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An assessment of Ramsar criteria and Limits of Acceptable Change for aquatic and littoral vegetation in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland

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Cover Photo: Shoreline of Lake Alexandrina at Raukkan showing *Phragmites australis*, *Typha domingensis* and *Schoenoplectus tabernaemontani* (Regina Durbridge).

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EXECUTIVE SUMMARY

The Coorong and lakes Alexandrina and Albert were designated as a 'Wetland of International Importance' under the Ramsar Convention on Wetlands in November 1985. Designation was based on satisfying the criteria that it supports large populations of waterbirds and contains a unique complex of ecologically diverse freshwater to hypersaline wetlands, which is unparalleled within Australia. As a signatory to the Ramsar Convention, Australia is committed to describe and maintain the ecological character of the site and implement policies that protect the system from unacceptable change. This report will contribute to a revised ecological character description for the wetland by relating the change in the vegetation of the Lakes, North Lagoon of the Coorong and Murray estuary since listing. It will also provide an assessment of how the wetland qualifies against vegetation related Ramsar criteria; assess and revise Limits of Acceptable Change (LAC) for vegetation-related critical Components, Processes and Services (CPS). Components may include plant and animals, processes may describe waterbirds and fish breeding and services may be benefits pertaining to anthropological use.

The vegetation of the Lakes, North Lagoon and Murray estuary has undergone significant changes since listing. The largest changes to the vegetation in the Lakes occurred between 2007 and 2010, when water levels fell below sea level. Submergent vegetation was lost from the Lakes and fringing vegetation was disconnected. However, when water levels were reinstated, submergent vegetation recolonised areas where it was historically present (albeit not to the extent prior to 2007) and fringing vegetation was reconnected. *Ruppia megacarpa* was the dominant submergent macrophyte in the Murray estuary and North Lagoon at the time of listing and was abundant throughout the aforementioned areas. By 1995 the distribution of *Ruppia megacarpa* was limited to the Murray estuary and northern most section of the North Lagoon and by 2005 it had become locally extinct.

Three Ramsar criteria relating to vegetation were identified and the wetland still qualifies for listing under the three criteria, despite the changes to the vegetation in recent years. Nine vegetation-related critical CPS were identified for the Lakes, North Lagoon of the Coorong and Murray estuary:

- Freshwater submergent plant communities
- *Phragmites australis* (Lower Lakes)

- *Typha domingensis*
- *Duma florulenta*
- Diverse reed beds
- *Melaleuca halmaturorum*
- Samphire and saltmarsh communities
- *Ruppia megacarpa*
- *Phragmites australis* (Coorong)

Due to the lack of suitable data, the LAC and management triggers (point at which an intervention should be undertaken to prevent a LAC from being exceeded) for the vegetation-related critical CPS were determined by expert opinion and conceptual models. Limits of Acceptable Change and management triggers all related to spatial extent because it was the most appropriate scale for the LAC and management trigger metrics.

Whilst the wetland currently meets the vegetation-related Ramsar criteria, there is evidence that the wetland has undergone significant changes since listing and the LAC for *Ruppia megacarpa* has been exceeded. In addition, the current extent of diverse reed beds and freshwater submergent plant communities is close to the management trigger; however, the extent of these CPS have been increasing since 2011.

1. INTRODUCTION

The Coorong and Lakes Alexandrina and Albert was designated as a 'Wetland of International Importance' under the Ramsar Convention on Wetlands on November 1st 1985 (Phillips and Muller 2006). Australia nominated the Coorong and Lakes Alexandrina and Albert Wetland on the basis that it regularly supported significant populations of waterbirds and contained a unique complex of ecologically diverse freshwater to hypersaline wetlands, which is unparalleled within Australia. As a signatory to the Ramsar Convention, Australia has made a commitment to describe and maintain the ecological character of the Coorong and Lakes Alexandrina and Albert Wetland and implement policies that protect the system from unacceptable change (Phillips and Muller 2006).

1.1. Updating Ecological Character Description (ECD) content

Understanding and documenting the ecological character of the Coorong and Lakes Alexandrina and Albert Wetland is important for the management of the site. The Ecological Character Description (ECD) identifies critical Components, Processes and Services (CPS) of the wetland and the Limits of Acceptable Change (LAC) associated with each of the critical CPS. In addition to LAC, management triggers can be identified to prevent LAC being exceeded to maintain the ecological character of the wetland.

Ideally a baseline survey of biota and scientifically defensible monitoring program would have been undertaken and established prior to (or soon after) listing as part of the initial ECD. This would determine critical CPS and after several years of monitoring and an understanding of the natural variability of the system will be obtained to develop data driven LAC. This was not undertaken and information regarding the vegetation of the system (particularly the Lakes) around the time of listing is sparse. However, there is published information regarding the distribution of *Ruppia megacarpa* around the time of listing and an aquatic and littoral vegetation monitoring program for the Lakes was established in 2008 as part of The Living Murray (TLM) program.

One aim of this project is to update justifications (to include most recent monitoring data) for the vegetation-related Ramsar criteria (listed below) to determine whether the wetland still meets the relevant criteria, and show quantitative assessments of such. Three Ramsar criteria that relate to vegetation for the Coorong and Lakes Alexandrina and Albert Wetland have been identified:

- Ramsar Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- Ramsar Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- Ramsar Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Another aim is to assess the LAC for each of the vegetation-related critical CPS to identify whether any changes in ecological character of the wetland has occurred since listing. The final aim is to provide a brief description of the current ecological character of the wetland (vegetation specific) and any management implications and/or monitoring recommendations around wetland changes.

1.2. Datasets used to assess Ramsar criteria, change since listing, describe current ecological character and define and assess Limits of Acceptable Change (LAC)

Nine data sets were used to assess Ramsar criteria, describe the change since listing, describe the current character of the vegetation, and assess LAC for the Lakes (Table 1). The earliest data set was an assessment of the aquatic plants of Hindmarsh Island undertaken in February 1989 (Renfrey *et al.* 1989). The 2004 (Holt *et al.* 2005) and 2005 (Nicol *et al.* 2006) wetland baseline surveys represent one-off snapshots of the vegetation of several wetlands and provide an indication of floristic composition just prior to the decrease in water levels throughout the Lakes. Two seed bank assessments were undertaken whilst water levels were low: the Goolwa Channel seed bank assessment (Nicol and Ward 2010b) and the Dunns and Shadows lagoons seed bank assessment (Nicol and Ward 2010a). The Goolwa Channel seed bank assessment was undertaken to determine the capacity of the vegetation to recover under different salinities, whilst the Dunns and Shadows lagoons was undertaken to prioritise the delivery of environmental water to gain the maximum benefit from that water (Nicol and Ward 2010a). Between 2009 and 2011, the vegetation in Goolwa Channel, lower Finniss River and lower Currency Creek was monitored to evaluate the effects of the Clayton regulator on vegetation (Gehrig and Nicol 2010a; Nicol and Marsland 2010; Gehrig *et al.* 2011a). A one off snapshot to map the distribution and abundance of large emergent species (*Typha domingensis, Phragmites australis, Duma florulenta* and *Schoenoplectus tabernaemontani*) was undertaken in autumn 2014 to aid in the identification of future potential sites to plant *Schoenoplectus tabernaemontani* (Nicol *et al.* 2014b). A monitoring program in 2013 was established to evaluate the establishment success of planting *Schoenoplectus tabernaemontani* and changes to the vegetation brought about by planting this species (Nicol *et al.* 2013; 2014a; 2015; 2016). Finally, The Living Murray vegetation condition monitoring program was established in spring 2008 and has monitored the change in vegetation, during drought and low water levels and subsequent reinstatement of water levels (Marsland and Nicol 2009; Gehrig and Nicol 2010a; Gehrig *et al.* 2010; 2011a; 2011b; 2012; Frahn *et al.* 2013; 2014).

Eight data sets were used to assess Ramsar criteria, describe the change since listing and the current character of the vegetation and asses LAC for the North Lagoon of the Coorong and Murray estuary (Table 2). Much of the data from the North Lagoon of the Coorong and Murray estuary was collected from the mid-1970s to the mid-1990s and raw data are not available. The earliest assessment of *Ruppia megacarpa* in the Coorong was undertaken by Geddes and Brock (1977) in the mid-1970s and made note of two forms of *Ruppia*, which turned out to be different species (*Ruppia megacarpa, Ruppia polycarpa* and *Ruppia tuberosa*). Two studies in the early to mid-1980s (Geddes and Butler 1984; Geddes 1987) documented changes in the distribution of *Ruppia megacarpa* in the North Lagoon and Murray estuary. There is a gap in the data until the mid-1990s, when data were collected as part of an assessment of the Murray Mouth region (Edyvane *et al.* 1996) and another nine year data gap (except for the observation of viable *Ruppia megacarpa* seeds in January 2001; Paton 2001) when The Living Murray funded monitoring for controlled barrage releases (Geddes 2005a; Geddes 2005b) and condition monitoring (Nicol 2007). No monitoring of *Ruppia megacarpa* has been undertaken after spring 2006.

Table 1: Summary of data collection methods for the main datasets used for the Lakes.

Dataset	Years	Timing	Months/year	# Days	Subregions surveyed	Location of surveys within subregions	Survey type	Survey method/area	Data recorded	References
The Living Murray Vegetation Condition Monitoring for the Lakes	2008–2016	Twice yearly	November and March	5	Lake Alexandrina, Lake Albert	Lake edges, wetlands	Quadrat based	Cover/abundance in 1 x 3 m quadrats at regular elevation intervals.	Cover/abundance of each taxon.	(Marsland and Nicol 2009; Gehrig *et al.* 2010; Gehrig *et al.* 2011b; Gehrig *et al.* 2012; Frahn *et al.* 2013; Frahn *et al.* 2014)
Schoenoplectus planting monitoring	2013–2016	Annual	April	5	Lake Alexandrina, Lake Albert	Lake edges	Quadrat based	Cover/abundance in 1 x 3 m quadrats at regular elevation intervals. Stem density and height of *Schoenoplectus* in five 1 x 1 m quadrats and *Schoenoplectus* stand width.	Cover/abundance of each taxon. *Schoenoplectus* stem density, stand width, height and number of stems in 100 m length of stand.	(Nicol *et al.* 2013; Nicol *et al.* 2014a; Nicol *et al.* 2015; Nicol *et al.* 2016)
Emergent vegetation mapping in Lakes Alexandrina and Albert	2014	Snapshot	April	3	Lake Alexandrina, Lake Albert	Lake edges	Mapping	Map of distribution and percentage cover of dominant emergent macrophyte species.	Spatial distribution and percentage cover of large emergent species at the time of the survey.	(Nicol *et al.* 2014b)
Aquatic and littoral vegetation monitoring of Goolwa Channel, the lower Finniss River and Lower Currency Creek	2009–2011	Twice yearly	November and March	2	Lake Alexandrina	Lake edges	Quadrat based, mapping	Cover/abundance in 1 x 3 m quadrat at regular elevation intervals. Map of dominant plant communities.	Cover/abundance of each taxon. Spatial distribution of dominant plant communities at the time of the survey.	(Gehrig and Nicol 2010a; Nicol and Marsland 2010; Gehrig *et al.* 2011a)
Dunns Lagoon and Shadows Lagoon seed bank assessment	2010	Snapshot	February–May	120	Lake Alexandrina	Wetlands	Seed bank assessment	Floristic composition and seed density of sediment seed bank.	Seed density of each taxon and response to salinity.	(Nicol and Ward 2010a)
Goolwa Channel seed bank assessment	2009	Snapshot	May–November	190	Lake Alexandrina	Wetlands	Seed bank assessment	Floristic composition and seed density of sediment seed bank.	Seed density of each taxon and response to salinity.	(Nicol and Ward 2010b)
2005 River Murray Wetlands Baseline	2005	Snapshot	October	10	Lake Alexandrina	Wetlands	Quadrat based, mapping	Cover/abundance in 1 x 15 m quadrats. Map of dominant plant communities.	Cover/abundance of each taxon. Spatial distribution of dominant plant communities at the time of the survey.	(Nicol *et al.* 2006)
2004 River Murray Wetlands Baseline Survey	2004	Snapshot	October	10	Lake Alexandrina, Lake Albert	Wetlands	Quadrat based, mapping	Cover/abundance in 30 x 30 m quadrats. Map of dominant plant communities.	Cover/abundance of each taxon. Spatial distribution of dominant plant communities at the time of the survey.	(Holt *et al.* 2005)
The Aquatic Flora of Hindmarsh Island	1989	Snapshot	February	10	Lake Alexandrina	Lake edges, wetlands	Quadrat based	Presence in ten contiguous 50 x 50 cm quadrats at regular elevation intervals.	Presence/absence for each taxon at each site.	(Renfrey *et al.* 1989)

Table 2: Summary of data collection methods for the main datasets used for the North Lagoon of the Coorong and Murray estuary.

Dataset	Years	Timing	Months/year	# Days	Subregions surveyed	Location of surveys within subregions	Survey type	Survey method/area	Data recorded	References
Impact of Barrage Releases on the Population Dynamics of *Ruppia megacarpa* in the Murray estuary and North Lagoon of the Coorong. Progress Report 2006/07.	2006	Snapshot	October	5	Coorong and Murray estuary	North Lagoon and Murray estuary	Grab samples	Number of shoots, turions and seeds in 12.5 x 12.5 cm Van Veen grab sample	Distribution and abundance of *Ruppia megacarpa*, propagule bank assessment	(Nicol 2007)
Ecological outcomes from the small barrage outflow of August 2004	2004	Snapshot	August		Coorong and Murray estuary	North Lagoon and Murray estuary	Observation	Observations	Distribution and abundance of *Ruppia* spp.	(Geddes 2005b)
Ecological outcomes for the Murray Mouth and Coorong from the managed barrage release of September-October 2003	2003	Monthly	September and October		Coorong and Murray estuary	North Lagoon and Murray estuary	Observation	Observations	Distribution and abundance of *Ruppia* spp.	(Geddes 2005a)
Monitoring biotic resources in the Coorong, January 2001	2001	Snapshot	January	5	Coorong	North and South Lagoon	Sediment cores	Number of shoots, turions and seeds in 5 cm diameter core	Distribution and abundance of *Ruppia* spp., propagule bank assessment	(Paton 2001)
Biological resource assessment of the Murray Mouth Estuary	1995	Snapshot	August		Coorong and Murray estuary	North Lagoon and Murray estuary	Observation	Observations	Distribution and abundance of *Ruppia* spp.	(Edyvane *et al.* 1996)
Changes in salinity and in the distribution of macrophytes, macrobenthos and fish in the Coorong lagoons, South Australia, following a period of River Murray flow	1983–1985				Coorong	North and South Lagoon	Observation	Observations	Distribution of *Ruppia* spp.	(Geddes 1987)
Physiochemical and biological studies on the Coorong lagoons, South Australia, and the effect of salinity on the distribution of macrobenthos	1981–1983	Monthly			Coorong	North and South Lagoon	Observation	Observations	Distribution of *Ruppia* spp.	(Geddes and Butler 1984)
Changes in salinity and in the distribution of macrophytes, macrobenthos and fish in the Coorong lagoons, South Australia, following a period of River Murray flow	1983–1985				Coorong	North and South Lagoon	Observation	Observations	Distribution of *Ruppia* spp.	(Geddes 1987)
Limnology of some lagoons in the southern Coorong	1976	Snapshot			Coorong	North and South Lagoon			Distribution of *Ruppia* spp.	(Geddes and Brock 1977)

1.3. Change in Coorong and Lakes vegetation since listing

Lakes

Baseline vegetation data from November 1985 when the wetland was listed under the Ramsar Convention were not collected; hence, it is impossible to describe the change in plant communities since listing. The earliest aquatic and littoral vegetation data collected from the Lakes were a one-off snapshot of the aquatic vegetation of Hindmarsh Island in February 1989 (Renfrey *et al.* 1989). No information was collected between 1989 and 2004, except for a one-off survey of Murray Mouth Reserves in March 2002 (Brandle *et al.* 2002) and habitat mapping (Seaman 2003). In spring 2004 (Holt *et al.* 2005) and spring 2005 (Nicol *et al.* 2006) two surveys of plant communities in selected wetlands were undertaken. Regular monitoring of plant communities in the Lakes (wetlands and shorelines) as part of The Living Murray condition monitoring program commenced in spring 2008 (Marsland and Nicol 2009; Gehrig *et al.* 2010; 2011b; 2012; Frahn *et al.* 2013; 2014). However, water levels in the Lakes were at unprecedented lows the first two years of the condition monitoring program and these data cannot provide a baseline or indication of natural (acceptable) variability of the system. The best available baseline for the vegetation of the Lakes is a summary of the literature and data prior to 2007 before water levels fell to below sea level. This will allow qualitative comparisons of the vegetation with data collected from The Living Murray condition monitoring (Marsland and Nicol 2009; Gehrig *et al.* 2010; 2011b; 2012; Frahn *et al.* 2013; 2014) and *Schoenoplectus* planting monitoring programs (Nicol *et al.* 2013; 2014a; 2015; 2016).

Vegetation of the Lakes prior to 2007

The vegetation in the Lakes was typical of systems with limited water level fluctuations (Walker 1985; 1986; Walker *et al.* 1992; Walker and Thoms 1993; Blanch *et al.* 1999; 2000) (Appendix 1). Water levels ranged from +0.5 to +1 m AHD with the highest levels occurring in spring and lowest in autumn (Figure 1; Department of Environment, Water and Natural Resources 2016). Nevertheless, salinity (e.g. Hart *et al.* 1991; 2003) and wave action (e.g. Wilson and Keddy 1985; Foote and Kadlec 1988; Coops and Van der Velde 1996; Hawes *et al.* 2003; Riis and Hawes 2003) are also important factors that can determine the distribution and abundance of plants.

Open water areas of lakes Alexandrina and Albert have generally been devoid of plants, probably due to wave action and depth. Many areas that are shallow and could support submergent or amphibious species are subjected to wave action and there is insufficient light penetration in areas that are deeper than 1 m to support submergent and amphibious species. Submergent and amphibious species were generally restricted to fringing wetlands, sheltered bays, Goolwa Channel and the lower reaches of Currency Creek and Finniss River. The areas with the greatest abundances of submergent and amphibious species were wetlands and sheltered areas along the western shoreline of Lake Alexandrina, northern shoreline of Hindmarsh Island and Goolwa Channel (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). For example, extensive beds of *Vallisneria australis* were present at Milang Shores, Dunns Lagoon, Clayton Bay and in the channels on Hindmarsh Island (Holt *et al.* 2005) and *Myriophyllum* spp. was abundant near the Hindmarsh Island bridge (J. Nicol pers. obs.), in Clayton Bay, Dunns Lagoon (Holt *et al.* 2005) and Hunters Creek (Nicol *et al.* 2006). The plant communities present in wetlands along the eastern shoreline of Lake Alexandrina and around the edges of Lake Albert suggested that salinity plays a role in structuring the community. The salt tolerant taxa *Ruppia* spp. and *Lepilaena cylindrocarpa* were the dominant submergents in wetlands along the eastern shoreline of Lake Alexandrina and around Lake Albert (Holt *et al.* 2005; Nicol *et al.* 2006).

The fringing vegetation of the Lakes was dominated by dense stands of the emergent species *Typha domingensis* and *Phragmites australis*, particularly the western shoreline of Lake Alexandrina, Goolwa Channel and lower reaches of Currency Creek and the Finniss River (Brandle *et al.* 2002; Seaman 2003). Nevertheless, there were areas of samphire and salt marsh vegetation (*Sarcocornia* spp*., Suaeda australis, Juncus kraussii, Tecticornia* spp.) and dense *Duma florulenta* shrublands predominantly around the edges of wetlands along the eastern shore of Lake Alexandrina, adjacent to the barrages and around Lake Albert (Seaman 2003; Holt *et al.* 2005; Nicol *et al.* 2006).

Melaleuca halmaturorum is the dominant tree on shorelines of the Lakes and forms small dense closed woodlands (Holliday 2004). *Melaleuca halmaturorum* woodlands are scattered around the edges of the Lakes with the largest woodlands located at the mouth of Hunters Creek, on the northern shore of Hindmarsh Island, on Goat and Goose islands near the township of Clayton in Lake Alexandrina, in Salt Lagoon on the south-eastern shore of Lake Alexandrina and Kennedy Bay on the southern shore of Lake Albert. Age class information is only available for the stand at the mouth of Hunters Creek, which are predominantly older trees (>28 years) and there was no evidence of recruitment in the 10 years prior to the survey (all juveniles were planted by the local land care group) (Nicol *et al.* 2006).

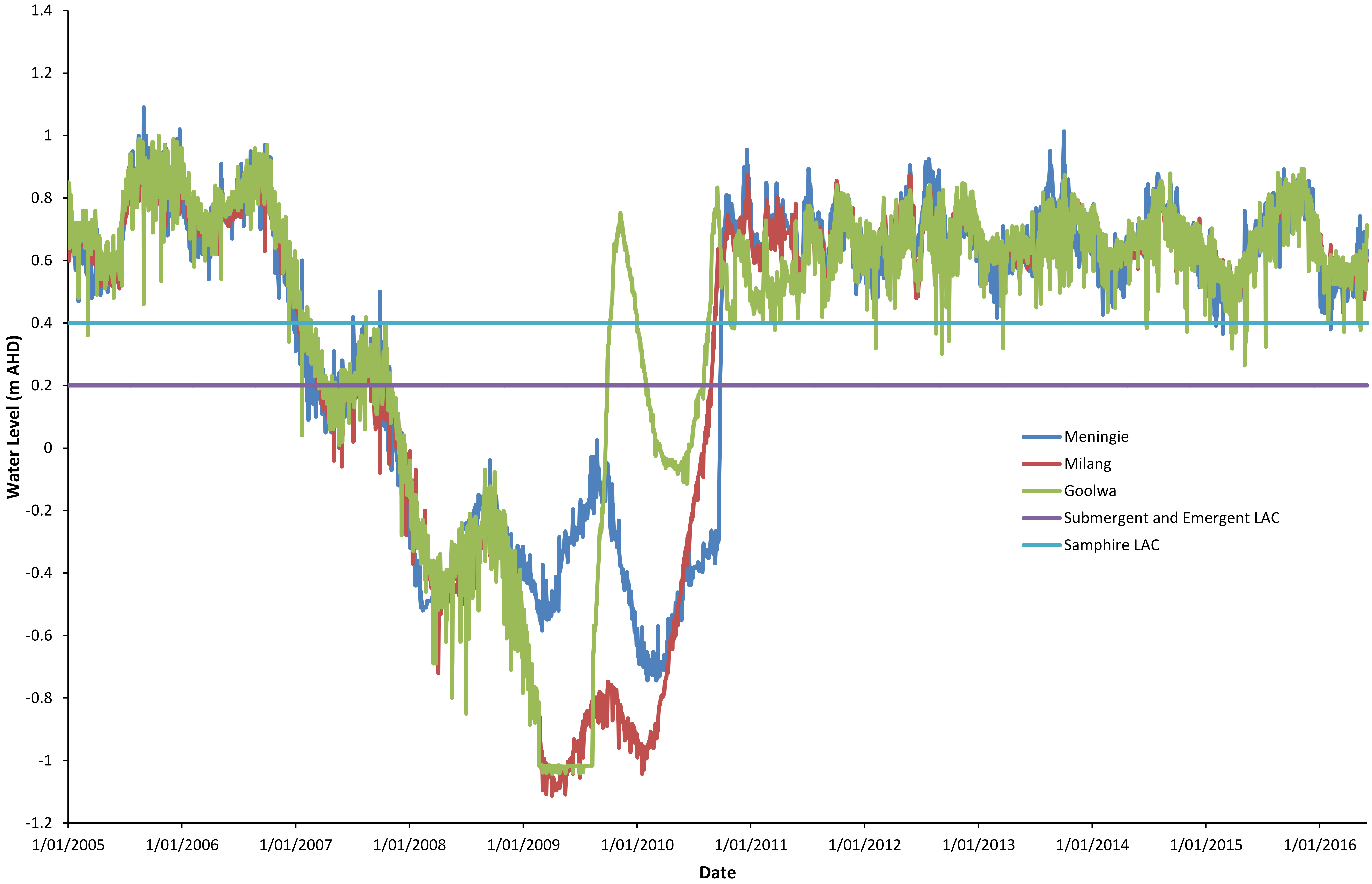

Figure 1: Water levels in Goolwa Channel (upstream of Goolwa Barrage), Lake Alexandrina (Milang) and Lake Albert (Meningie) from January 2005 to June 2016 (Department of Environment, Water and Natural Resources 2016), showing the water level LAC for the submergent and emergent vegetation CPS and samphire CPS.

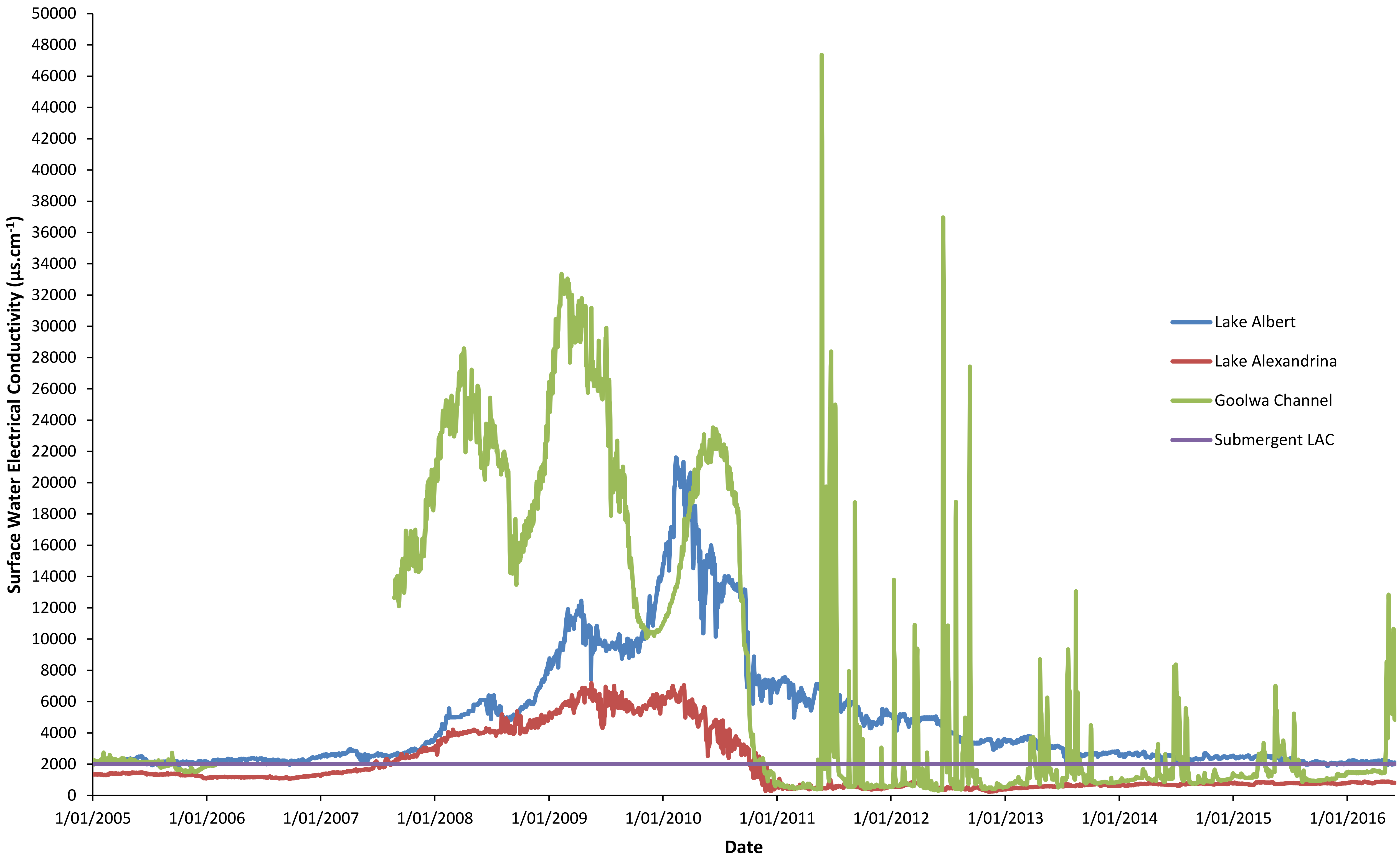

Figure 2: Surface water electrical conductivity in Goolwa Channel (upstream of Goolwa Barrage), Lake Alexandrina (Milang) and Lake Albert (Meningie) from January 2005 to June 2016 (Department of Environment, Water and Natural Resources 2016), showing the salinity LAC for the submergent vegetation CPS.

Vegetation of the Lakes between 2007 and 2010

Between 2007 and spring 2010, water levels fell to unprecedented low levels in the Lakes (Figure 1) and several engineering interventions were undertaken to manipulate water levels, which resulted in significant changes to the aquatic and littoral vegetation (Marsland and Nicol 2009; Gehrig *et al.* 2010; Nicol and Marsland 2010; Gehrig *et al.* 2011a; 2011b; 2012; Frahn *et al.* 2013; 2014). The two main interventions were the construction of the Narrung bund and Clayton regulator. Construction of the Narrung bund was completed in early 2008 and disconnected Lake Albert from Lake Alexandrina. Water was then pumped from Lake Alexandrina into Lake Albert to maintain water levels above -0.5 m AHD. Construction of the Clayton regulator was finished in August 2009 and impounded water from Finniss River and Currency and Tookayerta creeks. In addition, water was pumped from Lake Alexandrina to raise water levels to +0.7 m AHD in spring 2009 (Figure 1).

Construction of the Narrung bund and Clayton regulator enabled water levels in Lake Albert and Goolwa Channel to be managed independently of Lake Alexandrina, which was reflected in water levels (Figure 1). Water levels in Lake Alexandrina were dependent on River Murray inflows and, to a lesser extent, pumping into Lake Albert and Goolwa Channel. Due to low flows into South Australia, the water level in Lake Alexandrina remained below sea level from 2007 until spring 2010 (Figure 1). River Murray flows into Lake Alexandrina increased in April 2010 and water levels were restored to historical levels in August 2010 (Figure 1). Surface water electrical conductivity (EC) in Lake Alexandrina remained relatively constant and ranged from 4,000 to 7,000 $\mu S.cm^{-1}$ (Figure 2), whilst River Murray inflows were below average. When inflows increased, EC decreased and by December 2010 had fallen to around 500 $\mu S.cm^{-1}$ (Gehrig *et al.* 2012; Figure 2).

From August 2008 to August 2010, water levels in Lake Albert were dependent on pumping from Lake Alexandrina, local rainfall and evaporation. Between August 2008 and March 2009, water level decreased from -0.1 to -0.55 m AHD then increased to approximately -0.1 m AHD by September 2009 (Figure 1) as a result of pumping from Lake Alexandrina. Pumping ceased in September 2009 and water levels decreased to -0.7 m AHD in January 2010 (Figure 1). Pumping recommenced between April and June 2010 and water levels increased to -0.4 m AHD (Figure 1). In September 2010, the Narrung bund was breached, Lake Albert was reconnected with Lake Alexandrina, the water level increased rapidly to +0.8 m AHD and was dependent on water level in Lake Alexandrina from then on (Figure 1). Surface water EC increased from 5,000 to 12,000 μS.cm^{-1} from August 2008 to March 2009 and decreased to around 9,500 μS.cm^{-1} by May 2009 (Figure 2), as a result of dilution from pumping from Lake Alexandrina, and remained relatively constant until October 2009 (Gehrig *et al.* 2011b; Figure 2)). When pumping ceased, surface water EC increased and exceeded 20,000 μS.cm^{-1} by February 2010 (Gehrig *et al.* 2011b; Figure 2). When pumping recommenced, EC decreased to approximately 14,000 μS.cm^{-1} until September 2010 when the bund was breached after which EC decreased rapidly to 8,000 μS.cm^{-1} (Gehrig *et al.* 2011b; Figure 2).

Water levels in Goolwa Channel from August 2008 to August 2009, were dependent on River Murray inflows and from August 2009 to August 2010, on pumping from Lake Alexandrina, inflows from the Finniss River and Currency and Tookayerta creeks, local rainfall and evaporation. Prior to completion of the Clayton regulator in August 2009, water levels in Goolwa Channel were dependent on Lake Alexandrina water levels (Figure 1). The water level increased to +0.75 m AHD between August 2009 and November 2009 due to pumping and inflows from Currency and Tookayerta creeks and the Finniss River (Figure 1). Pumping ceased in November 2009 and water levels decreased to -0.1 m AHD in April/May2010 (Figure 1). Water levels increased to +0.2 m AHD in response to tributary inflows in July 2010 and the regulator was breached in September 2010, which resulted in water levels rising to +0.8 m AHD (Figure 1). Surface water EC at the beginning of the study period was approximately 21,000 μS.cm^{-1}, which decreased to around 14,000 μS.cm^{-1} in September 2008 then increased over spring and summer, reaching a maximum of 33,000 μS.cm^{-1} in February/March 2010 (Gehrig *et al.* 2011b; Figure 2). The elevated EC was due to a combination of low River Murray inflows and seawater leaking through Goolwa Barrage into Goolwa Channel (Gehrig *et al.* 2011b). From March 2009 to August 2009, EC decreased to around 20,000 μS.cm^{-1} (Figure 2) due to higher water levels in Lake Alexandrina and engineering works that reduced seawater leakage through Goolwa Barrage (Gehrig *et al.* 2011b). Construction of the Clayton regulator was completed and pumping from Lake Alexandrina commenced in August 2009, which reduced EC in Goolwa Channel to 10,000 μS.cm^{-1} until pumping ceased in November 2009 (Gehrig *et al.* 2011b; Figure 2). Surface water EC increased to around 20,000 μS.cm^{-1} by April 2010 and fluctuated between 20,000 and 22,000 μS.cm^{-1} until the regulator was breached in September 2010 after which it fell to approximately 500 μS.cm^{-1} (Gehrig *et al.* 2011b; Figure 2).

The low water levels resulted in drying of fringing habitats (wetlands and shorelines), where aquatic plant diversity is highest. Drying of these habitats resulted in the complete loss of submergent species (Gehrig *et al.* 2011b); however, a viable seed bank was present in Dunns and Shadows lagoons and Goolwa Channel indicating the capacity of the vegetation to recolonise these areas given appropriate hydrological conditions (Nicol and Ward 2010a; 2010b).

The extensive *Phragmites australis* stands and *Duma florulenta* and samphire shrublands that were present around the edges of Lake Alexandrina and Lake Albert prior to 2007 were still present and in many areas expanded their distribution down the elevation to colonise areas of dry lakebed (Marsland and Nicol 2009). *Typha domingensis* and *Schoenoplectus tabernaemontani* stands that had live plants present showed reduced extent and appeared to be in poor condition (Marsland and Nicol 2009). Whilst stands of emergent and amphibious species persisted they were not inundated and disconnected from the lakes (Marsland and Nicol 2009; Figure 1).

The construction of the Narrung bund enabled water levels to be raised in Lake Albert to mitigate acid sulfate soils but there was insufficient water to inundate fringing habitats (Figure 1). In contrast, the Clayton regulator enabled water levels in Goolwa Channel to be raised sufficiently to inundate fringing habitats (Figure 1). It was expected that the increased salinity in Goolwa Channel would result in significant mortality of fringing vegetation (Bailey *et al.* 2002); however, this did not occur and there was a noticeable improvement in the condition of the fringing vegetation during this period (Gehrig *et al.* 2011a). Submergent species also recruited in Goolwa Channel; however, the submergent vegetation was dominated by dense beds of *Potamogeton pectinatus* (Gehrig *et al.* 2011a). Dense monocultures of this species occupied 1,491 hectares of Goolwa Channel, with sparse *Potamogeton pectinatus* submerged herblands occupying a further 100 hectares and mixed *Potamogeton pectinatus/Myriophyllum salsugineum* submerged herblands occupying 572 hectares (Gehrig *et al.* 2011a). The combined area of the aforementioned submergent plant communities covered 53% of the area of Goolwa Channel below +0.8 m AHD (Gehrig *et al.* 2011a).

Vegetation of the Lakes after 2010

Increased inflows to the Lakes and breaching of the Clayton regulator and Narrung bund in spring 2010 resulted in reconnection throughout the Lakes and reinstatement of historical water levels (Figure 1). Flows over Lock 1 have been sufficient to maintain water levels between +0.4 and +1 m AHD in the Lakes since spring 2010 (Figure 1) and reduce surface water EC in Lake Alexandrina and Goolwa Channel to below 1,000 $\mu S.cm^{-1}$ and Lake Albert below 3,000 $\mu S.cm^{-1}$ (Figure 2).

The inflow of fresh turbid water into Goolwa Channel resulted in the extirpation of much of the submergent vegetation that recruited after the Clayton regulator was constructed (Gehrig *et al.* 2011a); however, this was slowly replaced with more diverse submergent vegetation consisting of *Potamogeton pectinatus, Myriophyllum salsugineum, Ceratophyllum demersum, Potamogeton crispus* and *Vallisneria australis* (Frahn *et al.* 2014). Since the Clayton regulator was breached there have also been increasing trends in the abundance of amphibious and emergent species and a decline in exotic terrestrial taxa (Frahn *et al.* 2014).

Reinstatement of water levels in lakes Alexandrina and Albert have also resulted in an improvement in vegetation condition (Frahn *et al.* 2014). Emergent and amphibious species have increased in abundance on the shorelines of both lakes and in fringing wetlands (Frahn *et al.* 2014). Submergent species are uncommon in Lake Albert but there have been increases in the abundance of submergents in Lake Alexandrina and wetland habitats (Frahn *et al.* 2014).

Planting of the robust emergent species *Schoenoplectus tabernaemontani* to control shoreline erosion was trialed prior to 2007 but abandoned after water levels fell between 2007 and 2010. The planting program recommenced after water levels were reinstated with 30 km of shoreline planted between 2010 and 2016. Monitoring results showed that stands planted prior to 2007 had persisted through the drought as rhizomes and reestablished and were increasing in density and extent (Nicol *et al.* 2016). Stands planted after 2010 had also established well and were increasing in density and extent (Nicol *et al.* 2016). In addition, the breakwater effect provided by planted (and natural) *Schoenoplectus tabernaemontani* stands provides a low wave energy environment that enables less robust submergent, emergent and amphibious species to establish (Nicol *et al.* 2016).

Coorong and Murray estuary

Change since listing for aquatic vegetation in the South Lagoon is described in Paton *et al.* (2015) and changes in the distribution and abundance of *Ruppia tuberosa* in the Coorong from the mid-1970s is summarised in Nicol (2005), and will not be discussed in this report. This report will focus on the distribution and abundance of *Ruppia megacarpa* in the North Lagoon and Murray estuary.

In contrast to the Lakes, there is information regarding the distribution and abundance of *Ruppia megacarpa* in the North Lagoon and Murray estuary from around the time of listing; however, there has been no regular long-term monitoring program. In a survey undertaken for the Nature

Conservation Society of South Australia, Geddes and Brock (1977) reported that *Ruppia* sp. was the most common angiosperm growing in the Coorong and adjacent ephemeral lakes. Specimens were found growing in waters of varying depth and salinity and generally the growth form appeared to be taller and more robust in the deeper, less saline areas and smaller and more delicate in the shallow areas (Geddes and Brock 1977). It was later determined that these different forms were different species; the taller more robust form was *Ruppia megacarpa* and the smaller delicate form was either *Ruppia tuberosa* or *Ruppia polycarpa* (Brock 1981;1982a; 1982b; 1983; Jacobs and Brock 1982).

A 16-month study from December 1981 to March 1983, was undertaken by Geddes and Butler (1984), during which the River Murray catchment was in drought and there was no outflow from the barrages. During this time there was always a longitudinal salinity gradient in the North Lagoon; with the lowest salinity closest to the Murray Mouth and highest at the southern end of the lagoon (Geddes and Butler 1984). Salinities in the North Lagoon ranged from 20–50‰ TDS in December 1981 and 40–80‰ TDS in January 1983 and showed a seasonal pattern, rising in the summer of 1981-82, falling during May, June and July 1982 and rising in October 1982 to the peak value in January 1983 (Geddes and Butler 1984). Whilst macrophytes were not quantitatively sampled, Geddes and Butler (1984) noted that *Ruppia megacarpa* was the dominant macrophyte in the North Lagoon and it was widely distributed in water less than 1 m deep and occasionally found in water up to 2 m deep throughout the duration of the study.

A 24-month study was undertaken during a period of above average flow in the River Murray from March 1983 to March 1985 when there was considerable discharge from the barrages (Geddes 1987). The salinity in both lagoons of the Coorong changed dramatically during this time in response to freshwater inflows, marine intrusions and evaporative concentration (Geddes 1987). *Ruppia megacarpa* was the dominant macrophyte in the North Lagoon in 1983 and 1984 (Geddes 1987). Beds of this species were vigorous, extensive and flowered profusely along the length of the lagoon; they remained extensive until June 1984 after which they died back (Geddes 1987). They became extensive and vigorous again by December 1984 but no flowering was observed (Geddes 1987). The expansion and die back of *Ruppia megacarpa* corresponded with falling and rising salinity in the Coorong, flowering also corresponded with a fall in salinity (Geddes 1987).

No investigations regarding the distribution and abundance of *Ruppia megacarpa* were undertaken until August 1995 when a survey of the Murray Mouth Estuary was undertaken (Edyvane *et al.* 1996). Extensive beds of *Ruppia megacarpa* were reported from south of Long

Point in the North Lagoon and throughout the Murray estuary between Goolwa and Tauwitchere barrages (Edyvane *et al.* 1996). These observations were the last reported occurrence of extant *Ruppia megacarpa* in the Coorong and Murray estuary. Geddes (2005a; 2005b) monitored the response of the biota in the Murray estuary to controlled barrage releases in spring 2003 and autumn 2004 and reported an absence of *Ruppia megacarpa* from the system. Despite the absence of *Ruppia megacarpa* plants in the Coorong and Murray estuary a seed bank was present until at least until January 2001 with seed densities ranging from 100 to 2,000 seeds m^{-2} at the southern end of the North Lagoon (Paton 2001). However, Nicol (2007) found no extant *Ruppia megacarpa* plants and only one viable seed in approximately 1,300 sediment samples in the North Lagoon and Murray estuary in spring 2006.

2. UPDATED CONTENT OF THE RAMSAR INFORMATION SHEET

Ramsar Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The justification for listing under Criterion 1 as described in Phillips and Muller (2006) and the updated Ramsar Information Sheet from 2013 (Department of Environment, Water and Natural Resources 2013) are still relevant with respect to vegetation. The 23 Ramsar wetland types listed are still present now water levels have been reinstated and it is the only estuarine system in the Murray-Darling Basin.

Ramsar Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Similar to Criterion 1, the justification for listing under Criterion 2 as described in Phillips and Muller (2006) and the updated Ramsar Information Sheet from 2013 (Department of Environment, Water and Natural Resources 2013) are still relevant with respect to vegetation. The boundaries of the site partially overlap with the critically endangered EPBC listed community of the Swamps of the Fleurieu Peninsula. The endangered metallic sun-orchid (*Thelymitra epipactoides*) and vulnerable sand hill greenhood orchid (*Pterostylis arenicola*) and silver daisy bush (*Olearia pannosa* ssp. *pannosa*) have been recorded in the Ramsar wetland; however, there is no monitoring program for these species and their current distribution and abundance are unknown.

Ramsar Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The justification for listing under Criterion 3 as described in the updated Ramsar Information Sheet from 2013 (Department of Environment, Water and Natural Resources 2013) is still relevant with respect to vegetation. However, it should be noted that the site is located at the junction of three of South Australia's Interim Biogeographic Regionalisation for Australia (IBRA) regions; the Western Murray-Darling Depression, Kanmantoo and Naracoorte Coastal Plain and the vegetation of the site represents a combination of the wetland flora of these three regions.

3. DEFINITION AND ASSESSMENT OF AQUATIC AND LITTORAL VEGETATION-RELATED CRITICAL COMPONENTS, PROCESSES AND SERVICES (CPS) AND LIMITS OF ACCEPTABLE CHANGE (LAC)

3.1. Vegetation-related critical Components, Processes and Services (CPS)

Due to the lack of vegetation data from when the Coorong and Lakes Alexandrina and Albert Wetland was listed, the vegetation-related critical CPS were determined by expert opinion. Eleven vegetation-related CPS were chosen, which represent species and communities that were deemed functionally important for the system (Table 3). Vegetation-related critical CPS differ between subregions and those relating to the Lakes, Murray estuary and North Lagoon of the Coorong will be discussed. Vegetation-related critical CPS identified for the Lakes were freshwater submergent plant communities, *Phragmites australis, Typha domingensis, Duma florulenta* and diverse reed beds; for the Murray estuary and North Lagoon *Ruppia megacarpa* was identified; *Ruppia tuberosa* and *Lamprothamnium macropogon* for the South Lagoon; and *Melaleuca halmaturorum* and samphire and salt marsh communities for the whole of the system (Table 3).

A series of conceptual models that summarise the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of critical vegetation-related CPS were developed to assist the development of LAC in the absence of long-term monitoring data from the wetland (*sensu* Davis and Brock 2008). A summary of the drivers, processes and thresholds (where data exists) outlined in the conceptual models is presented in Table 4.

Table 3: List of vegetation-related critical CPS, the subregion of the system where they occupy and metrics that could be used to set management triggers and LAC (*denotes assessed by Paton *et al.* (2015) and not assessed in this report).

Critical CPS	Subregion	Potential Management Triggers/LAC Metrics
Freshwater submergent plant communities	Lakes	Spatial extent, abundance, distribution, diversity, propagule bank
Phragmites australis	Lakes	Spatial extent, distribution
Typha domingensis	Lakes	Spatial extent, distribution
Duma florulenta	Lakes	Spatial extent, distribution
Diverse reed beds	Lakes	Spatial extent, abundance, distribution, diversity, propagule bank
Melaleuca halmaturorum	Whole of system	Spatial extent, distribution, abundance, recruitment, reproduction, demographics
Samphire and salt marsh communities	Whole of system	Spatial extent, abundance, distribution, recruitment, reproduction, propagule bank, demographics
Ruppia megacarpa	North Lagoon and Murray estuary	Spatial extent, distribution, recruitment, biomass, abundance, reproduction, propagule bank
*Ruppia tuberosa**	South Lagoon and saline lakes	Spatial extent, distribution, recruitment, biomass, abundance, reproduction, propagule bank
*Lamprothamnium macropogon**	South Lagoon and saline lakes	Spatial extent, distribution, recruitment, biomass, abundance, reproduction, propagule bank
Phragmites australis	Coorong	Spatial extent

Table 4: List of vegetation-related critical CPS with a summary of the (a.) the external drivers (b.) physico chemical processes (including thresholds where data exists) and (c.) biological processes outlined in the conceptual models.

a.

	External drivers					
Critical CPS	**Climate**	**Environmental water**	**Barrage operations**	**Elevation (m AHD)**	**Nutrients**	**Wave action**
Freshwater submergent plant communities	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	0.4 to 0 (-0.5 in Goolwa Channel)	Low	Low tolerance
Phragmites australis (Lakes)	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	0.9 to 0 (-0.5 in some areas)	High	Data deficient
Typha domingensis	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	0.8 to 0 (-0.2 in some areas)	High	Data deficient
Duma florulenta	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	>0.8	Data deficient	Data deficient
Diverse reed beds	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	0.9 to 0	Low	Data deficient
Melaleuca halmaturorum	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	>0.8	Data deficient	Data deficient
Samphire and salt marsh communities	Drives River Murray Flows and Lake Levels	Supplements flows	Controls lake levels	>0.8	Data deficient	Data deficient
Ruppia megacarpa	Drives River Murray Flows and Barrage Outflows	Supplements flows	Influences Murray estuary and North Lagoon salinities	>0	Low	Low tolerance
Phragmites australis (Coorong)	Drives local recharge	NA	NA	Data deficient	Data deficient	Data deficient

b.

	Physicochemical process					
Critical CPS	**River Murray Flow**	**Salinity (EC µS.cm^{-1})**	**Water level (m AHD)**	**Soil Moisture**	**Light Availability**	**Shear force**
Freshwater submergent plant communities	Drives lake levels	<2,000	+0.8 to +0.4 m , +0.2 m minimum	Inundation	Maximum depth determined by light availability	Low
Phragmites australis (Lakes)	Drives lake levels	<5,000	+0.8 to +0.4 m , +0.2 m minimum	High	NA	Data deficient
Typha domingensis	Drives lake levels	<5,000	+0.8 to +0.4 m , +0.2 m minimum	High	NA	Data deficient
Duma florulenta	Drives lake levels	<5,000	+0.8 to +0.4 m , +0.2 m minimum	High to low	NA	Data deficient
Diverse reed beds	Drives lake levels	<2,000	+0.8 to +0.4 m , +0.2 m minimum	High	Maximum depth of submergent species present is determined by light availability	Data deficient
Melaleuca halmaturorum	Drives lake levels and Barrage outflows	High	+0.8 to +0.4 m , +0.2 m minimum	High to moderate	NA	Data deficient
Samphire and salt marsh communities	Drives lake levels and Barrage outflows	High, although requires periods of lower salinity for recruitment	+0.8 to +0.4 m , +0.2 m minimum	High	NA	Data deficient
Ruppia megacarpa	Drives lake levels and Barrage outflows	<35 gL^{-1} TDS for recruitment from seed <46 gL^{-1} TDS for adult plant survival	>0 m	Inundation	High, Maximum depth determined by light availability	Low
Phragmites australis (Coorong)	NA	Localised freshening	Data deficient	High	NA	Data deficient

c.

	Biological Process							
Critical CPS	**Herbivory**	**Competition**	**Dispersal**	**Sexual reproduction**	**Asexual reproduction**	**Soil propagule bank**	**Recruitment**	**Related CPS**
Freshwater submergent plant communities	Swans	Data deficient	Water, animals	Yes	Yes	Yes	Inundation with freshwater	Threatened fish
Phragmites australis (Lakes)	Domestic stock	Data deficient	Wind	Limited	Yes	No	Data deficient	Waterbirds
Typha domingensis	Domestic stock	Data deficient	Wind	Yes	Yes	Yes	Wet soil or shallow inundation	Waterbirds
Duma florulenta	Domestic stock	Data deficient	Water, animals	Yes	Yes	No	Wet Soil	Waterbirds
Diverse reed beds	Swans/domestic stock	Data deficient	Wind, water, animals	Yes	Yes	Yes	Wet soil or shallow inundation	Threatened fish/ Waterbirds
Melaleuca halmaturorum	Domestic stock	Data deficient	Wind, water, animals	Yes	No	No	Wet Soil	Waterbirds
Samphire and salt marsh communities	Domestic stock	Data deficient	Water, animals	Yes	Samphire no, some salt marsh species yes	Yes	Wet Soil	Orange Bellied Parrot/Waterbirds
Ruppia megacarpa	Swans	Data deficient	Water, animals	Yes	Yes	Yes	Inundation with fresh to brackish water	Waterbirds
Phragmites australis (Coorong)	Data deficient	Data deficient	Wind	Limited	Yes	No	Data deficient	Data deficient

Submergent freshwater plant communities

Submergent plants play important roles in freshwater ecosystems; they are food for herbivorous waterfowl (e.g. Schmieder *et al.* 2006; Chaichana *et al.* 2011; Wood *et al.* 2012), provide fish (e.g. Wedderburn *et al.* 2007) and invertebrate habitat (e.g. Wright *et al.* 2002; Larned *et al.* 2006; Walker *et al.* 2013), oxygenate the sediment and water column (e.g. Thursby 1984) and improve water quality (e.g. Findlay *et al.* 2006; Dai *et al.* 2012). Submergent plants were historically abundant in areas that are protected from wave action in the Lakes, such as shoreline wetlands, bays, channels and throughout the lower reaches of the Murray River between Clayton and Goolwa Barrage (including the lower Finniss River and lower Currency Creek) (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006). Between 2007 and 2010, submergent vegetation was lost from the system (except in Goolwa Channel after August 2009 due to the Clayton regulator) but has returned (probably in reduced abundance and distribution) since August 2010 (Frahn *et al.* 2014). The submergent plant taxa recorded in the Lakes since 2010 are: *Myriophyllum salsugineum, Myriophyllum caput-medusae, Potamogeton crispus, Potamogeton pectinatus, Ruppia polycarpa, Ruppia tuberosa, Ruppia megacarpa, Ceratophyllum demersum, Vallisneria australis, Chara* spp., *Nitella* spp. and *Lamprothamnium macropogon* (Frahn *et al.* 2014). *Lepilaena cylindrocarpa, Lepilaena australis, Myriophyllum simulans* and *Ranunculus trichophyllus* have been historically recorded in the Lakes (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006) but have not been recorded since 2007 (Frahn *et al.* 2014).

The main factors that influence the distribution and abundance of submergent plants in the Lakes are water level and salinity. Water level in the Lakes is dependent on River Murray flow and barrage operations and salinity on River Murray flow (Table 4, Figure 3). Submergent plants generally do not colonise areas below sea level, except in Goolwa Channel where plants often grow in areas as low as -0.5 to -1 m AHD (Frahn *et al.* 2014). Therefore, water levels in the lakes need to be maintained at a minimum of +0.2 m AHD (the water level LAC for this CPS) (Figure 1), preferably +0.4 m AHD and above. The impact of salinity is less well understood, species that were reported to have low salinity tolerances (e.g. *Vallisneria australis, Ceratophyllum demersum*) (Bailey *et al.* 2002) colonised and persisted in Goolwa Channel between August 2009 and August 2010 when salinities exceeded 30,000 $\mu S.cm^{-1}$ at times (Gehrig *et al.* 2011a; Figure 2). However, whilst salinities were elevated, *Potamogeton pectinatus* dominated and formed large and almost monospecific beds throughout Goolwa Channel (Gehrig *et al.* 2011a). In contrast, after water levels were reinstated and salinities lowered, the submergent vegetation has become more diverse (Frahn *et al.* 2014). Therefore, it is desirable to maintain salinities below the 2,000 µS.cm^{-1} salinity LAC for this CPS (Figure 2) to maximise diversity and prevent dominance of one salt tolerant species.

There is very little information regarding the impact of other physico-chemical factors on the distribution and abundance of submergent plants in the Lakes. Monitoring and historical data showed that submergent plants are restricted to areas protected from wave action (Renfrey *et al.* 1989; Holt *et al.* 2005; Nicol *et al.* 2006; Gehrig *et al.* 2011a; Frahn *et al.* 2014; Nicol *et al.* 2016), which suggests they are sensitive to mechanical disturbance and stress. The Lakes are turbid water bodies and light availability will prevent submergent species from colonising deep water habitats (>1.5 m) (*sensu* Spence 1982). Furthermore all deep water habitats, with the exception of those in Goolwa Channel, are in open water areas in lakes Alexandrina and Albert and often subjected to wave action.

Similarly, there is little information available regarding the biotic interactions that influence the distribution and abundance of submergent species. All of the species present in submergent plant communities in the Lakes have evolved desiccation resistant seed banks (Nicol and Ward 2010a; 2010b); however, the longevity of the seed bank under different condition is not known. Sub-lethal salinity probably reduces growth rates (e.g. Blindow and Schutte 2007; Obrador and Pretus 2010) but also delays germination in *Myriophyllum salsugineum* and *Ruppia tuberosa* (Nicol and Ward 2010a; 2010b). All of the submergent species present in the Lakes reproduce asexually, which under favourable conditions is probably the dominant mode of reproduction and source of recruitment (e.g. Grace 1993). Nevertheless, sexual reproduction (flowering or spore production) has been observed in all submergent species (except *Ceratophyllum demersum*) in the Lakes (J. Nicol pers. obs.) and is required for the production of desiccation resistant propagules and for the formation of a seed bank. Dispersal is also poorly understood but all of the submergent species found in the Lakes have cosmopolitan distributions (Sainty and Jacobs 1981; Jessop and Tolken 1986; Romanowski 1998; Sainty and Jacobs 2003); therefore, are probably very good dispersers (Santamaria 2002). Hydrochory is probably the dominant dispersal mode for short-distance dispersal (Merritt and Wohlb 2002; Merritt and Wohl 2006; Greet *et al.* 2012). However, they require a vector (usually an animal, probably a water bird) for long-distance dispersal between catchments (Vivian-Smith and Stiles 1994; Clausen *et al.* 2002; Pakeman and Small 2009; Raulings *et al.* 2011).

The effects of competition and herbivory are also not well understood. The main herbivore of submergent plants in the Lakes is probably the back swam (*Cygnus atratus*); however, there is no information available regarding the impact of herbivory on submergent plant communities in the Lakes.

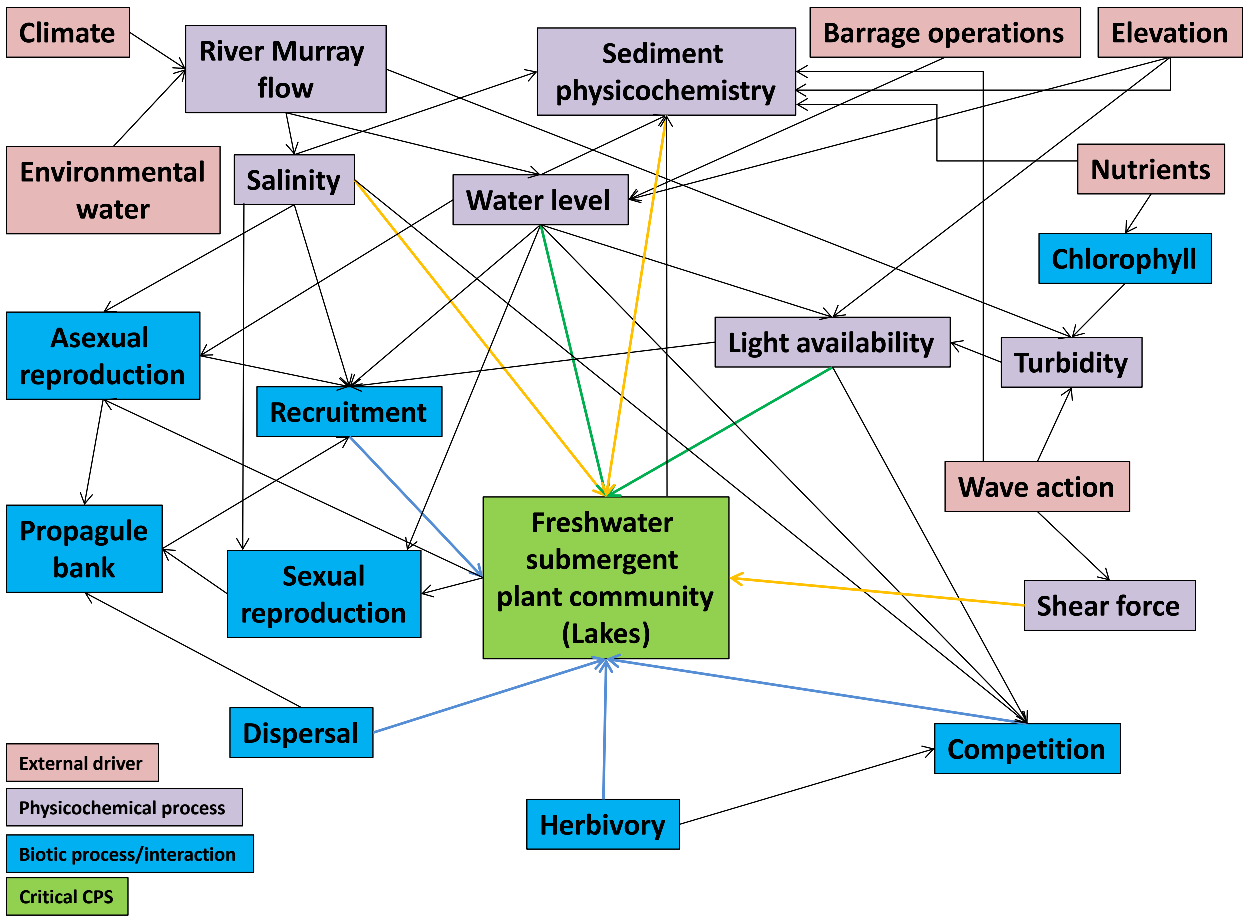

Figure 3: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of submergent freshwater plant communities in the Lakes.

The conceptual model presented in Figure 4 outlines the key external drivers, physicochemical and biotic processes that determine the distribution and abundance of diverse reed beds, *Typha domingensis*, *Phragmites australis* and *Duma florulenta* (emergent freshwater plant communities) in the Lakes. The factors that influence the distribution and abundance of the aforementioned communities and species are the very similar with small differences in a small number of factors that will determine floristic composition of the emergent vegetation.

Emergent freshwater plant communities

Emergent plants are important components of freshwater ecosystems; they are important primary producers (e.g. Roberts and Ganf 1986; Froend and McComb 1994), improve water quality (e.g. Kadlec and Wallace 2009; Maddison *et al.* 2009; Li *et al.* 2010; Borin and Salvato 2012), oxygenate the sediment and water column (e.g. Blom *et al.* 1990; Sorrell and Hawes 2010; Dickopp *et al.* 2011), provide habitat for fish (e.g. Beyer *et al.* 2010; Marsland *et al.* 2010; Zampatti *et al.* 2011; Leigh *et al.* 2012), water birds (e.g. Jansen and Robertson 2001; Kapa and Clarkson 2009) and invertebrates (e.g. Papas 2007; Walker *et al.* 2013) and stabilise shorelines (e.g. Abernethy and Rutherfurd 1998). In the Lakes, extensive stands of emergent macrophytes are present around the shorelines throughout the system. Often stands are monospecific *Typha domingensis* or *Phragmites australis*; however, in some areas there is distinctive zonation of *Duma florulenta, Phragmites australis* (at the top of the elevation gradient), *Typha domingensis* (middle elevations) and *Schoenoplectus tabernaemontani* (low elevation) or there is a diverse assemblage of emergent, amphibious, floating and submergent plants (diverse red beds) (Frahn *et al.* 2014; Nicol *et al.* 2014b; 2016).

The main factors that determine the distribution and abundance of emergent freshwater plant communities (similar to submergent plants) are water level and salinity. Emergent plants tend to occupy elevations between +0.9 m AHD to sea level; hence, water levels need to be maintained at a minimum of +0.2 m AHD, preferably +0.4 m AHD to maintain hydrological connection with the lakes and ensure there is sufficient water for plants growing at higher elevations. Furthermore, most emergent species require high soil moisture in the root zone when growing out of the water (Sainty and Jacobs 1981; Romanowski 1998; Sainty and Jacobs 2003; Roberts and Marston 2011). Between 2007 and 2010, when water levels were low, most emergent plants persisted but did not recruit further down the elevation gradient and were hydrologically disconnected from the lakes (Gehrig *et al.* 2012). Therefore, these did not provide the same function (e.g. aquatic habitat) as emergent vegetation that is hydrologically connected. The effect of salinity is less well understood, species that were reported to have low salinity tolerances (e.g. *Typha domingensis, Schoenoplectus tabernaemontani*) (Bailey *et al.* 2002) persisted in Goolwa Channel between August 2009 and August 2010 when surface water salinity exceeded 30,000 $\mu S.cm^{-1}$ at times (Gehrig *et al.* 2011a). Nevertheless, while salinities were elevated there was no recruitment from seed by the aforementioned species and abundances were lower compared to after water levels were reinstated and salinity reduced (Frahn *et al.* 2014). Therefore, it would be desirable to maintain salinities as low as possible to maximise abundance, allow recruitment from seed and provide conditions that will allow the greatest number of species to recruit.

Diverse reed beds

Diverse reed beds are characterised by a diverse assemblage of emergent, floating, amphibious and submergent plants. Typically diverse reed beds have greater than 5% cover of native amphibious species and native emergent species other than *Typha domingensis* and *Phragmites australis* between +0.8 and +0.6 m AHD and greater than 5% cover of native submergent species and emergent species other than *Typha domingensis* and *Phragmites australis* between 0 and +0.6 m AHD. Taxa present include: *Phragmites australis, Typha domingensis, Schoenoplectus tabernaemontani, Duma florulenta, Schoenoplectus pungens, Juncus* spp., *Berula erecta, Calystegia sepium, Eleocharis acuta, Azolla* spp. *Lemna* spp. *Triglochin procera, Rumex bidens, Lycopus australis, Hydrocotyle verticillata, Centella asiatica, Bolboschoenus caldwellii, Cyperus gymnocaulos, Persicaria lapathifolia, Myriophyllum* spp., *Potamogeton* spp., *Vallisneria australis* and *Ceratophyllum demersum* (Frahn *et al.* 2014; Nicol *et al.* 2016). Diverse reed beds are found at similar elevations to *Typha domingensis* and *Phragmites australis* monocultures (+0.9 to 0 m AHD) but generally in areas protected from wave action with gentle sloping shorelines and often develop along shorelines where *Schoenoplectus tabernaemontani* has been planted to control erosion (Nicol *et al.* 2016). It is unclear why the diversity in these areas is higher because there are protected areas with gentle sloping shorelines where there are *Typha domingensis* or *Phragmites australis* monocultures (Frahn *et al.* 2014; Nicol *et al.* 2014b).

Species that characterise diverse reed beds require shallow inundation or high soil moisture (Sainty and Jacobs 1981; Romanowski 1998; Sainty and Jacobs 2003; Roberts and Marston 2011) and are restricted to areas with low salinity, protected from wave action (Frahn *et al.* 2014; Nicol *et al.* 2015). Most species present reproduce sexually and asexually (Sainty and Jacobs 1981; Romanowski 1998; 2003) and form a desiccation resistant seed bank (Nicol and Ward 2010a; 2010b). *Typha domingensis* and *Phragmites australis* are wind dispersed (Sainty and Jacobs 1981; Sainty and Jacobs 2003) but there is little information regarding the dispersal of other species, which are probably dispersed by water and/or animals.

Phragmites australis

Phragmites australis plants often form extensive, dense monospecific stands around the edges of lakes Alexandrina and Albert (Seaman 2003; Nicol *et al.* 2014b). *Phragmites australis* tend to occupy higher elevations (+09 to +0.4 m AHD) but will colonise deeper water (0 m AHD or deeper) especially in areas with steep banks that are protected from wave action (e.g. the lower Finniss

River) (Frahn *et al.* 2014). On exposed shorelines plants are restricted to the upper elevations (Gehrig *et al.* 2011a) and are important for controlling shoreline erosion (Hocking *et al.* 1983).

Phragmites australis primary mode of reproduction in the Lakes is by rhizomes (asexual) (Koch 2001) and viable seeds have not been detected in the seed bank (Nicol and Ward 2010a; 2010b); however, a small number of seedlings were observed in Lake Albert when water levels were drawn down (J. Nicol pers. obs.). Bailey *et al.* (2002) reported that *Phragmites australis* died at 15 gL^{-1} TDS; however, Gehrig *et al.* (2011a) observed healthy plants growing in areas where the surface water salinity exceeded 22 gL^{-1} (over 30,000 $\mu S.cm^{-1}$) in Goolwa Channel (Figure 2). *Phragmites australis* are good competitors and able to rapidly colonise large areas with clonal reproduction outcompeting other species but is susceptible to grazing and trampling by domestic stock (Hocking *et al.* 1983). When viable seed is produced it is dispersed by wind; hence, its cosmopolitan distribution (Sainty and Jacobs 1981; 2003 Hocking *et al.* 1983; Romanowski 1998). *Phragmites australis* prefers high soil moisture when not inundated but will persist for short periods when subjected to low soil moisture and senesce to rhizomes when subjected to extended desiccation (Hocking *et al.* 1983); however, the longevity of rhizomes under dry conditions is unknown.

Typha domingensis

Similar to *Phragmites australis, Typha domingensis* plants also form extensive monospecific stands around the shorelines of lakes Alexandrina and Albert (Seaman 2003; Nicol *et al.* 2014b). *Typha domingensis* generally colonise areas between +0.8 and 0 m AHD but will colonise slightly deeper water (around -0.2 m AHD) especially in areas with steep banks that are protected from wave action (e.g. the lower Finniss River, Clayton Bay, Dunns Lagoon) (Gehrig *et al.* 2012). They are probably more susceptible to wave action than *Phragmites australis* as they rarely form for large stands in areas with high wave action (Gehrig *et al.* 2012).

Typha domingensis reproduce both sexually and asexually (Sainty and Jacobs 1981; 2003; Finlayson *et al.* 1983; Romanowski 1998). Plants produce large numbers of seeds (>250,000 seeds in a single inflorescence) that are dispersed long distances by the wind (Finlayson *et al.* 1983) and form a soil seed bank (Nicol and Ward 2010a; 2010b). Seeds germinate on wet soil and when inundated to at least 70 cm (Nicol and Ganf 2000). In addition, *Typha domingensis* forms an extensive rhizome network and once established can rapidly colonise areas excluding other species (Finlayson *et al.* 1983). *Typha domingensis* also aerates the sediment and water column (e.g. Sorrell and Hawes 2010) and will grow in areas with high nutrient concentrations

(Kadlec and Wallace 2009). Bailey *et al.* (2002) reported that *Typha domingensis* died when exposed to surface water salinity of 15 gL^{-1}; however, Gehrig *et al.* (2011a) observed healthy plants growing in areas where the surface water salinity exceeded 22 gL^{-1} in Goolwa Channel (Figure 2).

Duma florulenta

Duma florulenta can also form large stands but at higher elevations than *Typha domingensis* and *Phragmites australis* (>+1 to +0.8 m AHD) (Gehrig *et al.* 2012). This species is widespread around the shorelines of lakes Alexandrina and Albert and usually not affected by wave action because it grows higher on the elevation gradient than most other amphibious and emergent taxa (Seaman 2003; Nicol *et al.* 2014b). Plants are intolerant of long-term inundation but will tolerate short-term inundation, and extended water logging and desiccation (Roberts and Marston 2011).

Duma florulenta reproduce sexually and asexually by fragmentation and layering but do not form a long-lived soil seed bank (Chong and Walker 2005). Bailey *et al.* (2002) reported the maximum salinity tolerance of this species as 4.4 gL^{-1}; however, it grows on the River Murray floodplain in areas with much higher soil salinity (Craig *et al.* 1991) and persisted in Goolwa Channel whilst the Clayton regulator was in operation and surface water salinities exceeded its reported maximum salinity tolerance (Gehrig and Nicol 2010a; Figure 2).

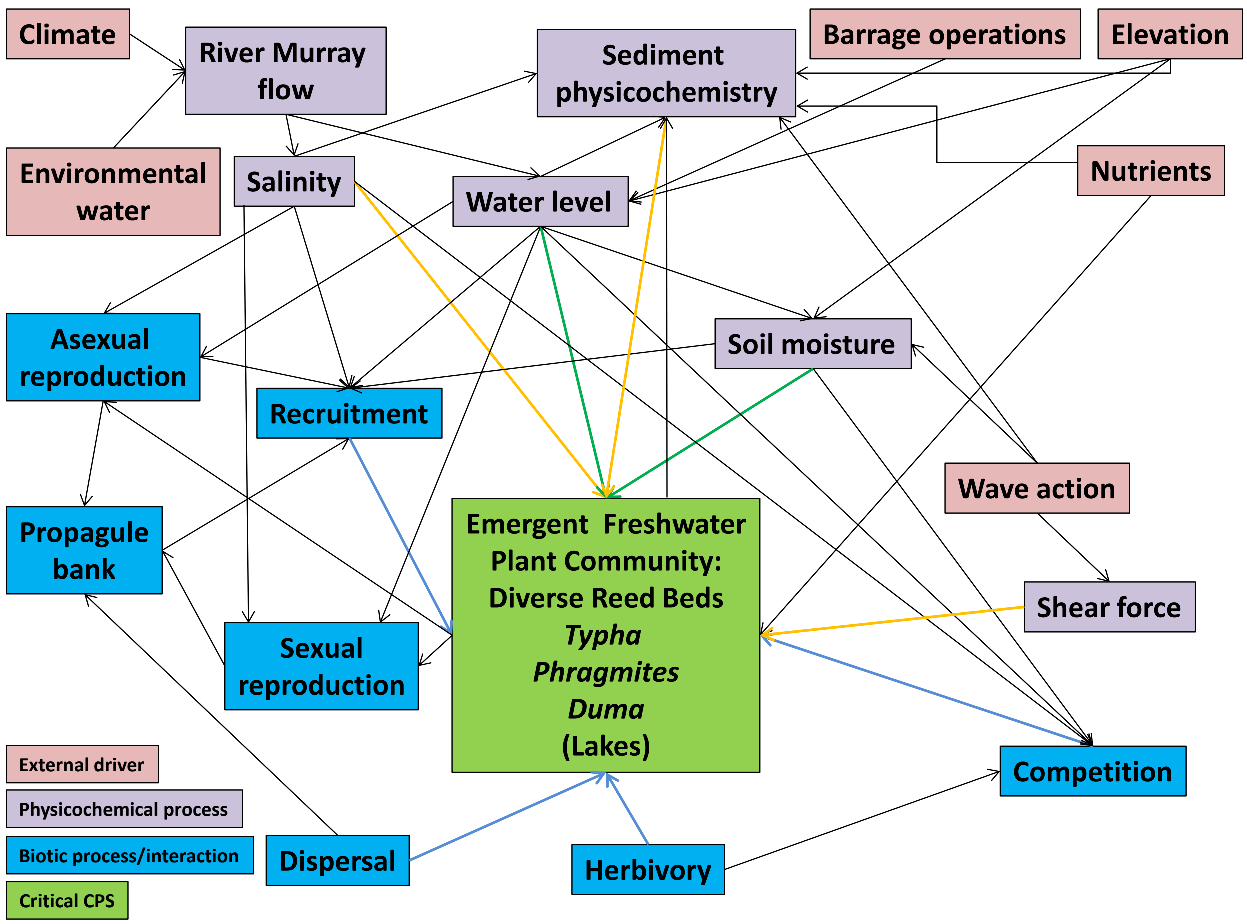

Figure 4: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of emergent freshwater plant communities in the Lakes.

Melaleuca halmaturorum

The conceptual model presented in Figure 5 outlines the key external drivers, physicochemical and biotic processes that determine the distribution and abundance of *Melaleuca halmaturorum* throughout the Coorong, Lakes and Murray Mouth region. *Melaleuca halmaturorum* is the dominant tree species in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland and forms small areas of closed woodlands downstream of Point Sturt (Seaman 2003; Marsland and Nicol 2009). *Melaleuca halmaturorum* is intolerant of medium-term flooding (particularly as juveniles) (Denton and Ganf 1994); therefore, is restricted to areas above +0.8 m AHD upstream of the barrages and +0.2 m AHD downstream of the barrages.

Reproduction is by seed, which germinates on exposed soil with high soil moisture (Nicol and Ganf 2000). Seed will not germinate under water and will lose viability when inundated for longer than four weeks (Nicol and Ganf 2000). This species does not form a soil seed bank but holds the seed in the canopy (an aerial seed bank or serotiny) (Rayamajhi *et al.* 2002). *Melaleuca halmaturorum* are highly salt tolerant and widespread throughout fresh to saline wetlands in south eastern Australia (Holliday 2004). However, it is not known whether lower salinity is required for germination and juvenile survivorship. The impact of other processes is not well understood but Cooke (1987) reported it was susceptible to herbivory by rabbits as juveniles.

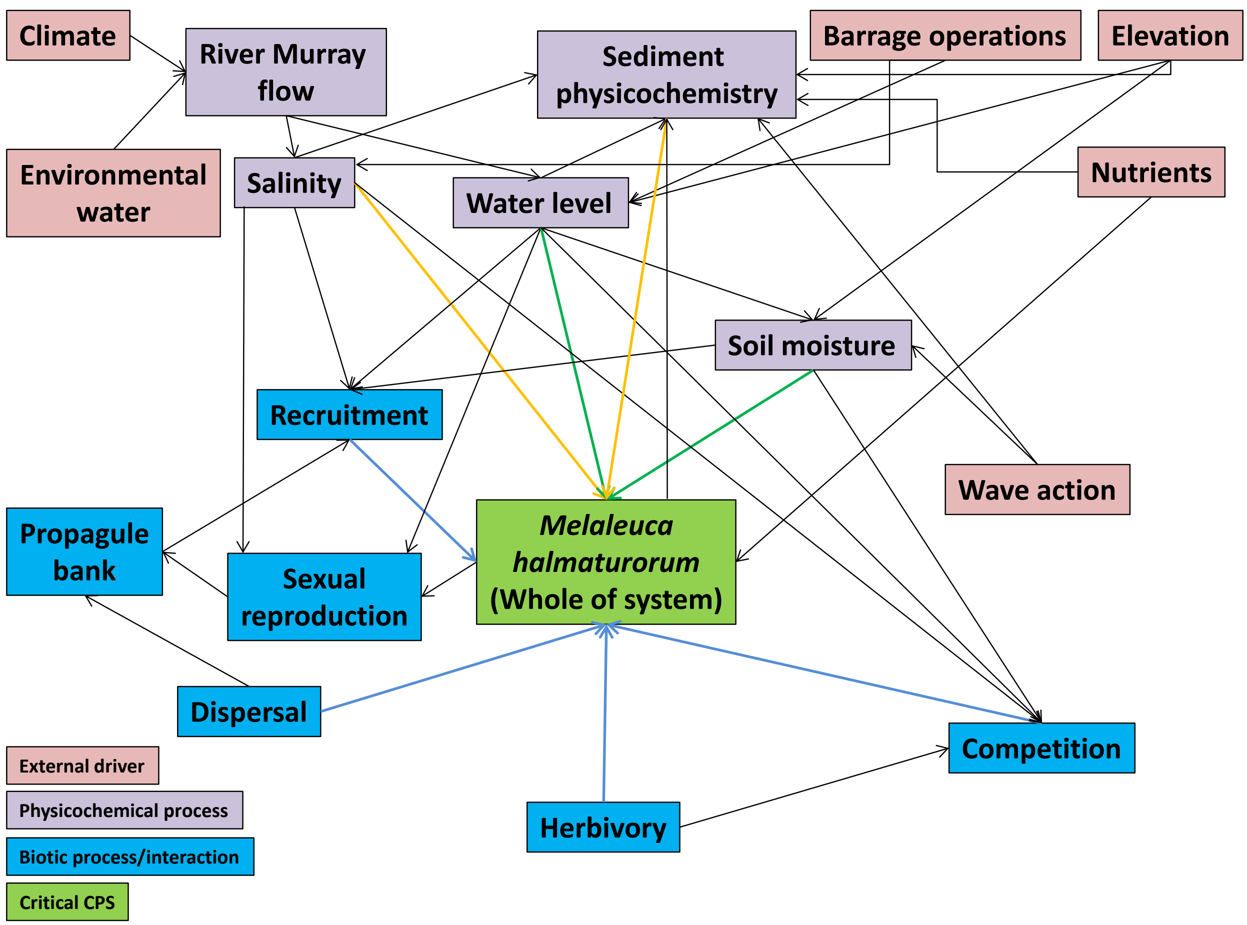

Figure 5: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of *Melaleuca halmaturorum* in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland.

Samphire and saltmarsh communities

The conceptual model presented in Figure 6 outlines the key external drivers, physicochemical and biotic processes that determine the distribution and abundance of samphire and salt marsh communities throughout the Coorong and Lakes Alexandrina and Albert Ramsar Wetland. Samphire and salt marsh communities are widespread throughout the Coorong and Lakes Alexandrina and Albert Ramsar Wetland in areas where there is moderate to high salinity (Seaman 2003). Most samphire and salt marsh species do not require high salinity (in fact they often have higher growth rates when grown at low salinities) but are out competed by species such as *Typha domingensis* or *Phragmites australis*; therefore, are restricted to areas with high salinity in nature (Ungar 1991). Taxa present in samphire and salt marsh communities in the Coorong, Lakes and Murray Mouth region include: *Tecticornia* spp., *Sarcocornia* spp., *Suaeda australis, Triglochin striatum, Juncus kraussii, Schoenoplectus pungens, Wilsonia rotundifolia* and *Samolus repens* (Frahn *et al.* 2014). Species are generally intolerant of long-term flooding but grow well in waterlogged soil (Sainty and Jacobs 1981; Romanowski 1998; Sainty and Jacobs 2003); hence, they are typically restricted to areas above +0.8 m AHD in the Lakes and above +0.2 m AHD in the Coorong. However, if water levels fall below +0.4 m AHD in the Lakes and +0.1 m AHD in the Coorong samphire and salt mash communities become disconnected from open water habitats that can result in a decline in recruitment and poor condition of existing plants.

With the exception of *Juncus kraussii* and *Schoenoplectus pungens* (which reproduce asexually with rhizomes), reproduction is by seed and all species form a soil seed bank (Nicol *et al.* 2003; Nicol and Ward 2010b). Germination occurs on wet soil and some species (e.g. *Juncus kraussii*) require salinities lower than they are able to tolerate as adults to germinate and survive while juveniles (Greenwood and MacFarlane 2006; Naidoo and Kift 2006). Little is known about the dispersal of samphire and salt marsh plants; however, it is likely they are dispersed by water and animals. The seeds of the samphire *Sarcocornia quinqueflora* are an important component of the diet of the EPBC listed orange bellied parrot (Mondon *et al.* 2009).

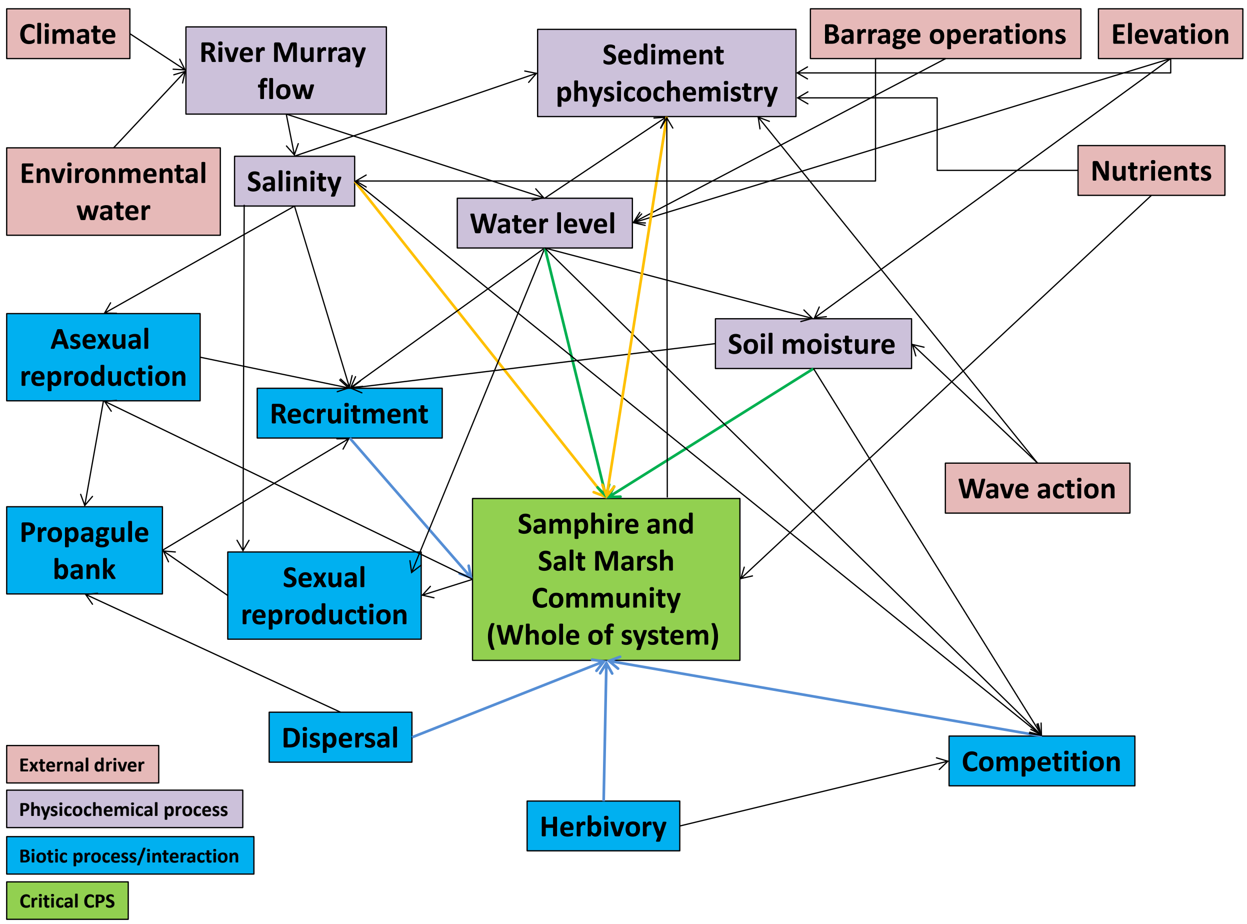

Figure 6: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of samphire and saltmarsh communities in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland.

Ruppia megacarpa

The conceptual model presented in Figure 7 outlines the key external drivers, physicochemical and biotic processes that determine the distribution and abundance of *Ruppia megacarpa* in the Murray estuary and North Lagoon of the Coorong. In the 1980s *Ruppia megacarpa* was the dominant submergent macrophyte in the North Lagoon of the Coorong and Murray estuary forming extensive beds throughout the aforementioned areas (Geddes and Butler 1984; Geddes 1987; Geddes and Hall 1990). Abundance declined throughout the 1990s and was distribution was restricted the Murray estuary (Edyvane *et al.* 1996), by 2002 it had become locally extinct (Nicol 2005) and there was no seed bank present in 2007 (Nicol 2007).

Ruppia megacarpa reproduces sexually and asexually (rhizomes) and will develop a desiccation resistant seed bank (Nicol and Ward 2010b; 2010a). The longevity of seed in the seed bank under different conditions is unknown. *Ruppia megacarpa* plants are intolerant of desiccation and exposure of five hours will result mortality (Adams and Bate 1994); hence, they require permanent water. The maximum salinity tolerance of *Ruppia megacarpa* is 46 gL^{-1}; however, plants did not flower when growing in water with salinity over 35 gL^{-1} and probably require lower salinity for germination and survival as juveniles (Brock 1979; Brock 1982a; Brock 1983). Therefore, flow through the barrages is required to lower salinity in the Murray estuary and North Lagoon of the Coorong to enable recruitment and reproduction. *Ruppia megacarpa* has cosmopolitan distribution that suggests it is a good disperser, with waterbirds and water the most likely vectors (Santamaria 2002; Nicol 2005; Triest and Sierens 2013).

Congdon and McComb (1979) reported that *Ruppia megacarpa* had a high light requirement and is restricted to shallow areas in turbid water bodies. During periods of high barrage outflows the turbidity in the Murray estuary and North Lagoon is higher compared with periods of low or no discharge; therefore, *Ruppia megacarpa* is probably restricted to shallow areas. Congdon and McComb (1981) reported that *Ruppia megacarpa* preferred areas with fine sediment and high organic matter content in areas with low current and wave action. In contrast, Carruthers *et al.* (1999) reported that *Ruppia megacarpa* was restricted to areas with coarse sediment but this may have been due to the areas with fine sediments being anoxic with high sulphide concentrations or in water too deep to support photosynthesis.

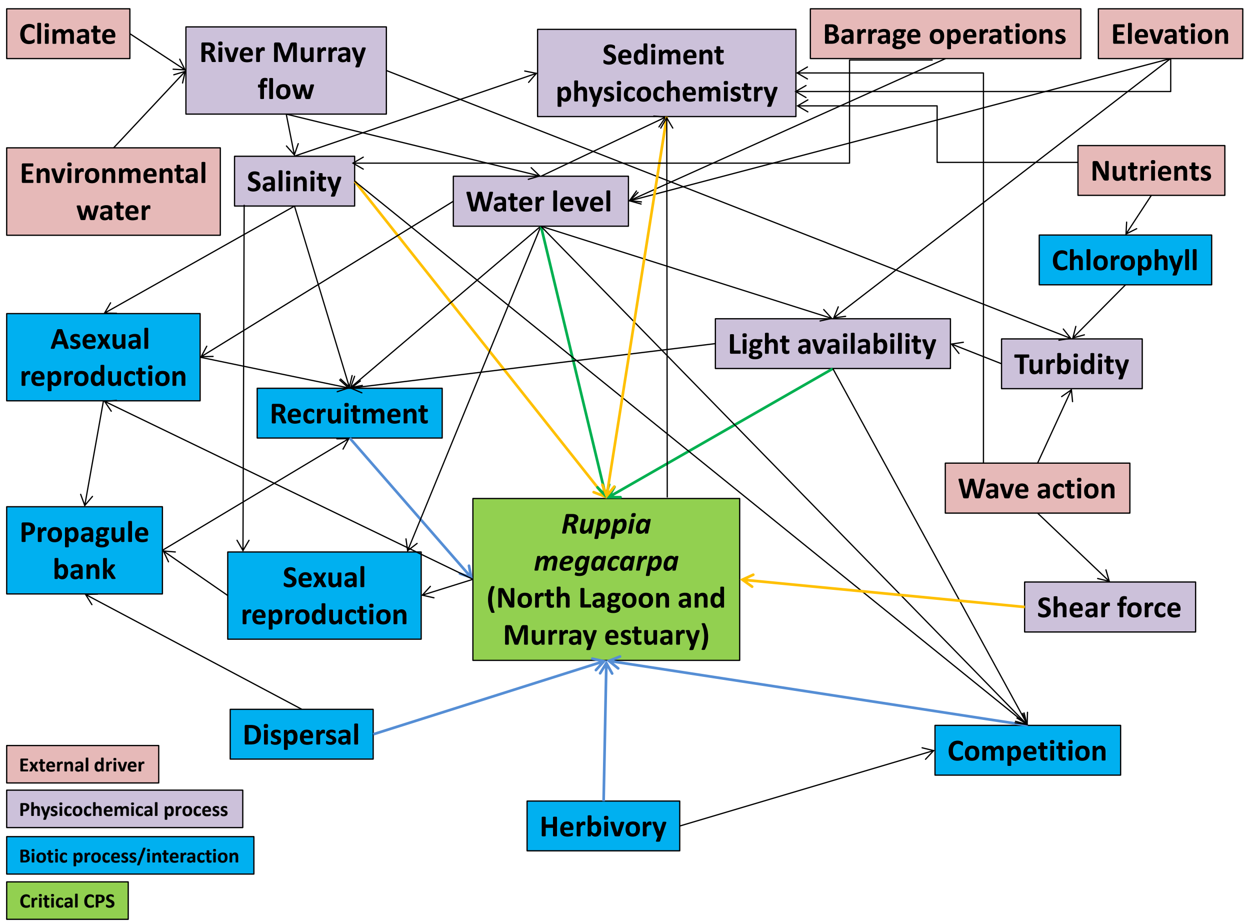

Figure 7: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of *Ruppia megacarpa* in the Murray estuary and North Lagoon of the Coorong.

Phragmites australis (Coorong)

Numerous freshwater soaks occur along the western shoreline of the Coorong (Sir Richard and Younghusband peninsulas) in areas where there is fresh groundwater discharge (freshwater soaks). There is a localised freshening of the surface water adjacent to the freshwater soaks, where *Phragmites australis* stands are often present. The main factor that influences the distribution and abundance of *Phragmites australis* is groundwater discharge (Figure 8), which needs to be sufficient to maintain the localised freshening to enable this species to persist. The main factor that influences discharge is recharge, which is from local rainfall that percolates through the sand dunes before it reaches an aquitard that causes it to discharge into the Coorong along the western shoreline. If there is a significant reduction in rainfall, recharge will also decrease leading to a decrease in discharge. However, there is no information regarding the relationship between rainfall, recharge and discharge for freshwater soaks or the time taken for water move through the aquifer. Freshwater soaks were important water sources for the Ngarrindjeri and are culturally import today (Phillips and Muller 2006).

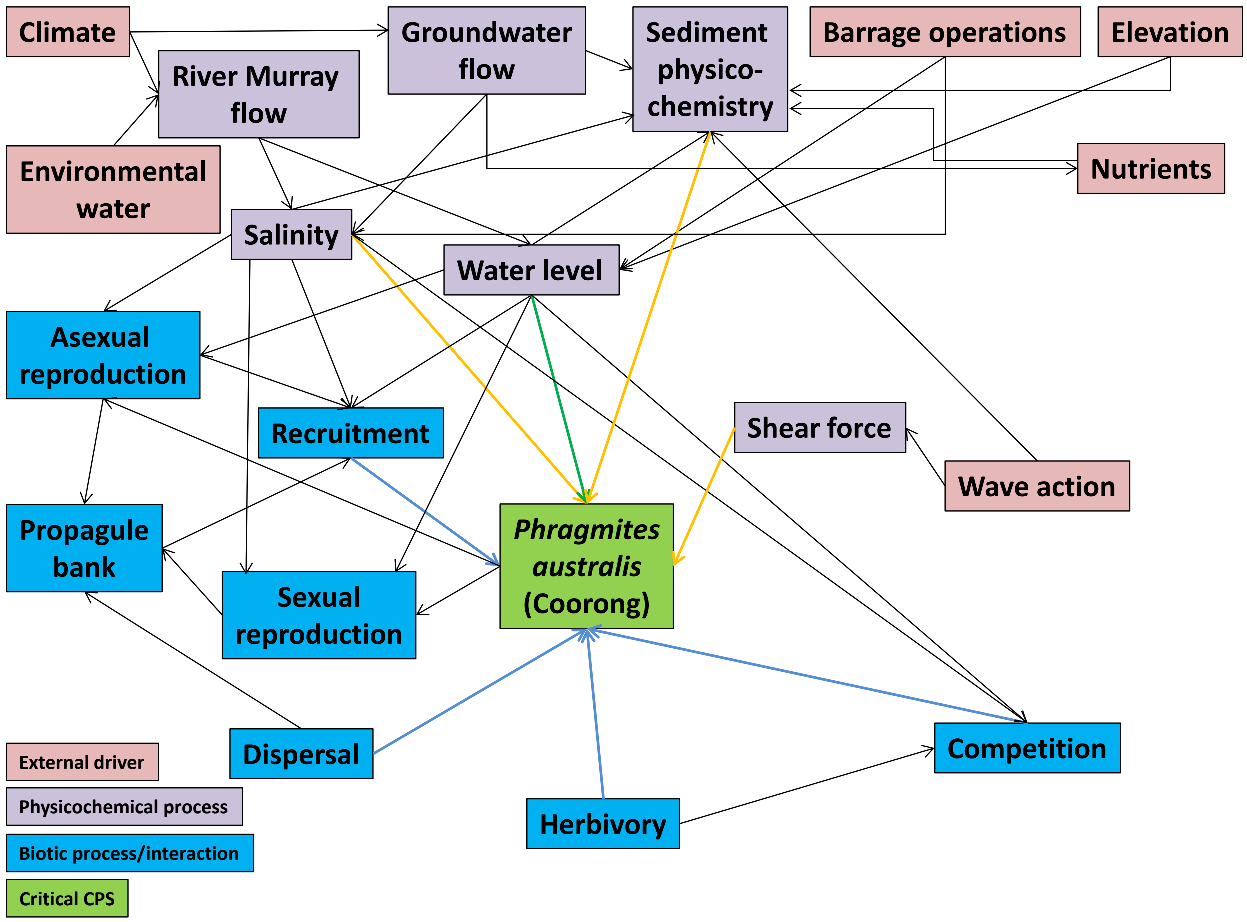

Figure 8: Conceptual model showing the key external drivers, physico-chemical and biotic processes that determine the distribution and abundance of *Phragmites australis* in the Coorong.

3.2. Limits of acceptable change for vegetation-related critical Components, Processes and Services

The LAC for the vegetation-related critical CPS were largely determined by expert opinion using conceptual models (*sensu* Davis and Brock 2008) due to a lack of data from when the site was listed. Data were taken into consideration (such as TLM vegetation condition monitoring data); however, the available data are insufficient to quantify the natural variability of the system that is required to determine data driven LAC.

In the Lakes, the two main drivers of the vegetation are hydrology (primarily water level) and salinity and if these two parameters are managed appropriately, it is likely that the extant vegetation will remain in an acceptable state and unlikely that there will be unacceptable change. Similarly, salinity is the main driver of *Ruppia megacarpa* abundance in the Murray estuary and North Lagoon and if salinity ranges are managed within the tolerances of *Ruppia megacarpa* unacceptable change is unlikely given an initial population that is in good condition.

To maintain aquatic and littoral vegetation in the Lakes it is important that water levels do not fall below +0.2 m AHD (+0.4 m AHD for samphire and salt marsh communities), which will result in fringing habitats drying, loss of submergent species and disconnection of fringing vegetation. Therefore, the water level LAC should be +0.2 m AHD with a management trigger at +0.4 m AHD. Monitoring has shown that the most species in the Lakes have a higher salinity tolerance than reported for other parts of Australia (Bailey *et al.* 2002; Gehrig *et al.* 2011a) but lower salinity resulted in vegetation that was in better condition and more diverse (Frahn *et al.* 2014). Therefore, the LAC for salinity in the Lakes is probably less critical than the water level LAC but a LAC in the Lakes of an average EC of 2,000 $\mu s.cm^{-1}$ with a management trigger of 1,500 $\mu s.cm^{-1}$ would be appropriate. Maintaining the water level and salinity within these ranges would probably result in diverse vegetation throughout the Lakes.

A salinity LAC for the Murray estuary and North Lagoon needs to take into consideration the requirements of *Ruppia megacarpa*. Whilst this species is generally believed to be locally extinct (Geddes 2005a; Geddes 2005b; Nicol 2007), it was common at the time of listing and any attempts at reintroduction will fail if water quality thresholds are exceeded. The salinity tolerance of adult *Ruppia megacarpa* plants is 46‰ TDS; therefore the LAC for salinity in the Murray estuary (the area where *Ruppia megacarpa* was last recorded; Edyvane *et al.* 1996) should be 46‰ TDS with a management trigger of 40‰ TDS. *Ruppia megacarpa* distribution was variable in the North Lagoon with the area of occupation changing in the 1970s and 1980s (Geddes and Butler 1984; Geddes 1987); therefore, an appropriate LAC for salinity for the North Lagoon is the northernmost 50% having an average salinity less than 46‰ TDS with a management trigger of 40‰ TDS and the southern half of the lagoon an average salinity of less than 50‰ TDS with a management trigger of 45‰ TDS.

The LAC targets and management triggers for the vegetation-related CPS proposed in the following sections are based on spatial extent in the system, except the LAC for *Typha domingensis* and *Phragmites australis*, which are based on extent and combined cover of the two species (Table 5). This approach will require a different monitoring approach than used for TLM; however, it is data that could be collected relatively inexpensively and in some cases remotely sensed using high resolution airborne videography. For example, Nicol *et al.* (2014b) were able to undertake the field component of mapping emergent plant communities on the shorelines of the Lakes in three days and Gehrig *et al.* (2011a) able to complete the field component of mapping plant communities in Goolwa Channel, the lower Finniss River and lower Currency Creek in two days. Furthermore, data collected annually will provide information regarding temporal changes in the extent of vegetation-related CPS, determine relationships with climate, hydrology and salinity and in the future provide data based LAC for the vegetation-related CPS for the system.

Table 5: List of vegetation-related critical CPS, LAC and management triggers based on spatial coverage.

	Point at which LAC is exceeded		**Management Trigger**	
Critical CPS	**Minimum Spatial Extent**	**Maximum Spatial Extent**	**Minimum Spatial Extent**	**Maximum Spatial Extent**
Freshwater submergent plant communities	Complete loss of freshwater submergent vegetation	NA	Autumn 2015 extent	NA
Phragmites australis (Lakes)	NA	50% of shoreline with a combined cover of *Typha* and *Phragmites* >75%	NA	40% of shoreline with a combined cover of *Typha* and *Phragmites* >75%
Typha domingensis	NA	50% of shoreline with a combined cover of *Typha* and *Phragmites* >75%	NA	40% of shoreline with a combined cover of *Typha* and *Phragmites* >75%
Duma florulenta	Complete loss of *Duma florulenta*	NA	Autumn 2015 extent - 50%	NA
Diverse reed beds	Complete loss of diverse reed beds	NA	Autumn 2015 extent	NA
Melaleuca halmaturorum	Complete loss of *Melaleuca halmaturorum*	NA	Autumn 2015 extent - 50%	NA
Samphire and salt marsh communities	Complete loss of samphire and saltmarsh communities	NA	Autumn 2015 extent - 50%	NA
Ruppia megacarpa	Complete loss of *Ruppia megacarpa*	NA	1995 extent	NA
Phragmites australis (Coorong)	Complete loss of *Phragmites australis* in the Coorong	NA	Autumn 2015 extent	NA

Submergent freshwater plant communities

Submergent freshwater plants were completely lost from the site between 2007 and 2009 (i.e. LAC exceeded) but have recolonised extensive areas but not to the extent prior to the drought and have been increasing and spatial coverage in recent years (Frahn *et al.* 2014). The spatial coverage of submergent species nearly five years after water levels were reinstated probably represents a point when management action should be taken to protect this CPS. The autumn 2015 extent also represented a level that is close to the TLM targets for Lake Alexandrina and Goolwa Channel.

Phragmites australis* (Lakes) and *Typha domingensis

Phragmites australis and *Typha domingensis* are important components of the vegetation of the Lakes; however, they can form dense stands that potentially exclude other species (Frahn *et al.* 2014; Nicol *et al.* 2014b). This can lead to reduced habitat diversity at the site scale; hence, LAC for these species relate to a maximum spatial extent (Table 5). The Living Murray for targets *Phragmites australis* and *Typha domingensis* are also based on maximum limits and the management trigger (40% of the shoreline) corresponds with the revised TLM target. The proposed LAC for *Phragmites australis* and *Typha domingensis* is 50% of the shoreline of the Lakes having a combined cover of the two species of over 75% (Table 5), which would represent a loss in shoreline habitat diversity.

Duma florulenta

Duma florulenta was one of the few species that was not greatly impacted by the drought and the change in abundance between 2007 and 2010 was not significant (Frahn *et al.* 2014). A management trigger of 50% loss of current cover (Table 5) will provide sufficient opportunity to undertake interventions to prevent the LAC of complete loss from the system from being reached.

Diverse reed beds

Diverse reed beds typically contain native amphibious, emergent species (other than *Phragmites australis* and *Typha domingensis*) and submergent species in addition to *Phragmites australis* and *Typha domingensis* (which are often the most abundant species but cover typically have a combined cover of less than 75%) (Frahn *et al.* 2014; Nicol *et al.* 2015). Many of the species that are present in diverse reed beds were extirpated between 2007 and 2010, but were present in the seed bank (Nicol and Ward 2010b). Similar to submergent freshwater plant communities, the spatial coverage of diverse reed beds nearly five years after water levels were reinstated probably represents a point at which management interventions could be undertaken to ensure the LAC is not exceeded.

Melaleuca halmaturorum

Similar to *Duma florulenta*, *Melaleuca halmaturorum* was a species that was not greatly affected by low water levels between 2007 and 2010 (Frahn *et al.* 2014). A management trigger of 50% loss of current cover (Table 5) will provide sufficient opportunity to undertake interventions to prevent the LAC of complete loss from the system from being reached.

Samphire and saltmarsh communities

The change in the distribution and abundance of samphire and saltmarsh species was not well documented during the period of low water levels between 2007 and 2010 in the Lakes or during periods of extend closure of the barrages during the drought. A management trigger of 50% loss of current cover (Table 5) will provide sufficient opportunity to undertake interventions to prevent the LAC of complete loss from the system from being reached.

Ruppia megacarpa

The distribution and abundance of *Ruppia megacarpa* in the North Lagoon of the Coorong and Murray estuary has generally been in decline since the Coorong and Lakes Alexandrina and Albert Ramsar Wetland was listed (Nicol 2005). Whilst there were data available at the time of listing (Geddes and Butler 1984; Geddes 1987), it did not provide an indication of the spatial and temporal dynamics of the *Ruppia megacarpa* population in the system. The spatial extent reported by Edyvane *et al.* (1996) probably represents when management interventions need to be undertaken to prevent the LAC from being exceeded. The Murray estuary between Goolwa and Tauwitchere could serve as a refuge during periods of unfavourable salinity in the North Lagoon and provide a source population for expansion during periods of favourable salinity.

***Phragmites australis* (Coorong)**

There is no information regarding the distribution of freshwater soaks and associated population of *Phragmites australis* along the northern shorelines of the Sir Richard and Younghusband peninsulas. Due to the lack of information, the management trigger is defined as a reduction in the current (autumn 2015) spatial extent of 50% that probably represents a point at which interventions could be undertaken to prevent the LAC from being exceeded.

4. DISCUSSION OF LIMITS OF ACCEPTABLE CHANGE ASSESSMENTS AND CURRENT ECOLOGICAL CHARACTER OF THE WETLAND

Limits of Acceptable Change (LAC) and management triggers were determined using conceptual models and expert opinion due to the paucity of vegetation data from when the wetland was listed and the absence of a long-term monitoring program until 2008. Therefore, the LAC and management triggers that are proposed in this document should be reviewed when more data become available to ensure that changes observed do in fact require management interventions and are not due to natural variability. To properly define LAC, a long-term monitoring program is required. The Living Murray vegetation condition monitoring for the Lakes and *Schoenoplectus* planting monitoring could provide some of the information required; however, the data are collected at a small scale (quadrats) and the data required to inform LAC and ECD need to be collected at the site scale (*sensu* Seaman 2003).

Area of occupation or spatial coverage based LAC for the vegetation-related critical CPS will provide landscape scale data and changes in coverage, over time, will result in understanding of the variability of the system and data driven LAC and management triggers will be developed. The suggested management triggers were developed to ensure there was opportunity to undertake interventions to prevent LAC from being exceeded. This will require a monitoring program (in addition to TLM) to be established to map vegetation-related critical CPS; however, much of the data may be able to be remotely sensed using high resolution airborne photography or videography or captured using unmanned aerial vehicles (drones). The extent of most vegetation-related critical CPS would be able to be mapped in this manner, except *Ruppia megacarpa,* submergent freshwater plant communities (although areas of dense submergent vegetation may be able to be identified) and diverse reed beds (although *Schoenoplectus tabernaemontani* and *Duma florulenta* may be used as indicators of this CPS). Furthermore, the data collected in Seaman (2003) could serve as a baseline to inform temporal changes in CPS to develop data driven LAC.

To prevent LAC being exceeded, interventions need to be identified, undertaken and monitored to ensure they have been effective. The primary intervention available for the Coorong and Lakes Alexandrina and Albert Ramsar Wetland is water allocation planning and delivery of environmental water. The delivery of water to the Lakes controls water level and salinity, the two primary divers of the distribution and abundance of plant species. Therefore, providing appropriate water and salinity regimes may prevent LAC from being exceeded. In addition to the provision of water to the site, there are other interventions that can be undertaken to prevent LAC of vegetation-related critical CPS being exceeded. The two main interventions that have been undertaken that apply to vegetation-related critical CPS are planting (revegetation) and lakeshore fencing. Planting *Schoenoplectus tabernaemontani* in 50 to 80 cm of water around the edges of lakes Alexandrina and Albert has resulted in increased species richness of native emergent, submergent and amphibious species along planted shorelines (Nicol *et al.* 2016), which has resulted in increased area of diverse reed beds. *Melaleuca halmaturorum* has been planted around the edges of the several wetlands in the Lakes at elevations between +0.8 and 1 m AHD and survivorship has been high, which when trees mature, will in time increase the area of *Melaleuca halmaturorum* woodlands (Frahn *et al.* 2014). Lakeshore fencing has had mixed results, shorelines grazed by domestic stock are often devoid of vegetation and subject to erosion; however, the exclusion of domestic stock often results in shorelines dominated by exotic clonal grasses such as *Paspalum distichum* and *Cenchrus clandestinus* (Frahn *et al.* 2014). Therefore, short duration high intensity grazing (i.e. crash grazing) by domestic stock in late summer and autumn when water levels are at their lowest may be a management option to reduce biomass of the aforementioned species and provide opportunities for the recruitment of native amphibious and emergent species.

Despite all the changes that have occurred in the Coorong and Lakes Alexandrina and Albert Ramsar Wetland since listing, the justification for listing from a vegetation perspective has not changed and the current Ramsar Information Sheet requires little updating. Currently over 90% of the Lakes is open water habitat with no vegetation, the shorelines are dominated by emergent species, primarily *Typha domingensis* and *Phragmites australis* (Frahn *et al.* 2014; Nicol *et al.* 2014b). Nevertheless, diverse reed beds are present along the western shorelines of lakes Alexandrina and Albert, throughout Goolwa Channel (including the lower reaches of the Finniss River and Currency Creek) (Frahn *et al.* 2014; Nicol *et al.* 2014b), in shoreline wetlands (Frahn *et al.* 2014) and areas where *Schoenoplectus tabernaemontani* has been planted (Nicol *et al.* 2015). Diverse submergent herblands are present throughout Goolwa Channel in permanent shoreline wetlands and associated with diverse reed beds (Frahn *et al.* 2014; Nicol *et al.* 2015). Samphire and saltmarsh communities are present in areas with elevated salinity (including temporary wetlands, such as Poltalloch, Waltowa and Point Sturt wetlands). *Melaleuca halmaturorum* woodlands have changed very little over recent years and form small closed woodlands around the mouth of Hunters Creek, along the southern shorelines of lakes Alexandrina and Albert and on Goose and Goat islands (Frahn *et al.* 2013). However, *Ruppia megacarpa* has become locally extinct in the Coorong and Murray estuary (Geddes 2005a; 2005b; Nicol 2007).

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APPENDICES

Appendix 1: Species list, functional classification (Gehrig and Nicol 2010b), life history strategy and conservation status (state conservation status from listings in Barker *et al.* (2005) and regional conservation status from listings in Lang and Kaeheneuhl (2001) vegetation studies undertaken in the Lakes from 1989 to the present day (*denotes exotic taxon, **denotes proclaimed pest plant in South Australia, ***denotes weed of national significance # denotes listed as rare in South Australia).

				Species Records							
Taxon	**Functional Group**	**Life history strategy**	**Status and Comments**	**The Aquatic Flora of Hindmarsh Island (Renfrey *et al.* 1989)**	**2004 River Murray Wetlands Baseline Survey (Holt *et al.* 2005)**	**2005 River Murray Wetlands Baseline Survey (Nicol *et al.* 2006)**	**Goolwa Channel seed bank assessment (Nicol and Ward 2010b)**	**Dunns Lagoon and Shadows Lagoon seed bank assessment (Nicol and Ward 2010a)**	**Aquatic and littoral vegetation monitoring of Goolwa Channel, the lower Finniss River and Lower Currency Creek (Gehrig *et al.* 2011a)**	***Schoenoplectus* planting monitoring (Nicol *et al.* 2015)**	**The Living Murray Vegetation Condition Monitoring for the Lakes (Frahn *et al.* 2014)**
Acacia myrtifolia	Terrestrial dry	Perennial	Native								*
*Agapanthus praecox**	Terrestrial dry	Perennial	Exotic								*
*Anagallis arvensis**	Terrestrial damp	Annual	Exotic				*				*
*Apium graveolens**	Terrestrial damp	Annual	Exotic	*					*	*	*
*Arctotheca calendula**	Terrestrial dry	Annual	Exotic			*			*		*
*Asparagus asparagoides****	Terrestrial dry	Perennial	Exotic-Proclaimed pest plant in SA and weed of national significance								*
*Asparagus officinalis**	Terrestrial dry	Perennial	Exotic								*
*Asphodelus fistulosus***	Terrestrial dry	Perennial	Exotic-Proclaimed pest plant in SA								*
*Aster subulatus**	Terrestrial damp	Annual	Exotic	*	*	*	*		*	*	*
Atriplex paludosa	Terrestrial dry	Perennial	Native	*							
*Atriplex prostrata**	Terrestrial damp	Perennial	Exotic			*	*		*	*	*
Atriplex semibaccata	Terrestrial dry	Perennial	Native-Listed as Uncommon in the Murray Region	*	*	*			*	*	*
Atriplex stipitata	Terrestrial dry	Perennial	Native						*		*
Atriplex suberecta	Floodplain	Perennial	Native						*		*
Avena spp.*	Terrestrial dry	Annual	Exotic-*Avena* spp. is comprised of *Avena barbata* and *Avena fatua*		*	*			*		*
Azolla filiculoides	Floating	Perennial	Native	*	*	*			*	*	*
Azolla pinnata	Floating	Perennial	Native		*						
Baumea juncea	Amphibious fluctuation tolerator-emergent	Perennial	Native	*							*
Berula erecta	Emergent	Perennial	Native	*	*	*				*	*
Bolboschoenus caldwellii	Emergent	Perennial	Native	*	*	*	*		*	*	*
*Brassica rapa**	Terrestrial dry	Annual	Exotic							*	*
*Brassica tournifortii**	Terrestrial dry	Annual	Exotic						*	*	*
*Briza minor**	Terrestrial dry	Annual	Exotic						*		*
*Bromus catharticus**	Terrestrial dry	Annual	Exotic			*	*		*		*
*Bromus diandrus**	Terrestrial dry	Annual	Exotic		*	*	*		*		*
Bromus hordeaceus ssp. *hordeaceus**	Terrestrial dry	Annual	Exotic				*		*		*
*Bromus rubens**	Terrestrial dry	Annual	Exotic								*
*Callitriche stagnalis**	Amphibious fluctuation tolerator-low growing	Annual	Exotic				*				
Calystegia sepium	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Uncommon in the Murray and Southern Lofty Regions	*	*				*	*	*
Carex fasicularis	Amphibious fluctuation tolerator-emergent	Perennial	Native								*
Carpobrotus rossii	Terrestrial dry	Perennial	Native	*		*					*
*Cenchrus clandestinus**	Terrestrial dry	Perennial	Exotic	*	*		*			*	*
*Centaurea calcitrapa**	Terrestrial damp	Annual	Exotic				*		*	*	*
*Centaurium tenuiflorum**	Terrestrial damp	Annual	Exotic						*		*

				Species Records							
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Centella asiatica	Amphibious fluctuation responder-plastic	Perennial	Native		*					*	*
Ceratophyllum demersum#	Submergent k-selected	Perennial	Native-Listed as Rare in South Australia	*		*				*	*
Chara spp.	Submergent r-selected	Annual	Native				*	*		*	*
*Chenopodium album**	Terrestrial damp	Annual	Exotic				*				*
*Chenopodium glaucum**	Terrestrial damp	Annual	Exotic						*		*
Chenopodium nitrariaceum	Terrestrial dry	Perennial	Native						*		*
*Cirsium vulgare**	Terrestrial damp	Annual	Exotic		*						
*Conyza bonariensis**	Terrestrial damp	Annual	Exotic				*		*		*
*Cotula bipinnata**	Amphibious fluctuation responder-plastic	Perennial	Exotic		*						
*Cotula coronopifolia**	Amphibious fluctuation responder-plastic	Perennial	Exotic	*	*	*	*		*	*	*
Cotula vulgaris	Amphibious fluctuation responder-plastic	Perennial	Native		*						
Crassula helmsii	Amphibious fluctuation tolerator-low growing	Perennial	Native	*	*	*	*	*		*	*
Crinum sp.*	Terrestrial dry	Perennial	Exotic-garden escapee not in any of the identification keys and could not be identified to species, probably a horticultural hybrid								*
*Cynodon dactylon**	Terrestrial dry	Perennial	Exotic	*	*	*					
Cyperus exaltatus	Amphibious fluctuation tolerator-emergent	Perennial	Native						*		*
Cyperus gymnocaulos	Amphibious fluctuation tolerator-emergent	Perennial	Native	*		*	*		*	*	*
Dianella revoluta	Terrestrial dry	Perennial	Native								*
Disphyma crassifolium	Terrestrial dry	Perennial	Native	*							*
Distichlis distichophylla	Terrestrial damp	Perennial	Native-Listed as Uncommon in the Murray Region	*		*			*	*	*
Duma florulenta	Amphibious fluctuation tolerator-woody	Perennial	Native	*	*	*			*	*	*
*Echinochloa crus-galli**	Terrestrial damp	Annual	Exotic								*
*Ehrharta longiflora**	Terrestrial damp	Annual	Exotic		*				*		*
Einadia nutans	Terrestrial dry	Perennial	Native						*		*
Eleocharis acuta	Emergent	Perennial	Native	*	*	*				*	*
Eleocharis sphacelata	Emergent	Perennial	Native			*					
Enchylaena tomentosa	Terrestrial dry	Perennial	Native	*	*	*			*		*
Epilobium pallidiflorum	Terrestrial damp	Perennial	Native-Listed as Uncertain in the Murray Region and uncommon in the Southern Lofty Region	*	*		*			*	*

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Eragrostis australasica	Floodplain	Perennial	Native								*
*Eragrostis curvula***	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA	*	*	*	*		*		*
Eragrostis sp.	Terrestrial damp	Annual	Native-could not identify to species			*			*		*
*Erodium cicutarium**	Terrestrial dry	Annual	Exotic								*
*Euphorbia terracina***	Terrestrial dry	Annual	Exotic-Proclaimed pest plant in SA	*		*				*	*
*Festuca arundinacea**	Terrestrial dry	Perennial	Exotic	*						*	
Ficinia nodosa	Amphibious fluctuation tolerator-emergent	Perennial	Native	*					*	*	*
*Foeniculum vulgare**	Terrestrial damp	Annual	Exotic						*		*
Frankenia pauciflora	Terrestrial dry	Perennial	Native	*	*						*
*Fumaria bastardii**	Terrestrial damp	Annual	Exotic						*	*	*
Gahnia filum	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Murray and Southern Lofty Regions	*	*	*					*
*Galenia secunda**	Terrestrial dry	Annual	Exotic		*						
Glyceria australis	Emergent	Perennial	Native								*
Helichrysum luteo-album	Floodplain	Annual	Native						*	*	*
*Heliotropium europaeum**	Floodplain	Annual	Exotic								*
*Holcus lanatus**	Terrestrial damp	Annual	Exotic								*
*Hordeum vulgare**	Terrestrial dry	Annual	Exotic	*	*				*		*
Hydrocotyle verticillata	Amphibious fluctuation responder-plastic	Perennial	Native-Listed as Uncertain in the Southern Lofty Region	*	*	*				*	*
*Hypochoeris glabra**	Terrestrial dry	Annual	Exotic			*	*		*	*	*
*Hypochoeris radicata**	Terrestrial dry	Annual	Exotic				*			*	*
Iris spp.*	Terrestrial dry	Perennial	Exotic								*
Isolepis platycarpa	Amphibious fluctuation tolerator-low growing	Perennial	Native	*			*		*		*
Isolepis producta	Amphibious fluctuation tolerator-low growing	Perennial	Native		*		*			*	*
*Juncus acutus**	Amphibious fluctuation tolerator-emergent	Perennial	Exotic	*					*	*	*
Juncus holoschoenus	Amphibious fluctuation tolerator-emergent	Perennial	Native	*						*	*
Juncus kraussii	Amphibious fluctuation tolerator-emergent	Perennial	Native	*	*	*	*		*	*	*
Juncus pallidus	Amphibious fluctuation tolerator-emergent	Perennial	Native	*							
Juncus subsecundus	Amphibious fluctuation tolerator-emergent	Perennial	Native							*	*
Juncus usitatus	Amphibious fluctuation tolerator-emergent	Perennial	Native			*			*	*	*
Lachnagrostis filiformis	Floodplain	Annual	Native			*	*		*	*	*
*Lactuca saligna**	Terrestrial dry	Annual	Exotic						*		*

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*Lactuca serriola**	Terrestrial dry	Annual	Exotic						*	*	*
*Lagurus ovatus**	Terrestrial dry	Annual	Exotic						*	*	*
Lamprothamnium macropogon	Submergent r-selected	Annual	Native	*							*
Lemna disperma	Floating	Perennial	Native		*	*				*	*
Lepidium bonariense	Floodplain	Annual	Native			*					
Lepilaena australis	Submergent r-selected	Perennial	Native		*						
Lepilaena cylindrocarpa	Submergent r-selected	Perennial	Native		*						
Lilaeopsis polyantha	Amphibious fluctuation tolerator-low growing	Perennial	Native		*		*			*	
Limosella australis	Amphibious fluctuation responder-plastic	Perennial	Native	*						*	*
Lobelia anceps	Terrestrial damp	Perennial	Native				*		*	*	*
Lolium spp.*	Terrestrial dry	Annual	Exotic-*Lolium* spp. comprises of *Lolium perenne* and *Lolium rigidum*	*	*	*	*		*		*
Ludwigia peploides ssp. *montevidensis*	Amphibious fluctuation responder-plastic	Perennial	Native	*	*	*					*
*Lupinus cosentinii**	Terrestrial dry	Annual	Exotic						*		*
*Lycium ferocissimum****	Terrestrial dry	Perennial	Exotic-Proclaimed pest plant in SA and weed of national significance		*					*	*
Lycopus australis	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Murray Region		*		*		*	*	*
Lythrum hyssopifolia	Amphibious fluctuation tolerator-emergent	Perennial	Native	*	*	*					*
Lythrum salicaria	Amphibious fluctuation tolerator-emergent	Perennial	Native							*	*
Maireana microcarpa	Terrestrial dry	Perennial	Native			*					
Maireana oppositifolia	Terrestrial dry	Perennial	Native	*							
*Malva parviflora**	Terrestrial dry	Annual	Exotic			*					*
*Marrubium vulgare***	Terrestrial dry	Annual	Exotic	*		*					*
Medicago spp.*	Terrestrial dry	Annual	Exotic-*Medicago* spp. comprises of *Medicago polymorpha, Medicago truncatula* and *Medicago minima*	*	*	*	*		*	*	*
Melaleuca halmaturorum	Amphibious fluctuation tolerator-woody	Perennial	Native	*		*					*
*Melilotus albus**	Terrestrial dry	Annual	Exotic								*
*Melilotus indicus**	Terrestrial dry	Annual	Exotic		*				*	*	*
Mentha australis	Amphibious fluctuation tolerator-emergent	Perennial	Native	*							*

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Mentha spp.*	Amphibious fluctuation tolerator-emergent	Perennial	Exotic-*Mentha* spp. comprises of *Mentha piperita, Mentha pulegium* and *Mentha spicata*	*	*				*		*
Mimulus repens	Amphibious fluctuation tolerator-low growing	Perennial	Native	*	*	*			*	*	*
Muehlenbeckia gunnii	Terrestrial dry	Perennial	Native		*						*
Myriophyllum caput-medusae	Submergent k-selected	Perennial	Native		*	*	*				*
Myriophyllum salsugineum	Submergent k-selected	Perennial	Native-Listed as Uncertain in the Southern Lofty Region	*	*	*	*	*	*	*	*
Myriophyllum siumulans	Submergent k-selected	Perennial	Native		*						
Nitella sp.	Submergent r-selected	Perennial	Native					*		*	
*Oenothera stricta**	Terrestrial dry	Annual	Exotic				*				
*Onopordum acanthium**	Terrestrial damp	Annual	Exotic			*					*
*Oxalis pes-caprae***	Terrestrial dry	Annual	Exotic-Proclaimed pest plant in SA							*	*
*Paspalum dilatatum**	Terrestrial damp	Perennial	Exotic		*						
*Paspalum distichum**	Terrestrial damp	Perennial	Exotic	*	*	*			*	*	*
Persicaria lapathifolia	Amphibious fluctuation responder-plastic	Perennial	Native		*	*	*		*	*	*
*Phalaris arundinacea**	Amphibious fluctuation tolerator-emergent	Perennial	Exotic								*
Phragmites australis	Emergent	Perennial	Native	*	*	*			*	*	*
*Phyla canescens**	Amphibious fluctuation tolerator-low growing	Perennial	Exotic								*
Picris angustifolia ssp. *angustifolia*	Terrestrial dry	Annual	Native						*		*
*Plantago coronopus**	Terrestrial dry	Annual	Exotic		*	*	*		*	*	*
*Plantago lanceolata**	Terrestrial dry	Annual	Exotic						*		*
*Plantago major**	Terrestrial dry	Annual	Exotic								*
*Poa annua**	Terrestrial damp	Annual	Exotic			*	*				*
*Polygonum aviculare**	Terrestrial dry	Perennial	Exotic	*		*	*		*		*
*Polypogon monspeliensis**	Amphibious fluctuation tolerator-emergent	Annual	Exotic	*	*	*			*	*	*
Portulaca oleracea		Perennial	Native				*				
Potamogeton crispus	Submergent k-selected	Perennial	Native		*	*	*			*	*
Potamogeton pectinatus	Submergent k-selected	Perennial	Native		*	*	*	*	*	*	*
Puccinellia sp.*	Terrestrial damp	Annual	Exotic-could not be identified to species but was not *Puccinellia stricta* or *Puccinellia perlaxa*	*	*						*
Ranunculus amphitrichus	Amphibious fluctuation responder-plastic	Perennial	Native		*						

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Ranunculus rivularis	Amphibious fluctuation responder-plastic	Perennial	Native	*							
*Ranunculus trichophyllus**	Submergent r-selected	Annual	Exotic			*					*
*Ranunculus trilobus**	Amphibious fluctuation tolerator-emergent	Annual	Exotic			*	*			*	*
*Reichardia tingitana**	Terrestrial dry	Annual	Exotic						*	*	*
Rhagodia spinescens	Terrestrial dry	Perennial	Native								*
*Rorippa nasturtium-aquaticum**	Amphibious fluctuation responder-plastic	Annual	Exotic								*
*Romulea rosea**	Terrestrial dry	Annual	Exotic				*				
*Rorippa palustris**	Floodplain	Annual	Exotic								*
Rumex bidens	Amphibious fluctuation responder-plastic	Perennial	Native	*	*	*				*	*
*Rumex conglomeratus**	Amphibious fluctuation responder-plastic	Perennial	Exotic	*	*						
*Rumex crispus**	Amphibious fluctuation responder-plastic	Perennial	Exotic	*							
Ruppia megacarpa	Submergent k-selected	Perennial	Native	*		*	*	*			*
Ruppia polycarpa	Submergent r-selected	Annual	Native	*	*	*	*	*			*
Ruppia tuberosa	Submergent r-selected	Annual	Native	*	*	*	*	*		*	*
*Salix babylonica**	Emergent	Perennial	Exotic		*				*		*
Salsola australis	Terrestrial dry	Perennial	Native								*
Samolus repens	Terrestrial damp	Perennial	Native- Listed as Rare in the Murray Region and Uncommon the Southern Lofty Region	*	*	*					*
Sarcocornia quinqueflora	Amphibious fluctuation tolerator-emergent	Perennial	Native	*	*	*			*		*
*Scabiosa atropurpurea**	Terrestrial dry	Annual	Exotic						*	*	*
Scaevola calendulacea	Terrestrial dry	Perennial	Native	*							*
Schoenoplectus pungens	Amphibious fluctuation tolerator-emergent	Perennial	Native-Listed as Rare in the Southern Lofty Region	*	*				*	*	*
Schoenoplectus tabernaemontani	Emergent	Perennial	Native	*	*	*	*		*	*	*
Sclerolaena blackiana	Terrestrial dry	Perennial	Native-Listed as Rare in SA								*
Sclerolaena muricata	Terrestrial dry	Perennial	Native		*						
Selliera radicans	Amphibious fluctuation responder-plastic	Perennial	Native	*							
Senecio cunninghamii	Floodplain	Perennial	Native		*				*		*
*Senecio pterophorus**	Terrestrial dry	Annual	Exotic		*	*	*		*	*	*
Senecio runcinifolius	Floodplain	Perennial	Native-Listed as Uncommon in the Murray Region		*						*

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*Silybum marianum***	Terrestrial damp	Annual	Exotic-Proclaimed pest plant in SA						*	*	*
*Solanum nigrum**	Terrestrial damp	Annual	Exotic						*	*	*
*Sonchus asper**	Terrestrial damp	Annual	Exotic		*				*	*	*
Sonchus hydrophyllus					*						
*Sonchus oleraceus**	Terrestrial damp	Annual	Exotic		*	*	*		*	*	*
*Spergularia brevifolia**	Terrestrial damp	Annual	Exotic		*		*		*		*
Spirodella punctata	Floating	Perennial	Native		*						
Suaeda australis	Amphibious fluctuation tolerator-emergent	Perennial	Native	*	*	*	*		*		*
*Tamarix aphylla****	Terrestrial dry	Perennial	Exotic								*
Tecticornia pergranulata	Amphibious fluctuation tolerator-emergent	Perennial	Native	*	*	*				*	*
Threlkeldia diffusa	Terrestrial damp	Perennial	Native	*							
Trifolium spp.*	Terrestrial dry	Annual	Exotic-*Trifolium* spp. comprises of *Trifolium angustifolium, Trifolium arvense, Trifolium repens* and *Trifolium subterraneum*		*	*	*		*	*	*
Triglochin procera	Emergent	Perennial	Native-Listed as Uncommon in the Southern Lofty Region	*	*	*			*	*	*
Triglochin striatum	Amphibious fluctuation tolerator-low growing	Perennial	Native	*	*	*	*			*	*
Triticum sp.*	Terrestrial dry	Annual	Exotic-could not be identified to species								*
Typha domingensis	Emergent	Perennial	Native	*	*	*	*	*		*	*
*Urtica urens**	Terrestrial damp	Annual	Exotic		*		*		*	*	*
Vallisneria australis	Submergent k-selected	Perennial	Native-Listed as Uncommon in the Murray Region and Threatened in the Southern Lofty Region		*	*	*	*		*	*
*Vicia sativa**	Terrestrial dry	Annual	Exotic								*
Wilsonia rotundifolia	Terrestrial damp	Perennial	Native	*	*						*
Wolffia sp.	Floating	Perennial	Native							*	