002). Consecutive annual cuts have also been shown to provide better results than a single annual cut (Russell and Kraaij 2008). The timing of the cut is important, and should be undertaken in late summer in order to maximise nutrient depletion through removing above-ground biomass before translocation of nutrients from stems to rhizomes. Cutting in permanently inundated areas is likely to be more successful than areas that are infrequently or rarely inundated (Russell and Kraaij 2008).

Phragmites will very likely continue to regenerate over time via the rhizome network, and so periodic cutting will need to be ongoing. Specialised equipment is required for boat-based cutting, and it is uncertain how effective boat based cutting would be amongst the dense stands of *Phragmites* in Reedy Lake. Significant machinery repair / maintenance costs may be encountered. In addition, all cut biomass needs to be removed from the site.

Plastic barriers

Applying plastics sheets to treatment areas can be an effective non-herbicide option for controlling *Phragmites* (Norris *et al.* 2002). The site must first be mowed or burned to reduce biomass, and then sheets of 6mm plastic can be applied and held in place with stakes, sandbags or chains. As under plastic temperatures increase, complete surface kill can be achieved in only 3-4 days. An increased treatment time is required to kill rhizomes. However, plastic sheets can be difficult to manage, and to clean up if they break down or are torn (extended time in the sun can cause plastic to deteriorate into hundreds of tiny pieces). Given the Ramsar listing of Reedy

Lake, the use of plastic sheeting is not considered to be appropriate. A specific trial on a small area would be required prior to considering this approach over a broader area.

Controlled burning

Controlled burning can be an effective way to remove above ground biomass, and is commonly used in combination with other measures such as chemical spraying (e.g. Ailstock *et al.* 2001). The reduction in biomass allows more sunlight to surface, increasing opportunity for other plants to grow. However routine annual burning may diminish soil nutrients, and the disturbance may actually provide ideal conditions for *Phragmites* establishment. Disturbance associated with drying and burning may also be problematic for contaminant release and ecosystem disturbance. In the case of Reedy Lake, controlled burning may require special permits.

Re-planting (with other taxa)

Re-planting affected areas with other species of wetland plant may assist with providing competition for *Phragmites*, and if combined with other methods of *Phragmites* reduction, can assist in the creation of the desired vegetation mosaic. In the case of Reedy Lake, this might be appropriate at the dryer margins of the lake. Given the highly competitive nature of *Phragmites*, however, it is unlikely to work as a control mechanism over large parts of the lake.

4.4 Chemical control

Chemical control is one of the most effective means of killing *Phragmites* plants. However, given the Ramsar listing of the wetland, chemical methods should be used as a last resort in wet areas of the lake (only if mechanical and watering regime options are ineffective). A similar example is Wilderness Lakes in South Africa, a Ramsar listed wetland where it was considered in-appropriate to use herbicide, and so cutting techniques were employed for *Phragmites* control (Russell and Kraaij 2008). However, in dry areas around the margins of Reedy Lake, the use of herbicide in combination with mowing/slashing may be appropriate for reducing *Phragmites* extent in that zone.

Spraying

Spraying is one of the most common approaches for applying chemical treatments as translocation of chemical to the root system can successfully kill the entire plant. Aerial spraying of fusilade for example, is used to control *Spartina* infestations in coastal saline wetlands across Victoria by Parks Victoria (Victorian Saltmarsh Study 2011). The challenge lies in correct timing of the spraying application. Spraying is most effective in autumn when plants are in bloom and leaves are open (stored energy moving to rhizomes) (Norris *et al.* 2002). Care needs to be taken to avoid top kill of the plant before the herbicide can be translocated properly, and so two half doses may work better than a single full strength application. The second dosage should be applied 15 – 30 days after the first (Cross and Fleming 1989). Spraying is more appropriate for dryland areas, such as the margins of Reedy Lake, particularly where stems have been slashed / mowed.

Wicking

Wipe-on herbicide application, 'wicking', is a more environmentally acceptable alternative to spray-on, particularly if applying in wet areas, since it allows a more specific and restricted application of the poison (Norris *et al.* 2002). Applicators are attached to a boat, and applied to plants that come into contact with boat. This allows for targeting of *Phragmites* without affecting other plant species. Application difficulties include bending and breaking of plants (reducing opportunity of chemical reaching the rhizomes). The application of chemical in wet parts of Reedy Lake by wicking is not practical given the density of reeds and preference to keep chemicals out of the water.

Sulphide treatments

Sulphides react with oxygen and can quickly cause the death of *Phragmites* communities. An increase of sulphides is expected to occur naturally with drying of the Reedy Lake. A direct manipulation of sulphide concentrations in the sediments is unlikely to be feasible, and the release of sulphides may have negative implications for the broader ecosystem (e.g. acid sulphate soils).

4.5 Biological control

Classic biological weed control is the instruction of host specific natural enemies (usually insects, less often pathogens) from the native range of the plant. Although several biological control options exist, they provide a significant risk to the broader ecosystem and are not considered to be appropriate for the Reedy Lake ecosystem.

Rhizome and shoot mining moths and flies

Over 100 insect species are known to attack *Phragmites* in Europe (Norris *et al.* 2002). The insects will destroy selective parts of the plant, commonly the leaves and stems, and this is usually followed by a controlled burn to destroy the insects with the above ground biomass. This approach is experimental in North America, and is currently not an appropriate option for Australia.

Grazing

Grazing has potential to cause some reduction in above ground biomass; however it would also impact other native vegetation and the broader ecosystem. Grazing would not impact on the Rhizome network, and so the density of *Phragmites* would likely persist.

Carp

Carp has been present in Reedy Lake for the last couple of decades, and the density of *Phragmites* stands have continued to increase. It is reported that Carp were observed to have destroyed reed beds in the lake in the early 1990s (burrowing into roots causing reed collapse) (Ian McLachlan, pers. comm. March 2013). Research on comparable large emergent elsewhere in Australia suggests that carp are unlikely to have significant long term impact on the substantial rhizome network of *Phragmites*, especially at the scale of control required for Reedy Lake (Koehn *et al.* 2000). In any case, promoting the spread and biomass of carp within the Ramsar site would be counter to current management objectives to control the species within Reedy Lake.

4.6 Shortlist of options

Based on the review of options, and the environmental setting of Reedy Lake, the most appropriate list of available *Phragmites* control options are considered to be:

- Manipulation of the water regime
    - Drying
    - Tidal flushing

- Mechanical control – moderate disturbance
    - Boat based cutting and subsequent plant submergence
    - Dryland slashing / mowing (tractor)
    - Revegetation

- Chemical control
    - Use of herbicide to accompany dryland slashing/mowing.

These options have been shortlisted on the basis that they present the least amount of disturbance to the lake bed and ecosystem, while still presenting an effective means for *Phragmites* control. These options are considered in the scenarios assessed in the following section.

5 Scenario assessment

5.1 Approach

Based on the shortlist of control options identified in Section 4, and with agreement of the panel during the first workshop, a range of scenarios were developed for further investigation in the second workshop. The implications of each scenario were considered in comparison with the 'no change' scenario (Table 6), over 5, 10 and 20 year time frames.

Table 6. Scenarios assessed for *Phragmites* control over 5, 10 and 20 year timeframes

Option type#	No.	Scenarios
Watering regimes	1	No change (historical regime - high lake, rare drying)
	2	Annual drying (10 years)
	3	Less regular drying
Other water	4	Tidal flushing
Mechanical*	5	Cutting
Combinations*	6	Less regular drying and cutting
	7	Less regular drying and tidal flushing
	8	Cutting and tidal flushing
	9	Less regular drying, cutting and tidal flushing

* Cutting can include boat based and/or mowing/slashing

\# Re-vegetation around lake margins could be applied for all scenarios

5.2 Objectives

To assess the potential implications of each scenario in some detail, a sub-set of twelve potential management objectives for Reedy Lake were considered, based on the known values of the system (Table 7).

These objectives were discussed and refined as part of the second project workshop. The future management objectives for Reedy Lake as a system are currently being developed independently of this specific investigation, and the objectives proposed here are only for the purpose of illustrating the varying implications of *Phragmites* control options.

Table 7. Sub-set of potential management objectives for Reedy Lake for the purpose of assessing scenarios

Area	No.	Objective
Regulation	1	Comply with Federal and State legislation
Ecological	2	Avoid contaminant release
	3	Reduce *Phragmites* extent
	4	Achieve intended vegetation mosaic
	5	Achieve intended open water bird habitat
	6	Reduce population of adult carp (large bodied)
	7	Meet other flow-ecology objectives (identified by Lloyd *et al.* 2012)
Human health	8	Avoid exposure to contaminants
Social	9	Maintain recreation opportunity

5.3 Comparison of scenarios

The following discussion outlines the key implications of each scenario considered, relative to the objectives. For each scenario, the likelihood of assisting with achieving each individual objective over various time frames is illustrated in Table 8.

Scenario 1 – No change (high lake level, rare drying)

Under the no-change scenario, a high lake level is maintained with only rare drying for carp control (approx. every 4 - 7 years). Under this future, the current *Phragmites* extent will likely be maintained and indeed may increase over time. As a result, compliance with federal Ramsar legislation is unlikely (requiring a reduction in *Phragmites* extent towards mapped EVC). With no change in the flow regime, other ecological objectives are not likely to be achieved. Contaminant release will be largely avoided, since sediments will remain mostly inundated and the contaminants should remain relatively inert in the soil. There is, however, still a risk of contaminants being released during carp-control drying events in the longer term. Carp will continue to be problematic, as drying events are relatively rare under this scenario.

Scenario 2 – Annual summary drying

Annual summer drying over a 10 year period was proposed by Lloyd *et al.* (2012) for *Phragmites* control. The intention was that the combination of drying and an associated intrusion of saline groundwater would limit *Phragmites* growth and cause some die-back. It is possible that annual summer drying may result in some reduction in *Phragmites* along the higher (dryer) parts of the lake bed, particularly in the longer term, but there is also potential that fluctuating water levels may actually create an environment more favourable to *Phragmites*.

The reeds are also likely to be highly tolerant of the saline groundwater intrusion and it is not clear whether sufficiently saline conditions will be created to kill the reeds, given the known high salinity tolerance of many *Phragmites* strains. Even if they were killed by the newly saline sediments, there is some uncertainty around what new type of vegetation (presumably more salt-tolerant) would take the place of the dead *Phragmites.* Thus although the longer term intrusion of saline groundwater may assist other species to establish, enhancing the vegetation mosaic, it is uncertain if annual summer drying will achieve the desired reduction in *Phragmites* extent. Annual summer drying has also been identified as high risk for the exposure of acid sulfate soils and mobilisation of heavy metals, particularly arsenic and chromium, in the lake bed sediments (Alluvium 2013). This scenario would also be difficult to implement as the lake can take up to 6 months to dry (Ian McLachlan, pers. comm. March 2013).

Scenario 3 – Less regular drying (1 in 4 years)

The longer term flow regime proposed by Lloyd *et al.* (2012) included drying of Reedy Lake 1 year in 4, to meet a suite of other flow-ecology objectives. This intervention was intended to be implemented after *Phragmites* control had been undertaken (proposed through the 10 years of annual drying). As a scenario on its own (with no annual drying preceding, or other *Phragmites* intervention), this less regular drying is unlikely to assist with *Phragmites* reduction. Therefore it is unlikely to assist with achieving Ramsar compliance and open -water bird habitat. It may, however, provide opportunity for changes towards the desired vegetation mosaic, and is likely to assist with achieving other flow-ecology objectives. With more regular drying (than scenario 1), this may also assist with carp reduction. Contaminant release will still be a concern, but less so than for annual drying (Alluvium 2013).

Scenario 4 – Tidal flushing

Tidal flushing involves allowing the periodic incursion of seawater into the now freshwater Reedy Lake system. The saline water may make conditions less favourable for *Phragmites*, and provide opportunity for other vegetation species to establish. However as *Phragmites* are highly salt tolerant, it is uncertain if this would have any significant impact on *Phragmites* extent with the salinities likely to be created. With no other changes in the flow regime, tidal flushing alone is unlikely to assist with meeting other flow-ecology objectives, although more detailed studies would be required to gain more confidence in this preliminary conclusion. The intrusion of saline water would assist with avoiding contaminant release, as the salt water provides buffering capacity for acids released following any activation of potential acid sulfate soils, and may assist also with carp reduction (if salinities were high enough to prevent carp spawning etc).

Scenario 5 – Cutting (boat based and/or dryland slashing/mowing)

This scenario relates to using cutting methods to control *Phragmites*, with no changes to the water regime. Boat based cutting and drowning of the cut reeds (cut below water, or raise water level after cut) is one of the more effective mechanical options for *Phragmites* control in lake systems. This is assuming the specialised equipment is available, can manoeuvre amongst the dense reeds, and can collect cut biomass (refer to Section 4). Cutting in the deeper water, permanently inundated areas should be the priority for boat based cutting, as this has been shown to be more effective on the permanence of the reed reduction that in other less frequently inundated areas (Russell and Kraaij 2008).

Dryland slashing / mowing and the use of a herbicide can be undertaken in areas where the ground is dry enough for accesses around the edges of the lake, but may not be appropriate across the majority of the lake bed, even when the lake has been dried over summer (due to boggy ground as drying events are only for a couple of months which is not long enough for the ground to harden completely). The use of a tractor also has the potential to disturb sediments and mobilise contaminants. There may be some potential in a summer drying event to expand the area of slashing and herbicide use inwards from the margins of the lake to cover more area, and then submerge the cut area when filling the lake again in autumn, which may reduce the need for extensive (or any) boat based cutting. Care should be taken however to minimise soil disturbance, and a trial area should be completed first to determine the level of disturbance to the lake bed from using a tractor (for slashing), and any implications for contaminant release.

Cutting provides a means to reduce the biomass of reeds relatively quickly, and this has the extra benefit of increasing open-water habitat. However, with no other changes to the flow regime, cutting alone is unlikely to assist with meeting other flow-ecology objectives. Although *Phragmites* biomass will be reduced, if flow conditions are unchanged it is unlikely that there will be any change in the vegetation mosaic and the cut reeds will probably simply regrow, perhaps even faster than before they were cut. The effects on contaminant release are likely to be complex and uncertain. On the one hand, the cut reeds will no longer be able to aerate their rhizospheres and sediments may become anoxic. This would probably facilitate additional release of contaminants from the sediments, although this may be relatively localised depending on the extent of cutting. On the other hand, the maintenance of high water levels could assist with avoiding contaminant release, as a high lake level is maintained. Carp will continue to be problematic.

Scenario 6 – Less regular drying and cutting

Less regular drying (1 in 4 yrs) can be combined with boat based cutting This combination would help to achieve a quick reduction in *Phragmites* biomass as well as assist with achieving other flow-ecology objectives, and assist with carp control. The drawback is that less regular drying will still be a concern for activation of acid sulfate soils and for contaminant release.

Scenario 7 – Less regular drying and tidal flush

Less regular drying (1 in 4 yrs) can be combined with a tidal flush. The incursion of saline water will help to mitigate the risk of contaminant release associated with the drying events, and assist with Carp control. The changed flow regime will assist with meeting flow-ecology objectives, but this scenario is unlikely to achieve the desired reduction in *Phragmites* extent.

Scenario 8 – Cutting and tidal flush

Boat based cutting (and submerging of cut reeds) can be combined with a tidal flush. The cutting will assist with rapid *Phragmites* reduction, and increase open water habitat. The tidal flush and high lake level will assist with minimising contaminant release, assist with Carp control and provide some opportunity for other vegetation in the mosaic to increase. However, with no change to the flow regime, this scenario is unlikely to assist with achieving the suite of other flow-ecology objectives. A tidal flush currently requires the lake to be almost completely dry in order for saline water incursion (could be conducted during Carp control events).

Scenario 9 – Less regular drying and cutting and tidal flush

This final scenario comprises of less regular drying (1 in 4 yrs), boat based cutting, and a periodic tidal flush. Cutting will assist with rapid reduction in *Phragmites* extent, while the less regular drying assists with achieving the suite of flow-ecology objectives. A periodic tidal flush can assist with mitigating potential for contaminant release, and assist with Carp control.

Table 8. Comparison of scenarios against objectives over 5, 10 and 20 year scenarios – likelihood of options assisting with achieving objectives

		1			2			3			4			5			6			7			8			9		
		No change			Annual drying			1 in 4 dry			Tidal flush			Cutting			1 in 4 dry & cut			1 in 4 dry & flush			Cut and flush			1 in 4 dry, cut & flush		
	Objectives	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20
1	Comply with legislation	Unlikely	Unlikely	Unlikely	May	May	May	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	May	Likely	Likely	Likely	Likely	Likely	May	May	May	May	Likely	Likely	Likely	Likely	Likely
2	Avoid contaminant release	Likely	May	May	Unlikely	Unlikely	Unlikely	May	Unlikely	Unlikely	Likely	Likely	Likely	Likely	Likely	Likely	Unlikely	Unlikely	Unlikely	May	May	May	Likely	Likely	Likely	May	May	May
3	Reduce Phragmites extent	Unlikely	Unlikely	Unlikely	May	Likely	Likely	May	May	May	May	May	May	Likely	Likely	Likely	Likely	Likely	Likely	Unlikely	Unlikely	May	Likely	Likely	Likely	Likely	Likely	Likely
4	Achieve intended vegetation mosaic	Unlikely	Unlikely	Unlikely	May	May	May	May	Likely	Likely	May	May	May	Unlikely	Unlikely	Unlikely	May	May	Likely	Unlikely	May	May	May	May	May	May	Likely	Likely
5	Achieve intended open water bird habitat	Unlikely	Unlikely	Unlikely	May	Likely	Likely	May	May	May	Unlikely	Unlikely	May	Likely	Likely	Likely	May	Likely	Likely	Unlikely	May	May	Likely	Likely	Likely	Likely	Likely	Likely
6	Reduce population of adult carp	Unlikely	Unlikely	Unlikely	Likely	Likely	Likely	May	Likely	Likely	May	May	May	Unlikely	Unlikely	Unlikely	May	May	May	Likely	Likely	Likely	May	May	May	May	May	May
7	Meet other flow-ecology objectives	Unlikely	Unlikely	Unlikely	May	May	May	Likely	Likely	Likely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Likely	Likely	Likely	Likely	Likely	Likely	Unlikely	Unlikely	Unlikely	Likely	Likely	Likely
8	Avoid exposure to contaminants	Likely	Likely	Likely	Unlikely	Unlikely	Unlikely	May	Unlikely	Unlikely	Likely	Likely	Likely	Likely	Likely	Likely	Unlikely	Unlikely	Unlikely	May	May	May	Likely	Likely	Likely	May	May	May
9	Maintain recreation opportunity	May	May	May	Unlikely	Unlikely	Likely	May	May	May	May	May	May	Likely	Likely	Likely	May	Likely	Likely	May	May	May	Likely	Likely	Likely	May	Likely	Likely

Likely to assist with achieving objective

May assist with achieving objective – but with significant uncertainty

Unlikely to assist with achieving objective

5.4 Feasibility

The practicality of various *Phragmites* control options is also an important consideration for future management decisions; there is little benefit in recommending a reed control option if, for any number of reasons, it cannot be implemented effectively in the field. The following logistical matters have been considered, and include information discussed at the second project workshop, and feedback from the Reedy Lake advisory group.

Watering regimes

The manipulation of flow required for various changes to the water regime is relatively simple to implement, as it involves only opening and closing of the lake inlet and outlets as required. The lake can take up to 6 months to dry completely (Ian McLachlan, pers. comm. March 2013), and 6 weeks to drain the bulk of the water, depending on weather conditions and river levels, and the condition of the outlet channel. There are complicating factors to consider such as overbank flows from the Barwon River that can't be controlled, and increasing stormwater inputs from encroaching development. The safety and efficiency of flow inlet and outlet control structures is currently being reviewed, and new penstock gates are being installed on the inlet. Periodic channel clearing will be required for optimum inflow and outflow.

Vandalism is a potential drawback with any manipulation of water-control structures that are easily accessible to the public (see Attachment A). In the case of current infrastructure on Reedy Lake vandalism is unlikely as control structures are relatively inaccessible (Ian McLachlan, pers. comm. March 2013), however should be kept in mind if installing additional infrastructure in the future.

Tidal flushing

Tidal flushing is quite difficult to implement, and has not previously been done for Reedy Lake. A trial flush would be useful, in order to determine how far the saline water can intrude into the wetland under current arrangements. It is understood that the lake level needs to be low (near empty) as high tide currently only gets about 20 cm above the sill level. Modifications to the existing regulating structures may need to be made, saline water pumped in, or a second inlet made to achieve the required amount of tidal flushing. As well, saline water getting into the lake under current arrangements may not readily distribute across the whole lake due to the dense reeds and micro–topography, and so any impacts are likely to be spatially complex.

Pumping may be the most feasible option to facilitate a flush. The 150 m section of outlet channel between the outlet weir and the river may need widening (and clearing) to accommodate pump inlet rates, especially at low tide, however this is considered to be relatively minor works (Ian McLachlan, pers. comm. March 2013).

Boat based cutting

Boat based cutting will involve costs associated with hire of a contractor with the necessary specialised equipment. The cost will be dependent on the area of reeds to be cut. Hire of a contractor is likely to be in the order of $1000 - $1500 / day. We understand that a local contractor has the specialised machinery for boat based cutting of reeds (to cut below the water).

The cost per hectare for boat based cutting will depend on the rate of cutting that is possible. Boats may have difficulty getting through dense reeds, and there may be maintenance issues with the machinery used. It is envisaged that a cutting program should focus on 'trimming' the edges of reed stands and not attempt to push through dense areas. Ideally the cut should occur below the water level at a depth sufficient to drown the reeds, and all cut biomass will need to be collected and removed.

Prior to proceeding with the cutting program, it would be beneficial to conduct a one week trial cut to test the boat based machinery, rate of cutting feasible, and biomass collection, and ultimately gain a better estimate for the costs per hectare associated with a boat based cutting program.

Land based slashing / mowing

Areas where summer slashing/mowing of *Phragmites* would be possible include along the south side of the lake. The access track to the breakwater is through this area but when cut in spring, suffers from regrowth in the same season (Ian McLachlan, pers. comm. March 2013). Other areas around the margins of the lake may also be feasible, and extending in from the margins during drying event years.

Land based slashing/mowing in dry areas will have costs associated with hire of contractors and purchase of herbicide (if used). The costs will depend on the area of reeds treated, but will likely be considerably cheaper than boat-based cutting. However, regrowth associated with dryland slashing/mowing, even with herbicide application, will likely be faster than regrowth from boat based cutting in deeper waters. Therefore more frequent dryland slashing/mowing may be required to get the same impact as boat based cutting, which may make the relative costs more comparable in terms of cost per hectare of reeds reduced over a certain time frame (e.g. 5 years).

Similar to the boat based cutting program, if proceeding with cutting control methods for Reedy Lake, it is recommended that a trial of dryland slashing/mowing be conducted to better determine rates of reed control and regrowth, and future costs associated with the slashing/mowing program. The trial should commence in an area of the lake margin that is accessible over summer.

Revegetation around the lake margin, if implemented, will have costs associated with the plants and maintenance, and rabbit control may also become an issue.

Compliance

Any actions undertaken in the management of Reedy Lake will need to comply with relevant Ramsar (Federal Government) requirements and protections. Any '*activities which will affect any species or ecological community within a Commonwealth area*' need approval under the Environment Protection and Biodiversity Conservation Act (the EPBC act). Given that proposed actions to control *Phragmites* are in accord with improvements to ecological character of the site, and in accord with the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site – Strategic Management Plan (DSE 2003), it is unlikely that Federal Government approvals will be required. However, once a plan for the trial works has been completed, a check with the EPBC act approvals criteria is recommended.

The Victorian Government's policy for native vegetation is outlined in Victoria's *Native Vegetation Management – A Framework for Action* (the framework). The framework is an incorporated document in all Victorian Planning Schemes. Planning and responsible authorities must consider the framework when assessing proposals to clear vegetation. Permit applicants generally need to provide offsets for permitted clearing of native vegetation. If clearing of native vegetation results in a permanent loss, it must be offset with a permanent 'gain' in vegetation quality and/or quantity. To ensure this permanent gain, offsets for permitted clearing must be secure and ongoing. This means that an offset site will need to be 'secured' to ensure it is managed for its conservation values in perpetuity. In the case of Reedy Lake, the reduction of *Phragmites* (a native species) is in line with the ecological character description of the site, and therefore may not require a permit. However, approval may still need to be sought for a cutting program, and a check with the framework is recommended once the plan for the trial works has been completed.

The Department of Sustainability and Environment also recommended a check is done with the local council before starting any work that could impact native vegetation as a planning permit may be required. There may also additional requirements under the *State's Flora and Fauna Guarantee Act 1988* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.

Additional special permits from council may be required if other major disturbance control measures (not shortlisted in this investigation) are trialled, including burning and/or dredging/bulldozing.

6 Recommendations

6.1 Preferred option

Annual summer drying for an initial 10 year period as proposed by Lloyd *et al.* (2012) poses significant risks for contaminant release from the lake bed sediments (Alluvium 2013), and is therefore not recommended for *Phragmites* control.

Less regular drying (1 in 4 yrs) will assist in achieving a range of desired flow-ecology objectives, but will probably not be effective in *Phragmites* reduction as a measure on its own. Given this conclusion, if a reduction in *Phragmites* is required to achieve management objectives for Reedy Lake, mechanical intervention is likely to be required as it t cannot be achieved with changes to water regimes alone.

Based on consideration of the scenarios assessed, the preferred option for *Phragmites* control that achieves the best outcomes for a range of objectives is ***less regular drying (1 in 4yrs), cutting (boat based and/or dryland slashing/mowing) and tidal flushing***. Cutting or slashing provides for a rapid reduction in *Phragmites* extent (pending a trial of the logistics), the changed flow regime will assist with meeting other flow-ecology objectives, and tidal flushing will assist with mitigating the risk of contaminant release posed by the drying events (and increase salinity levels which may have some impact on *Phragmites* growth and Carp control).

Boat based cutting is preferred where possible to minimise disturbance to the lake bed (to avoid contaminant release). If boat based cutting proves to be too costly or difficult logistically, dryland slashing/mowing (with herbicide if appropriate) around the margins of the lake may be the preferred method for cutting, and combined with tidal flushing may in itself achieve the desired reed reduction.

It is important to stress, however, that the benefits of this scenario come with a significant ongoing cost associated with cutting (and herbicide). The underlying problem is that Reedy Lake provides all the environmental conditions suitable for the rapid growth of *Phragmites*, and so it is not surprising that reeds cover a large area of the wetland. The corollary is that with conditions being so suitable for *Phragmites*, control is likely to be extremely difficult to achieve.

6.2 Clarification of uncertainties

As noted previously in this report, the hydrology, topography and sediments of Reedy Lake form an ideal environment or *Phragmites*, and it is likely that *Phragmites* will continue to grow back after cutting. Long-term control of *Phragmites* extent will be a difficult task and require a relatively expensive program of ongoing management intervention. There is a high level of uncertainty around the potential success of these interventions given the underlying environmental conditions.

There is also uncertainty around the implications of reducing *Phragmites* extents – including potential for algal blooms. The *Phragmites* currently have a significant role in the uptake of nutrients from Reedy Lake, and in the absence of *Phragmites*, nutrients will become available for other species of plant. Uptake by algae, either in the water column as phytoplankton or on the sediments as benthic mats, cannot be ruled out. The form and impact of such algae should be considered prior to *Phragmites* reduction. If algae do not benefit from the removal of *Phragmites*, it is still uncertain what other species of vascular plant might colonise Reedy Lake following the removal of extensive areas of reed bed. Lloyd et al. (2012) propose various conceptual models on potential future vegetation mosaics, however there is no available data or precedence to indicate that anticipated vegetation species will actually return in place of *Phragmites*.

With the considerable cost and management intervention required for the reduction of *Phragmites* in Reedy Lake, now and in the longer term, it may be beneficial to re-visit the overarching management objectives for the lake in the context of the Ramsar wetland complex.

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Attachment A
Experience from elsewhere

Experience from elsewhere

Although there is a large body of research and experience on *Phragmites australis* control in North America (several references included in this report), where strains of it are seriously invasive weeds in many wetlands, care should be used when drawing on this experience as freezing (frost) is often an element of the control process in the Northern Hemisphere and this is obviously not applicable to the case study area in Australia. Moreover, there are likely to be cultural differences in the way weeds are controlled in different regions, for example, attitudes to herbicide use and large-scale environmental manipulations to eradicate problematic weeds.

Closer to home, there are a range of experiences of *Phragmites* dynamics and control in other wetlands across Victoria including at Seaford wetland (south-east Melbourne) and Dowd Morass (Sale). A snapshot of experience from these two studies are provided below.

Seaford Wetland

(courtesy of Damian Magner – project team)

Seaford Wetland is a Ramsar-listed wetland in Victoria. *Phragmites* had become problematic by establishing as a monoculture across large areas of previously open wetland margins and open water areas. These *Phragmites* stands excluded all other indigenous vegetation, were dense and impenetrable, and provided little habitat value. The invasion of previously open wetland margins threatened a key value of the site, being habitat for foraging shorebirds.

After over a decade of predominantly dry conditions, the wetland base dried and hardened to the point where opportunity arose to access normally boggy areas with a tractor-slasher. Advantage was taken of this extended dry spell and designated sections were slashed in early March 2007. Some linear sections of *Phragmites* were left to provide cover for some bird species, whilst in another area trial lines were slashed through the middle of a dense thicket of *Phragmites* to see if this encouraged habitat niches. Slashing resulted in each stem being cut into multiple pieces, thus allowing for a fast decomposition of this waste biomass.

Problems with the pumping system meant the planned submergence of the cut stems was not possible and by early April significant stem re-growth (up to 30 centimetres) had already occurred. This regrowth was subsequently boom sprayed, however it was now autumn and too late to have effect. The areas was re-slashed a year later in May-June 2008.

Post this treatment, *Phragmites* has recovered significantly and in most sections it has had no significant effect on the plants growth. The main advantage gained through the intervention was to reduce the impenetrable thickets and huge amounts of old biomass which provided poor quality habitat, and replace it with 'cleaner' and more open stands of *Phragmites*. The slashed areas also provided more open water for a few years before stems gained height again. As stated the slashing reduced the amount of biomass on the site, which was also a fire hazard consideration due to the close proximity of houses adjoining the site.

Outcomes from this investigation highlight the importance of reed submergence after cutting (to avoid rapid re-growth), correct timing of herbicide use (pre-autumn), and the need for a continued cutting program to maintain achieved open water space.

Dowd Morass

(courtesy of Paul Boon – leader of the research team that undertook the study)

Dowd Morass is one of the largest wetlands in the Gippsland Lakes Ramsar site in eastern Victoria. It covers an area of ~ 1,500 ha and is vegetated mostly with a mixture of Swamp Paperbark (*Melaleuca ericifolia*) and Common Reed (*Phragmites australis*), plus some open water areas that may or may not be dominated by Eelgras (*Vallisneria australis*). The wetland had slowly become highly salinised as a result of the opening of the permanent entrance to the Southern Ocean at Lakes Entrance in 1889. Parks Victoria, the agency managing the Ramsar site, had maintained high water levels in the Morass in an attempt to prevent intrusions of saline water into Dowd Morass from the adjacent Lake Wellington (which links to the sea via Lakes Victoria and King).

Concerns had been raised, by local hunting groups and conservation groups, as well as by Parks Victoria staff, that the combination of permanently high water levels and high salinity was causing the death of the paperbarks and overall environmental degradation. This was viewed as an important problem, as the paperbarks provide essential roosting habitat for colonial-nesting waterbirds in the Ramsar site, including ibis and spoonbill.

In response to the perceived problem of paperbark decline, a multidisciplinary R&D project was commenced in 2003 to examine the effect of altered water regimes and high salinity on paperbarks and reeds in Dowd Morass. Led by Associate Professor Paul Boon, the program had two post-doctoral fellows, one research technician, four PhD students, and a host of BSc(Hons) students working on it. Field work ran until 2008, and final analysis of the voluminous amounts of data generated ended only in 2011.

The research indicated that, contrary to common belief, paperbarks were actually expanding in Dowd Morass and the area of reed had decreased markedly since the 1950s (Boon *et al.* 2008). A set of glass house experiments examined the response of paperbarks and reed to different water and salinity regimes (Morris *et al.* 2008). In addition, water regimes at the whole-of-wetland scale were manipulated in a series of long-term, large-scale hydrological interventions. These were reported in a number of papers (Boon 2011; Raulings *et al.* 2010, 2011), which showed among other things that small-scale changes in sediment micro-topography were essential for the maintenance of complex vegetation mosaics in the wetland. *Phragmites* was a powerful element that helped create these micro-topographical mosaics.

The water-control structures were vandalised during the course of the field experiments, as outlined in Boon *et al.* (2007). Similar actions of vandalism have occurred elsewhere in the Gippsland Lakes Ramsar site in response to managers' attempts to introduce ecologically more-acceptable water regimes, and could well present a problem for controlling water levels in Reedy Lake.

The R&D project did not address ways to control reed growth, and indeed a significant finding was that instead of trying to 'rescue' paperbark woodlands in the Ramsar site, it was *Phragmites* beds that had suffered most from decades of inappropriate salinity and water regimes and probably required efforts to improve their performance in the wetland.