Salinity Risk Assessment template: Plankton

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Major changes in community composition	0-3ppt	Late summer-autumn annually	Lx	95	B	2	4	Able to survive in regions of Lake Alex directly influenced by the river with low salinity (such patches will change in size over time) remaining 5% around Wellington persistent. Will be reseeded from the river. Some species have higher salinity tolerance and will survive higher salinities	Probably typical of natural conditions where only confluence suitable for riverine species during low flow periods, however these species are highly responsive to changing river conditions and may extend throughout the lake and into the Coorong during high flows
River sourced zooplankton	Major changes in community composition	0-3ppt	Late summer-autumn annually	Lx	95	B	2	4	Able to survive in regions of Lake Alex directly influenced by the river with low salinity (such patches will change in size over time) remaining 5% around Wellington persistent. Will be reseeded from the river. Some species have higher salinity tolerance and will survive higher salinities	Probably typical of natural conditions where only confluence suitable for riverine species during low flow periods, however these species are highly responsive to changing river conditions and may extend throughout the lake and into the Coorong during high flows
Low salinity phytoplankton	Major changes in community composition	3-10ppt	Late summer autumn annually	Lx					Lake Alex remains below 10 ppt throughout period	
Low salinity zooplankton	Major changes in community composition	3-10ppt	Late summer autumn annually	Lx					Lake Alex remains below 10 ppt throughout period	

Scenario: Do-Nothing pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mid salinity phytoplankton	Major changes in community composition	5-15ppt		Lb						Maximum 16.5 briefly in two summers, average 5-12 so essentially below maximum of ca. 15
Mid salinity zooplankton	Major changes in community composition	5-15ppt		Lb						

Scenario: Seawater pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Mortality	0-3ppt	Seasonally in summer	Lx	100	A	2	3	Plankton change from fw to brackish forms as summer salinities are ca. 15. May enter during winter flows but will not persist as salinity too high, Some species, particularly from the Darling may persist in higher saline water	
River sourced zooplankton	Change in community composition	0-3ppt	Seasonally in summer	Lx	100	A	2	3	Some species, particularly from the Darling may persist in higher saline water	
Low salinity phytoplankton	Change in community composition	3-10ppt	Seasonally in summer	Lx	100	A	2	3	Salinity mixes more quickly through lakes than with CP. Lake ca. 10 in winter but addition of SW in Spring causes salinity to increase to ca.15 throughout lake in summer.	No large pH changes as observed with CP scenario. Salinity dominant effect, Changes in community composition from Alex to more like Albert, *Planctonema* to *Nodularia* and *Anabaena*

Scenario: Seawater pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity zooplankton	Change in community composition	3-10ppt	Seasonally in summer	Lx	100	A	2	3	Major changes in community composition from Riverine to more tolerant species	
Mid salinity phytoplankto n	Change in community composition	5-15ppt	From October 2010 seasonal fluctuations	Lx	15	A	1	3	Only likely to persist in middle and northern parts of lake throughout the year as winter freshening to about 10ppt. In summer up to 35ppt in south which excludes these species (barrages to Pt Sturt spit). Leading to mixed assemblages in the lake.	Major changes in community composition toward species able to tolerate estuarine then marine conditions
Mid salinity zooplankton	Change in community composition	5-15ppt	From October 2010 seasonal fluctuations	Lx	15	A	1	3		
Mid salinity phytoplankton	Change in community composition	5-15ppt	Summer 2010-2011	Lb	95	A	2	5	Salinities rise above 15 from 26/1/2011 and although a seasonal cycle of freshening salinity rises to give an average summer peak of 38 in 2012/13 with the prior winter average minimum at 22 therefore above threshold	No pH or drying effects cf. CP Narrung narrows stays below 15 at all times. Major changes in community composition toward species able to tolerate estuarine then marine conditions.
Mid salinity zooplankton		5-15ppt	Summer 2010-2011	Lb	95	A	2	5		
Marine phytoplankton	Change in community composition	25-50 ppt	Whole period	MM					All of MM, action has no effect	Action only changes salinity by <8ppt

Scenario: Seawater pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Marine zooplankton		25-50 ppt	Whole period	MM					All of MM, action has no effect	Action only changes salinity by <8ppt
Marine phytoplankton	Change in community composition	25-50 ppt	Whole period	NL					Generally in range to Sites 4 and 5, action has no effect	Action only changes salinity by <8ppt
Marine zooplankton		25-50 ppt	Whole period	NL					Generally in range to Sites 4 and 5	Action only changes salinity by <8ppt
Hypersaline phytoplankton	Change in community composition	50-150 ppt	Whole period	SL					Generally in 50-150 range except for first year or two	Action only changes salinity by up to 14ppt
Hypersaline zooplankton		50-150 ppt	Whole period	SL					Generally in 50-150 range except for first year or two	Action only changes salinity by up to 14ppt
Salt tolerant phytoplankton	Change in community composition	>150 ppt	Whole period	SL					No effect	Action only changes salinity by up to 4ppt
Salt tolerant zooplankton		>150 ppt	Whole period	SL					No effect	Action only changes salinity by up to 4ppt

Scenario: Freshwater pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Change in community composition	0-3ppt		Lx					Area of Alex Origin often has salinities below ca. 3 so river plankton can survive. Whole lake has salinities between 7 providing "typical" conditions.	
River sourced zooplankton		0-3ppt		Lx						
Low salinity phytoplankton	Change in community composition	3-10ppt		Lx					Whole lake has average salinities <7 with average <4.5 providing "typical" conditions suitable for Lx (Low salinity) plankton.	

Scenario: Freshwater pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity zooplankton		3-10ppt		Lx						
Mid salinity phytoplankton	Change in community composition	5-15ppt		Lb					Whole lake has average salinities <15 with average 6-10 providing "typical" conditions suitable for Lake Albert (mid) plankton.	
Mid salinity zooplankton		5-15ppt		Lb						

Scenario: Do-Nothing cease pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Change in community composition	0-3ppt	Late summer-autumn annually	Lx	95	B	2	4	Able to survive in regions of Lake Alex directly influenced by the river with low salinity (such patches will change in size over time) remaining 5% around Wellington persistent. Will be reseeded from the river. Some species have higher salinity tolerance and will survive higher salinities	Probably typical of natural conditions where only confluence suitable for riverine species during low flow periods, however these species are highly responsive to changing river conditions and may extend throughout the lake and into the Coorong during high flows
River sourced zooplankton	Change in community composition	0-3ppt		Lx	95	B	2	4		
Low salinity phytoplankton	Change in community composition	3-10ppt	Late summer autumn annually	Lx					Lake Alex remains below 10 ppt throughout period	
Low salinity zooplankton		3-10ppt		Lx						

Scenario: Do-Nothing cease pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mid salinity phytoplankton	Change in community composition	5-15ppt	December 2010 onwards	Lb	100	A	2	5	Loss of typical Lake Albert species, salinities rise above 20ppt from January 2011	Although the salinity changes will impact phytoplankton populations the pH changes and drying of the lake are more significant;
Mid salinity zooplankton		5-15ppt		Lb	100	A	2	5		
Estuarine phytoplankton/ zooplankton		15-25ppt		Lb					Limited opportunity for colonisation between Jan 2011 and June 2011 when salinities and pH are both suitable	
Marine phytoplankton/ zooplankton		25-50ppt							Generally in range to Site4 and all of MM	Action only changes salinity by <3ppt
Hypersaline phytoplankton		50-150ppt							Generally in 50-150 range except for early year or two	Action only changes salinity by <3ppt

Scenario: Seawater cease pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Mortality	0-3ppt	Seasonally in summer	Lx	100	A	2	3	Plankton change from fw to brackish forms as summer salinities are ca. 15. May enter during winter flows but will not persist as salinity too high, Some species, particularly from the Darling may persist in higher saline water.	Loss of riverine phytoplankton during summer when salinities are high

Scenario: Seawater cease pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced zooplankton	Change in community composition	0-3 ppt	Seasonally in summer	Lx	100	A	2	3	Some species, particularly from the Darling may persist in higher saline water.	
Low salinity phytoplankton	Change in community composition	3-10 ppt	Seasonally in summer	Lx	100	A	2	3	Initially salinity gradient from barrages to Points then mixes through lake. Lake <5 ppt in winter but addition of SW in Spring causes salinity to increase to ca.15 throughout lake in summer.	Also pH effects.
Low salinity zooplankton	Change in community composition	3-10 ppt	Seasonally in summer	Lx	100	A	2	3		Major changes in community composition from Riverine to more tolerant species
Mid salinity phytoplankton	Change in community composition	5-15 ppt	From October 2010 seasonal fluctuations	Lx	10	A	1	3	Only likely to persist in middle and northern parts of lake throughout the year as winter freshening to about 7 ppt. In summer up to 35 ppt in south which excludes these species (barrages to Pt Sturt spit). Leading to mixed assemblages in the lake.	Major changes in community composition toward species able to tolerate estuarine then marine conditions
Mid salinity zooplankton	Change in community composition	5-15 ppt		Lx	10	A	1	3		
Mid salinity phytoplankton	Change in community composition	5-15 ppt	Summer 2010 - 2011 onwards	Lb	100	A	2	5	Salinities rise above 20 from 26/1/2011	Although the salinity changes will impact phytoplankton populations the pH changes and drying of the lake are more significant. Major changes in community composition toward species able to tolerate estuarine then marine conditions.

Scenario: Seawater cease pumping (Salinity: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mid salinity zooplankton		5-15 ppt	Summer 2010 - 2011 onwards	Lb	100	A	2	5		
Marine phytoplankton	Change in community composition	25-50 ppt	Whole period	MM					All of MM, action has no effect	Action only changes salinity by <3 ppt
Marine zooplankton	Change in community composition	25-50 ppt	Whole period	MM					All of MM, action has no effect	Action only changes salinity by <3 ppt
Marine phytoplankton	Change in community composition	25-50 ppt	Whole period	NL					Generally in range to Sites 4 and 5, action has no effect	Action only changes salinity by 2-3 ppt
Marine zooplankton	Change in community composition	25-50 ppt	Whole period	NL					Generally in range to Sites 4 and 5	Action only changes salinity by 2-3 ppt
Hypersaline phytoplankton	Change in community composition	50-150 ppt	Whole period	SL					Generally in 50-150 range except for first year or two	Action only changes salinity by up to 3-10 ppt
Hypersaline zooplankton	Change in community composition	50-150 ppt	Whole period	SL					Generally in 50-150 range except for first year or two	Action only changes salinity by up to 3-10 ppt
Salt tolerant phytoplankton	Change in community composition	>150 ppt	Whole period	SL					No effect	Action only changes salinity by up to 3-10 ppt
Salt tolerant zooplankton	Change in community composition	>150 ppt	Whole period	SL					No effect	Action only changes salinity by up to 3-10 ppt

Scenario: Freshwater cease pumping (Salinity: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton		0-3ppt		Lx					Area of Alex often has salinities below ca. 3 so river plankton can survive. Whole lake has salinities between 8-15 providing "typical" conditions.	
River sourced zooplankton		0-3ppt		Lx						
Low salinity phytoplankton		3-10ppt		Lx					Whole lake has average salinities between 8-15 providing "typical" conditions suitable for Alex to Albert phytoplankton.	
Low salinity zooplankton		3-10ppt		Lx						
Mid salinity phytoplankton	Major changes in community composition	5-15ppt	Summer 2010 - 2011 onwards	Lb	100	A	2	5	Salinities rise above 20 from 26/1/2011	Although the salinity changes will impact phytoplankton populations the pH changes and drying of the lake are more significant
Mid salinity zooplankton	Major changes in community composition	5-15ppt	Summer 2010 - 2011 onwards	Lb	100	A	2	5	Salinities rise above 20 from 26/1/2011	Although the salinity changes will impact phytoplankton populations the pH changes and drying of the lake are more significant

Water level Risk Assessment template: Plankton

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity phytoplankton	Reduced area for growth	Reduction in lake level	03/2013, 03/2014, 03/2015	Lx	0.7	B	2	3	Lake is only 30% of October 2009 area. Significant drop 12/2010 to -1.5, then again 10/2011 (these match volume reductions in Lb under ceasepump), then further reduction 01/2013 so by 02/2013 0.3 area, then oscillates to around the lowest water level then with some refilling towards end	Acidity having additional perhaps greater effect.
Low salinity zooplankton	Reduced area for growth	Reduction in lake level	03/2013, 03/2014, 03/2015	Lx	0.7	B	2	3		
Low salinity plankton	Reduced area for growth			Lb					Volume maintained at -0.5	

Scenario: Seawater pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All plankton	Reduced area for growth	Reduced lake level	January 2011 on	Lx	0.15	A	1	4	Water level oscillates around -1.5m with some occasional increases.	85% of lake is still suitable
All plankton	Reduced area for growth			Lb					Fluctuations around -0.5m with minor changes.	

Scenario: Seawater pumping (Water level: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Estuarine plankton	Reduced area for growth			MM, NL						
Marine plankton										Minimal depth changes, <2.5cm
Hypersaline plankton										Minimal depth changes, <2.5cm

Scenario: Freshwater pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity phytoplankton	Reduced area for growth	Reduced lake level	April 2011 annually	Lx	0.15	A	1	4	Water level osciallates around -1.5m with some occasional increases.	85% of lake is still suitable
Mid salinity phytoplankton	Reduced area for growth			Lb					Fluctuations around -0.5m with minor changes.	

Scenario: Do-Nothing cease pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity phytoplankton	Reduced area for growth	Fraction of full lake ca. 0.75	9/02/11 onwards	Lx	25	B	4	3	Drawdown in volume	

Scenario: Do-Nothing cease pumping (Water level: Plankton) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mid salinity phytoplankton	Reduced area for growth	Fraction of full lake: zero	9/11/11 onwards	Lb	100	A	1	3	Lakes is essentially dry with occasional pools.	Salinity is also high and from mid 2011 pH <4.

Scenario: Seawater cease pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All plankton	Reduced area for growth	Reduced lake level	February 2011 on	Lx	0.15	A	1	4	Water level oscillates around -1.5 m with some occasional increases.	85% of lake is still suitable
All plankton	Reduced area for growth	Reduced lake level	9/11/11 onwards	Lb	1	A	1	3	Lakes is essentially dry with occasional pools.	Salinity is also high and from mid 2011 pH <4.
Estuarine plankton	Reduced area for growth			MM, NL						
Marine plankton				MM, NL						Minimal depth changes, <2.5cm
Hypersaline plankton				SL						Minimal depth changes, <2.5cm

Scenario: Freshwater cease pumping (Water level: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity phytoplankton	Reduced area for phytoplankton growth								Water level osciallates around -1.5m with some occasional increases.	
Mid salinity phytoplankton	Reduced area for phytoplankton growth	Fraction of full lake: zero	9/11/11 onwards	Lb	100	A	1	3	Lakes is essentially dry with occasional pools.	Salinity is also high and from mid 2011 pH <4.

pH Risk Assessment template: Plankton

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Mortality	<5	March - May 2012	Lx	90	A	1	3	Rapid changes in community composition between pH 5-6, restricted species below pH 5, some edge acidification then following 28/3/2012 after drop in volume all Alex Opening <4 and in general remains impacted	If river inflow is low then low presence of riverine species; 90% of the areas fresh enough to support river sourced organisms
River sourced zooplankton	Mortality	<4	March - May 2012	Lx	80	B	3	3	Most species have a range near neutral, several species able to tolerate down to pH 4.2, acidophiles unlikely to establish due to transient low pH, worst in 2013	If river inflow is low then low presence of riverine species; 75% of the areas fresh enough to support river sourced organisms
Low salinity phytoplankton	Mortality	<4	June - July 2013	Lx	65	A	1	3	Some edge acidification then following 28/3/2012 after drop in volume all Alex Opening <4 and in general remains impacted. This acidification spreads through lake from each end by 26/06/12 ca. 50% lake, then by June-July 13 approaches 60% area has <4. Lake oscillates with frequent low pH but begins to improve towards end.	Loss of all lake phytoplankton and replaced with acidophiles

Scenario: Do-Nothing pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Low salinity zooplankton	Mortality	<4	June - July 2013	Lx	65	A	1	3	Most species have a range near neutral, several species able to tolerate down to pH 4.2, acidophiles unlikely to establish due to transient low pH	If river inflow is low then low presence of riverine species; 10% of lake
All plankton				Lb						pH remains generally acceptable

Scenario: Seawater pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced plankton	Mortality	<5		Lx					Minor edge effects	
Low salinity plankton	Mortality	<5		Lx					Minor edge effects	
Mid salinity plankton	Mortality	<4		Lb	0					

Scenario: Freshwater pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced plankton	Mortality	<5		Lx					Minor edge effects with some slightly lowered pH's at river inflow but small area and short lived and >6.8	
Low salinity plankton	Mortality	<5		Lx					Minor edge effects	
Mid salinity plankton	Mortality	<4		Lb					Minor pH reductions occur spasmodically	

Scenario: Do-Nothing cease pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced phytoplankton	Mortality	<5	Autumn each year from 2010	Lx	75	B	3	3	Rapid changes in community composition between pH 5-6, restricted species below pH 5, worst in 2013	If river inflow is low then low presence of riverine species; 75% of the areas fresh enough to support river sourced organisms
River sourced zooplankton	Mortality	<4	Autumn each year from 2010	Lx	75	B	3	3	Most species have a range near neutral, several species able to tolerate down to pH 4.2, acidophiles unlikely to establish due to transient low pH, worst in 2013	If river inflow is low then low presence of riverine species; 75% of the areas fresh enough to support river sourced organisms
Low salinity phytoplankton	Mortality	<5	Autumn each year from 2010	Lx	10	B	4	3	Rapid changes in community composition between pH 5-6, restricted species below pH 5	This is same region as above but for lake derived phytoplankton
Low salinity zooplankton	Mortality	<4	Autumn each year from 2010	Lx	10	B	3	3	Most species have a range near neutral, several species able to tolerate down to pH 4.2, acidophiles unlikely to establish due to transient low pH, worst in 2013	If river inflow is low then low presence of riverine species; 10% of lake
Mid salinity phytoplankton	Mortality	<4	From June 2011	Lb	100	A	1	5	Below pH 3.5/4 specialised phytoplankton likely to occur	Salinity is also high and volume at end of 2011 onwards negligible. Replacement with acidophiles.

Scenario: Seawater cease pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced plankton	Mortality	<5							Spasmodic pH changes	
All phytoplankton	Mortality	<6: <5: <4: <3.5	October 2011: May 2012: September-October 2012	Lx	0.33	A	1	3	Approximately one third of lake at western end has pH<4 for ca. three weeks	Will be rapidly replaced on remixing of lake when pH increases as seawater added. Greater effect probably salinity. Acidophiles tolerate pH<4 but not likely to be abundant.
All zooplankton	Mortality	<4	October 2011: May 2012: September-October 2012	Lx	0.33	A	1	3	Approximately one third of lake at western end has pH<4 for ca. three weeks	Will be rapidly replaced on remixing of lake when pH increases as seawater added. Greater effect probably salinity. Some specialist acidophiles may be able to persist. Dependant upon what phytoplankton remains or if acidophiles are detritovores
Mid salinity plankton	Mortality	<4	June-July 2011 On	Lb	100	A	1	5	Below pH 3.5/4 specialised plankton likely to occur	Salinity is also high and volume at end of 2011 onwards negligible.

Scenario: Freshwater cease pumping (pH: Plankton)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
River sourced plankton	Mortality	<5							Minor edge effects with some slightly lowered pH's at river inflow but small area and short lived and >6.8	
Low salinity plankton	Mortality	<5		Lx					Minor edge effects	
Mid salinity plankton	Mortality	<4	June 2011 On	Lb	100	A	1	5	Below pH 3.5/4 specialised plankton likely to occur	Salinity is also high and volume at end of 2011 onwards negligible. Replacement with acidophiles.

Salinity Risk Assessment: Vegetation

Completed by: Workshop: J. Nicol and S. Gehrig **Date:** 22/06/2010

Scenario: Do-Nothing pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	March 2013	Lx	0				Salinity below maximum threshold for 100% of lake that has water in it. Always potential for recolonisation from upstream.
Floating plants	Loss of all life stages	10,000 EC	April 2012: March 2013	Lb	80	A	2	4	Salinity above maximum salinity tolerance for 80% of the lake. Always potential for recolonisation from Lake Alexandrina, highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown

Scenario: Seawater Pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	October 2010: March 2013	Lx	100	A	2	4	Salinity above maximum salinity tolerance for 99% of the lake; salinity thresholds for this area of L. Alex (near MM and GC) exceeded thresholds approximately October 2010 resulting in 20% loss. Always potential for recolonisation from upstream, highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown
Floating plants	Loss of all life stages	10,000 EC	December 2010: March 2013	Lb	100	A	2	4	Salinity > max. salinity tolerance for 100% of the lake; threshold exceeded in parts, Dec. 2010. Maximum salinity threshold exceeded in January 2011, highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown.

Scenario: Freshwater Pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	March 2013	Lx	0				Salinity below maximum threshold for 100% of lake that has water in it. Always potential for recolonisation from upstream.

Scenario: Freshwater Pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	November 2010; March 2013	Lb	80	A	2	4	Threshold initially exceeded November 2010 in parts of the lake; salinity above maximum salinity tolerance for 80% of the lake.Always potential for recolonisation from Lake Alexandrina; highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown.

Scenario: Do-Nothing Cease pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	March 2013	Lx	0				Salinity below maximum threshold for 100% of lake that has water in it. Always potential for recolonisation from upstream.
Floating plants	Loss of all life stages	10,000 EC	November 2010: March 2013	Lb	100	A	2	4	Salinity threshold exceeded after November 2010, dessication of entire lake by March 2013. Maximum salinity threshold exceeded in January 2011, highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown.

Scenario: Seawater Cease Pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	September 2010: March 2013	Lx	100	A	2	4	Salinity above maximum salinity tolerance for 100% of the lake; salinity thresholds for this area of L. Alex (near MM and GC 20%) exceeded thresholds in September 2010; maximum extent threshold exceeded approximately March 2011. Always potential for recolonisation from upstream; highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown.
Floating plants	Loss of all life stages	10,000 EC	December 2010: March 2013	Lb	100	A	2	4	Salinity above maximum salinity tolerance for 100% of the lake; threshold exceeded approximately December 2010. Maximum salinity threshold exceeded in January 2011, highly likely that sub-lethal effects occur prior to theshold date; however threhsolds are unknown.

Scenario: Freshwater Cease Pumping (Salinity)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	10,000 EC	March 2013	Lx	0				Salinity below maximum threshold for 100% of lake that has water in it. Always potential for recolonisation from upstream.
Floating plants	Loss of all life stages	10,000 EC	December 2010: March 2013	Lb	100	A	2	4	Threshold exceeded approximately December 2010 in sections of lake; salinity above maximum salinity tolerance for 100% of the lake in March 2013. Maximum salinity threshold exceeded in December 2010.

Water Level Risk Assessment: Vegetation

Completed by: Workshop: J. Nicol and S. Gehrig **Date:** 22/06/2010

Scenario: Do-Nothing Pumping (Water Level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lx	65	A	1	5	No complete drying out of system, but water levels very low, approximately 35% open water habitat remaining
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lb	0				Water is present

Scenario: Seawater Pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lx	0				Not likely that L. Alex will dry out under this scenario. Lowest water levels approximately Mar-Apr of each year
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lb	0				Not likely that L. Albert will dry out under this scenario

Scenario: Freshwater Pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	Complete drying	March 2011 annually	Lx	10	A	1	5	Complete drying
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lb	0	A	1	5	Water is present

Water Level Risk Assessment template: Vegetation

Completed by: Workshop: J. Nicol and S. Gehrig **Date:** 22/06/2010

Scenario: Do-Nothing Cease Pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lx	10	A	1	5	Not likely that L. Alex will dry out under this scenario. Lowest water levels approximately Mar-Apr of each year
Floating plants	Loss of all life stages	Complete drying	Mar 2015	Lb	95	A	1	5	Water levels begin to receed in Jan 2011, Jan 2010 disconnection from Lake Alex, 95% dry by March 2013, 5% pools remaining

Scenario: Seawater Cease Pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	Complete drying	March 2011 annually	Lx	10	A	1	5	Not likely that L. Alex will dry out under this scenario
Floating plants	Loss of all life stages	Complete drying	Dec 2010; March 2013	Lb	95	A	1	5	Starts to drop December 2010, disconnect in January 2012; 95% loss in March 2013. However; other stressors may mean conditions within these areas still conducive for growth.

Scenario: Freshwater Cease Pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	habitat contraction	Complete drying	March 2011 annually	Lx	10	A	1	5	Significant contraction in water levels 02/02/2011 to 01/06/2011. Low seasonal levels infer some habitat contraction.
Floating plants	Loss of all life stages	Complete drying	Dec 2010; Mar 2013	Lb	95	A	1	5	Water level starts to drop Dec 2010, disconnect in Jan 2012, maximum contraction 95% in March 2013

pH Risk Assessment: Vegetation

Completed by: Workshop: J. Nicol and S. Gehrig **Date:** 22/06/2010

Scenario: Do-Nothing Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4	Jun-13	Lx	65	B	2	2	Large areas of the lake acidify in July 2013; threshold exceeded in region to west of Low Point on 21/03/2012 (4%); threshold exceeded on north & north-eastern edges, western & southwestern edges or eastern edges in period between 9/5/2012 - 12/12/2012 may be habitat contraction (30-60%); threshold exceeded on lake edges in period between - 3/04/2013 to 11/12/2013 may be habitat contraction (30-65%); threshold exceeded on predominantly northern and western lake edges in period between - 16/04/2014 to 23/07/2013 - may be habitat contraction (20-40%).sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.
Floating plants	Loss of all life stages	pH<4		Lb	0				All of the inundated areas of the lake are > pH 4.

Scenario: Seawater Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4	October-November 2012	Lx	15	B	4	3	Most of the lake > 4 but in October 2012 a significant area acidifies near Point Sturt; threshold in region of Boggy Lake, and below township of Milang (western edge) exceeds threshold 26/5/2010 and may mean minor habitat contraction (2%); threshold in region of MM and GC may exceed threshold on 8/6/2011 - may minor habitat contraction (2%); threshold in SW region of Lake may exceed threshold on 24/03/2012 to 4/4/2012 may mean habitat contraction (15%); threshold in SW bottom corner region of Lake may exceed threshold on 24/10/2012 to 7/11/2012 and may mean habitat contraction (15%). Sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.
Floating plants	Loss of all life stages	pH<4		Lb	0				All of the inundated areas of the lake are > pH 4.

Scenario: Freshwater Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4		Lx	0				All of the inundated areas of the lake are > pH 4
Floating plants	Loss of all life stages	pH<4		Lb	0				All of the inundated areas of the lake are > pH 4

Scenario: Do-Nothing Cease Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.**	Consq.^^	Conf.#	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4	May 2013 annually	Lx	10	B	2	2	pH > 4 for all of the lake except near the north eastern shoreline; threshold in region of Boggy Lake, and below township of Milang (western edge) exceeds threshold 2/6/2010 to 23/6/2010 and may mean minor habitat contraction (4%); threshold in region btween Pt Sturt and Pt Macleay may exceed threshold on 16/2/2011 - may be minor habitat contraction (5%); threshold in region south of Low Point may exceed threshold on -1/5/2012 to 22/5/2012 - therefore may be minor habitat contraction (8%). Sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.
Floating plants	Loss of all life stages	pH<4	June 2011: January-March 2015	Lb	100	A	1	4	Lake is below pH 4; threshold exceeded approximately June 2011. All of inundated area of lake pH falls below 4 in July 2011; sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.

Scenario: Seawater Cease Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.**	Consq.^^	Conf.#	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4	39721	Lx	25	B	4	3	Areas around Milang and Point Sturt acidify in October 2012; threshold in region of Boggy Lake, and below township of Milang exceeds threshold 2/6/2010 may mean minor contraction of possible habitat (2%); threshold in region of MM and GC may exceed threshold on 19/10/2011 - may mean minor contraction of possible habitat (5-8%); threshold in SW region of Lake may exceed threshold on 30-10/2012 - may mean possible habitat contraction (25%). sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.
Floating plants	Loss of all life stages	pH<4	August 2011: January 2012 whole lake affected	Lb	100	A	1	4	Lake is below pH 4; theshold exceeded in lake on 03/08/2011. All of inunated areas of lake pH falls below 4 in July 2011; sub-lethal effects may occur earlier to adult threshold period; however thresholds unknown.

Scenario: Freshwater Cease Pumping (pH)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location(s)	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Floating plants	Loss of all life stages	pH<4		Lx	0				All of the inundated areas of the lake remain abve pH 4 for the duration of the management action.
Floating plants	Loss of all life stages	pH<4	May 2011: June 2011: December 2011	Lb	100	A	1	4	Lake is below pH 4; threshold in southern edges of lake exceeds threshold 11/05/2011 to 25/05/2011 and may mean minor habitat contraction (15%); threshold exceeded in entire lake approximately 22/06/2011(90%) Narrows gone in December 2011. All of inundated areas of lake pH falls below 4 in July 2011

Salinity Risk Assessment: *Ruppia tuberosa* (Coorong)

Completed by: Dan Rogers

Date: 8/06/2010

Scenario: Do-Nothing pumping (Salinity: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	shoot abundance; presence of Enteromorpha	seasonally; ~April each year	NL	0.2	E	5	3	Changes in salinity (relative to SW scenario) do not increase risk of exposure to Enteromorpha.	Much of NL inherently outside of salinity tolerance for Coorong.
Ruppia tuberosa	Mortality	shoot abundance; propagule abundance	June 2010-June 2013 (period of SLSRS)	SL	0.9	D	5	3	Changes in salinity (relative to SW scenario) do not increase riskof crossing upper salinity thresholds, or of increasing risk of exposure to Enteromorpha.	

Scenario: Seawater pumping (Salinity: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	shoot abundance; presence of Enteromorpha	seasonally; ~April each year	NL	20%	D	3	3	Relative to seasonal changes in salinity, and in response to other interventions (SLSRS), short-term drop salinity in response to SW scenario is small. Risk of lethal and sub-lethal (growth rate) effects of 'swamping' by Enteromorpha if drops in salinity result in Enteromorpha incursions into southern parts of NL.	Much of NL inherently outside of salinity tolerance for Coorong. Parts that are not, are likely to be impacted by increases in salinity due to SW scenario, although a small risk of Enteromorpha incursions in response to short-term salinity reduction due to SW scenario.

Scenario: Seawater pumping (Salinity: *Ruppia tuberosa*) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	shoot abundance; propagule abundance	June 2010-June 2013 (period of SLSRS)	SL	90%	D	3	3	In north of SL, upper tolerance thresholds only approached during summer (little relevance), but become more relevant in mid-south of SL (although increases in salinity due to SW scenario in southern SL are small). Risk of reduction in viability of SL population during SLSRS phase of assessment, where salinity approaches upper threshold	Small risks are associated with the potential salinity benefits provided by the SLSRS, where an increase in salt accumulation may offset the salt removal provided by the scheme. In the absence of salinity reduction (by the SLSRS or other means, e.g. MDB flows), risk less relevant as SL salinity rarely falls below upper tolerance thresholds.

Scenario: Freshwater pumping and cease pumping (Salinity: *Ruppia tuberosa*)

For the period of assessment, there is no difference in the hydrological response of the Coorong between FW and DDN scenarios. However, there are other risks associated with DDN vs FW that are relevant outside of the assessment window, primarily through reduction/loss of opportunities to provide freshwater flows from the MDB via the barrages under the DDN/SW scenarios vs the FW scenario. This has significant implications, particularly for recovery of the Coorong.

Scenario: Do-Nothing cease pumping (Salinity: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	*shoot abundance; presence of Enteromorpha*	seasonally; ~April each year	*NL*	0.2	*E*	5	*3*	Changes in salinity (relative to SW scenario) do not increase risk of exposure to Enteromorpha.	*Much of NL inherently outside of salinity tolerance for Coorong.*
Ruppia tuberosa	Mortality	*shoot abundance; propagule abundance*	June 2010-June 2013 (period of SLSRS)	*SL*	0.9	*D*	5	*3*	Changes in salinity (relative to SW scenario) do not increase riskof crossing upper salinity thresholds, or of increasing risk of exposure to Enteromorpha.	

Scenario: Seawater cease pumping (Salinity: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	shoot abundance; presence of Enteromorpha	seasonally; ~April each year	NL	0.2	D	5	3	Relative to seasonal changes in salinity, and in response to other interventions (SLSRS), short-term drop salinity in response to SW scenario is very small.	Much of NL inherently outside of salinity tolerance for Coorong. Parts that are not, risk of Enteromorpha incursions in response to short-term salinity reduction due to SW scenario is insignificant due to very small changes in salinity.
Ruppia tuberosa	Mortality	shoot abundance; propagule abundance	June 2010-June 2013 (period of SLSRS)	SL	0.9	D	5	3	In north of SL, upper tolerance thresholds only approached during summer (little relevance), but become more relevant in mid-south of SL (although increases in salinity due to SW scenario in southern SL are very small)	Small risks are associated with the potential salinity benefits provided by the SLSRS, where an increase in salt accumulation may offset the salt removal provided by the scheme. In the absence of salinity reduction (by the SLSRS or other means, e.g. MDB flows), risk less relevant as SL salinity rarely falls below upper tolerance thresholds.

Water Level Risk Assessment: *Ruppia tuberosa* (Coorong) **Completed by:** Dan Rogers
Date: 8/06/2010

Scenario: Do-Nothing pumping and cease pumping (Water level: *Ruppia tuberosa*)

Risks associated with water levels relate to timing of water level declines (--> premature exposure of mudflats). These risks are not increased relative to SW scenarios. Upper depth limits (related to light availability) are not impacted during growth season by alternative scenarios

Scenario: Seawater pumping (Water level: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	summertime propagule abundance	Spring-Summer, annually	NL	0.2	C	3	2	mortality due to premature exposure of mudflats. Risk to population if exposure/mortality occurs prior to propagule production.	Risk is associated with small drop in water levels associated with SW scenarios (on scale of 3-4 cm), on top of seasonal water level declines, occurring at critical season for R. tuberosa propagule production. Confidence limitations primarily based on relating absolute drops in water level at critical times to increases in mudflat exposure during these times. This requires an adequate bathymetry for the Coorong.
Ruppia tuberosa	Mortality	summertime propagule abundance	Spring-Summer, annually	SL	0.9	C	4	2	mortality due to premature exposure of mudflats. Risk to population if exposure/mortality occurs prior to propagule production.	Risk is associated with small drop in water levels associated with SW scenarios (on scale of 3-9 cm), on top of seasonal water level declines, occurring at critical season for R. tuberosa propagule production. Confidence limitations primarily based on relating absolute drops in water level at critical times to increases in mudflat exposure during these times. This requires an adequate bathymetry for the Coorong.

Scenario: Seawater cease pumping (Water level: *Ruppia tuberosa*)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq	Conf.	Rationale	Considerations
Ruppia tuberosa	Mortality	summertime propagule abundance	Spring-Summer, annually	NL	0.2	C	2	2	Mortality due to premature exposure of mudflats. Risk to population if exposure/mortality occurs prior to propagule production. Potential consequences much lower due to smaller drop in water levels relative to SW Pumping scenario.	Risk is associated with small drop in water levels associated with SW scenarios (on scale of 1-2cm), on top of seasonal water level declines, occurring at critical season for R. tuberosa propagule production. Confidence limitations primarily based on relating absolute drops in water level at critical times to increases in mudflat exposure during these times. This requires an adequate bathymetry for the Coorong.
Ruppia tuberosa	Mortality	summertime propagule abundance	Spring-Summer, annually	SL	0.9	C	2	2	Mortality due to premature exposure of mudflats. Risk to population if exposure/mortality occurs prior to propagule production. Potential consequences much lower due to smaller drop in water levels relative to SW Pumping scenario.	Risk is associated with small drop in water levels associated with SW scenarios (on scale of 1-2 cm), on top of seasonal water level declines, occurring at critical season for R. tuberosa propagule production. Confidence limitations primarily based on relating absolute drops in water level at critical times to increases in mudflat exposure during these times. This requires an adequate bathymetry for the Coorong.

Salinity Risk Assessment template: Freshwater Macroinvertebrates

Completed by: Workshop
Date: 16/06/2010

Scenario: Do-Nothing Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Cherax destructor	Mortality	LC50 of >45g/L. Max field salinities 8.16g/L; ANZECC >3.4g/L	Jan2010	Lb	90	B	2	2	Based upon tolerance of max field salinity of 8.16. Seasonal increase in salinity in summer. Jan 2010 is first occurrence.	Able to migrate to better conditions therefore not catastrophic.
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Oct2009	Lb	85	B	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	
Littoral macroinvertebrates	Mortality	>20 g/L	Mar2012	Lb	40	B	3	2		
Brackish macroinvertebrates	Mortality	>30 g/L	Mar2012	Lb	0				Distribution and abundance are likely to increasein main water body. Likely to be last of receptor list to remain prior to marine taxa become dominant.	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Oct2009	Lb	85	B	2	2	sub-lethal effects at <2g/L. Worse case scenario for Lb has 85% habitat at approx 15g/L, and for Lx 95% is affected at approx 10g/L. Thresholds unknown. Avoidance behaviour available for a period of time.	ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L

Scenario: Seawater Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	Oct 2010 - Dec 2010	Lx	95	A	1	2	Based upon tolerance of max field salinity of 8.16. Insufficient resolution in movies, therefore relied on timeseries data.	
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Oct2009	Lx	95	A	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	Physidae max field salinities at 3.3g/L. Ancylidae egg tolerance 6.2g/L (gastropods). LC50 for H. viridissima 2.5g/L (hydra). Maximum field salinities of 9.2g/L (mites).Baetidae LC50 start at 7.74 g/L. Caenid salinity tolerance at 8g/L (ephemeroptera). Species loss for all groups.
Littoral macroinvertebrates	Mortality	>20 g/L	Oct 2010-Mar2011	Lx	80	B	2	2		
Brackish macroinvertebrates	Mortality	>30 g/L	Nov 2010	Lx	15	B	3	2	Likely to be last of receptor list to remain prior to marine taxa become dominant.	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Oct2009	Lx	95	A	1	2		
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	Dec2009	Lb	95	A	1	2	Based upon tolerance of max field salinity of 8.16.	Able to migrate to better conditions.

Scenario: Seawater Pumping (Salinity: Freshwater macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Oct2009	Lb	95	A	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Oct2009	Lb	95	A	2	2	sub-lethal effects at <2g/L. Thresholds unknown. Avoidance behaviour available for a period of time. Doesn't reach threshold for adults.	ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L

Scenario: Freshwater Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Oct 2009	Lx	95	B	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	Physidae max field salinities at 3.3g/L. Ancylidae egg tolerance 6.2g/L (gastropods). LC50 for H. viridissima 2.5g/L (hydra). Maximum field salinities of 9.2g/L (mites).Baetidae LC50 start at 7.74 g/L. Caenid salinity tolerance at 8g/L (ephemeroptera). Species loss for all groups.
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Oct 2009	Lx	95	B	3	2	sub-lethal effects at <2g/L. Thresholds unknown. Avoidance behaviour available for a period of time.	ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L

Scenario: Freshwater Pumping (Salinity: Freshwater macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	Dec 2009	Lb	75	B	2	2	Based upon tolerance of max field salinity of 8.16.	Able to migrate to better conditions.
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Oct 2009	Lb	100	A	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Oct 2009	Lb	100	A	1	2	sub-lethal effects at <2g/L. Thresholds unknown. Avoidance behaviour available for a period of time.	ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L

Scenario: Do-Nothing Cease Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	Mar2010	Lx	<5	D	4	2	Based upon tolerance of max field salinity of 8.16. Insufficient resolution in movies, therefore relied on timeseries data.Habitat percentage refers to disconnected wetlands on Poltalloch Plains and north of Hindmarsh Island.	

Scenario: Do-Nothing Cease Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Jan 2012 - May 2012	Lx	95	C	1	2	Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown	Physidae max field salinities at 3.3g/L. Ancylidae egg tolerance 6.2g/L (gastropods). LC50 for H. viridissima 2.5g/L (hydra). Maximum field salinities of 9.2g/L (mites).Baetidae LC50 start at 7.74 g/L. Caenid salinity tolerance at 8g/L (ephemeroptera). Species loss for all groups.
Littoral macroinvertebrates	Mortality	>20 g/L	Mar 2010	Lx	<5	D	4	2	Habitat percentage refers to disconnected wetlands on Poltalloch Plains and north of Hindmarsh Island.	
Brackish macroinvertebrates	Mortality	>30 g/L	Mar 2010	Lx	<5	D	4	2	Habitat percentage refers to disconnected wetlands on Poltalloch Plains and north of Hindmarsh Island. Distribution and abundance are likely to increasein main water body. Likely to be last of receptor list to remain prior to marine taxa become dominant.	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Jan 2012 - May 2012	Lx	95	D	2	2	sub-lethal effects at <2g/L. Worse case scenario for Lb has 85% habitat at approx 15g/L, and for Lx 95% is affected at approx 10g/L. Thresholds unknown. Avoidance behaviour available for a period of time.	ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L

Scenario: Do-Nothing Cease Pumping (Salinity: Freshwater macroinvertebrates) (Cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	Dec 2009 onwards	Lb	95	B	1	2	Based upon tolerance of max field salinity of 8.16. Seasonal increase in salinity in summer with freshening during winter of 2010 to below threshold but thereafter exceeds threshold even during winter.	
Freshwater macroinvertebrates	Mortality	>3.4g/L ANZECC	Nov 2009	Lb	100	A	1	2		
Littoral macroinvertebrates	Mortality	>20 g/L	Mar 2010 onwards	Lb	100	A	1	2		
Brackish macroinvertebrates	Mortality	>30 g/L	Feb 2011 onwards	Lb	100	A	1	2	Likely to be last of receptor list to remain prior to marine taxa become dominant.	
Velesunio ambiguus	Mortality	>3.5 g/L reproduction; > 10 g/L adult survival	Nov 2009	Lb	100	A	1	2		
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	*Oct2010 - Mar2011*	*Lx*	*100*	*A*	*1*	*2*	*Based upon tolerance of max field salinity of 8.16.*	
Freshwater macroinvertebrates	Mortality	*>3.4g/L ANZECC*	*Oct2010 - Mar2011*	*Lx*	*100*	*A*	*1*	*2*	*Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown*	*Physidae max field salinities at 3.3g/L. Ancylidae egg tolerance 6.2g/L (gastropods). LC50 for H. viridissima 2.5g/L (hydra). Maximum field salinities of 9.2g/L (mites).Baetidae LC50 start at 7.74 g/L. Caenid salinity tolerance at 8g/L (ephemeroptera). Species loss for all groups.*

Scenario: Seawater Cease Pumping (Salinity: Freshwater macroinvertebrates) Cont.

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Littoral macroinvertebrates	Mortality	*>20 g/L*	*Oct2010*	*Lx*	*15*	*B*	*4*	*2*	*High salinity restricted to areas south of Pt Sturt*	
Brackish macroinvertebrates	Mortality	*>30 g/L*	*Mar2011*	*Lx*	*15*	*B*	*4*	*2*	*Likely to be last of receptor list to remain prior to marine taxa become dominant. High salinity restricted to areas south of Pt Sturt.*	
Velesunio ambiguus	Mortality	*>3.5 g/L reproduction; > 10 g/L adult survival*	*Oct2010 - Mar2011*	*Lx*	*100*	*A*	*1*	*2*	*sub-lethal effects at <2g/L.Thresholds unknown. Avoidance behaviour available for a period of time.*	*ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L*
Cherax destructor	Mortality	LC50 of >45g/L. *Max field salinities 8.16g/L; ANZECC >3.4g/L*	*Nov2009*	*Lb*	*95*	*A*	*1*	*2*	*Based upon tolerance of max field salinity of 8.16. Remaining 5% of habitat is Narrung Narrows.*	
Freshwater macroinvertebrates	Mortality	*>3.4g/L ANZECC*	*Oct2009*	*Lb*	*100*	*A*	*1*	*2*	*Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown*	
Littoral macroinvertebrates	Mortality	*>20 g/L*	*Jan2011*	*Lb*	*95*	*A*	*1*	*2*		
Brackish macroinvertebrates	Mortality	*>30 g/L*	*Feb2011*	*Lb*	*95*	*A*	*1*	*2*	*Likely to be last of receptor list to remain prior to marine taxa become dominant.*	
Velesunio ambiguus	Mortality	*>3.5 g/L reproduction; > 10 g/L adult survival*	*Oct2009*	*Lb*	*100*	*A*	*1*	*2*	*sub-lethal effects at <2g/L. Thresholds unknown.*	*ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L*

Scenario: Freshwater Cease Pumping (Salinity: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Freshwater macroinvertebrates	Mortality	*>3.4g/L ANZECC*	*Oct 2009*	*Lx*	*95*	*B*	*1*	*2*	*Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown*	*Physidae max field salinities at 3.3g/L. Ancylidae egg tolerance 6.2g/L (gastropods). LC50 for H. viridissima 2.5g/L (hydra). Maximum field salinities of 9.2g/L (mites).Baetidae LC50 start at 7.74 g/L. Caenid salinity tolerance at 8g/L (ephemeroptera). Species loss for all groups.*
Velesunio ambiguus	Mortality	*>3.5 g/L reproduction; > 10 g/L adult survival*	*Oct 2009*	*Lx*	*95*	*B*	*3*	*2*	*sub-lethal effects at <2g/L. Thresholds unknown. Avoidance behaviour available for a period of time.*	*ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L*
Freshwater macroinvertebrates	Mortality	*>3.4g/L ANZECC*	*Oct 2009*	*Lb*	*100*	*A*	*1*	*2*	*Expect lethal effects with prolonged exposure to high levels. Egg loss. Thresholds unknown*	
Velesunio ambiguus	Mortality	*>3.5 g/L reproduction; > 10 g/L adult survival*	*Oct 2009*	*Lb*	*100*	*A*	*1*	*2*	*sub-lethal effects at <2g/L. Thresholds unknown. Avoidance behaviour available for a period of time.*	*ANZECC Guidelines for freshwater ecosystems - trigger level of 3.4g/L*
Cherax destructor	Mortality	*LC50 of >45g/L. Max field salinities 8.16g/L; ANZECC >3.4g/L*	*Dec 2009*	*Lb*	*95*	*A*	*1*	*2*	*Based upon tolerance of max field salinity of 8.16.*	*Able to migrate to better conditions.*
Brackish macroinvertebrates	Mortality	*>30 g/L*	*Feb 2011 onwards*	*Lb*	*75*	*B*	*2*	*2*	*Likely to be last of receptor list to remain prior to marine taxa become dominant.*	
Brackish macroinvertebrates	Mortality	*>20 g/L*	*Feb 2011 onwards*	*Lb*	*95*	*A*	*1*	*2*	*Remaining 5% habitat is Narrung Narrows which exceeds tolerance in April 2011.*	

pH Risk Assessment template: Freshwater Macroinvertebrates

Completed by: Workshop
Date: 16/06/2010

Scenario: Do-Nothing Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	Fringes Jun2010; Jun2012	Lx	50	B	2	2	Oligochaeta and Chironomids distributed within sediments thus greater exposure to interstital water quality. Remaining 50% of habitat is deep water (approximately 3m) which is of unknown value as habitat.	Ferrissia has been found at pH 4.75 (Fiske 1987)
All macroinvertebrates	Mortality	< 6.5		Lb	0				pH remains above 6.5 throughout action period	

Scenario: Seawater Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	Feb - Nov 2012	Lx	15	C	4	2	Primary area affected is south of Pt Sturt. Series of low pH pulses.	
All macroinvertebrates	Mortality	< 6.5		Lb	0				Remains above tolerance level throughout action period.	

Scenario: Freshwater Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	Mar - May 2010	Lx	5	C	4	2	W/NW fringes. Greater abundance in fringe areas.	
All macroinvertebrates	Mortality	< 6.5		Lb	0				Remains above threshold throughout action period	

Scenario: Do-Nothing Cease Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	May-June annually	Lx	15	C	4	2	W/NW fringing habitats	
All macroinvertebrates	Mortality	< 6.5	June 2011	Lb	95	A	1	2	Includes impacts of reduced water level. By Jan 2012 100% of lake with pH <4. Oligochaeta and Chironomids distributed within sediments thus greater exposure to interstital water quality.	Ferrissia has been found at pH 4.75 (Fiske 1987)

Scenario: Seawater Cease Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	Jan2012 - Oct2012	Lx	50	B	3	2	Consequences could be greater because most areas of the lake are affected at some time during the action period, particularly in fringes.	
All macroinvertebrates	Mortality	< 6.5	Jun - July 2011; Jan2012	Lb	100	A	1	2	100% by Jan2012	

Scenario: Freshwater Cease Pumping (pH: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6.5	Mar - May 2010	Lx	<5	C	4	2	W/NW fringes . Higher abundance in fringes.	
All macroinvertebrates	Mortality	< 6.5	May - June 2011; Jan2012	Lb	100	A	1	2	95%of habitat in June 2011, pH drops in Narrung Narrows such that 100% by Jan2012.	

Dissolved Oxygen Risk Assessment template: Freshwater Macroinvertebrates

Completed by: Workshop
Date: 16/06/2010

Scenario: Do-Nothing Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	03/15	Lx	50	B	2	2		Lb has little open water affected by low DO , only the channel, at 5mg/L . Lx has entire lake in March usually at approx DO 5.5mg/L ANZECC guidelines of 6mg/L (90% saturation)
All macroinvertebrates	Mortality	< 6	05/14	Lb	10	C	4	2	Lb has 100% of littoral habitat affected with <5mg/l	

Scenario: Seawater Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	04/14	Lx	90	B	1	2	Lx at end of summer each year becomes increasingly lower in DO with 100% of the lake affected	
All macroinvertebrates	Mortality	< 6	02/14	Lb	50	B	2	2	Lb had 100% of lake affected by DO ranging from 5 - 6	

Scenario: Freshwater Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	03/15	Lx	50	B	2	2		Lb has little open water affected by low DO , only the channel, at 5mg/L . Lx has entire lake in March usually at approx DO 5.5mg/L ANZECC guidelines of 6mg/L (90% saturation)
All macroinvertebrates	Mortality	< 6	05/14	Lb	10	C	4	2	Lb has 100% of littoral habitat affected with <5mg/l	

Thresholds to Dissolved oxygen generally unknown

Freshwater mussel can tolerate low DO for a period of time. Thresholds unknown.

Cherax destructor: Avoidance behaviour by burrowing. Also known to occur in deeper waters as well as littoral areas (depending on food supply). Thresholds unknown.

Amarinus lacustris: Possible avoidance behaviour in Lb. Thresholds unknown.

Oligochaeta: Worms possibly exposed to differing levels of DO in the sediments. Thresholds unknown. Oligochaetes inhabit the sediments and could be found in deeper waters

Scenario: Do-Nothing Cease Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	Mar-Apr annually	Lx	55	B	3	2		
All macroinvertebrates	Mortality	< 6	Mar-Apr annually	Lb	80	A	2	2		

Scenario: Seawater Cease Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	Mar - May annually	Lx	95	A	1	2	Patches of around 2mg/L in south	
All macroinvertebrates	Mortality	< 6	Mar2010; Mar2011	Lb	80	A	2	2	Mar2011 is 80% of habitat <5mg/L with patches 2mg/L	

Scenario: Freshwater Pumping (Dissolved oxygen: Freshwater macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All macroinvertebrates	Mortality	< 6	04/14	Lx	10	C	4	2	Lx in worst case scenario has approx 90% of the lake at a DO < 6 mg/L but > 5mg/L	
All macroinvertebrates	Mortality	< 6	03/11	Lb	50	B	2	2	Lb has good DO until the water level drops then the worse case has at least 50% of the lake at DO 3 - 5.5	

Thresholds to Dissolved oxygen generally unknown

Freshwater mussel can tolerate low DO for a period of time. Thresholds unknown.

Cherax destructor: Avoidance behaviour by burrowing. Also known to occur in deeper waters as well as littoral areas (depending on food supply). Thresholds unknown.

Amarinus lacustris: Possible avoidance behaviour in Lb. Thresholds unknown.

Salinity Risk Assessment: Marine macroinvertebrates

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Oligochaeta	Mortality	0-93 ppt	None	*Lx*		*E*	*3*	*2*	salinity remains suitable for oligochaetes, occur in low numbers only	
Oligochaeta	Mortality	0-93 ppt	None	*Lb*		*E*	*3*	*2*	projected salinities would not decrease oligochaetes, water level and sediment properties more important	
Amphipoda	Mortality	1-125 ppt	None	*Lx, Lb*		*D*	*3*	*3*	amphipods occurring in low numbers at present, salinities not changing beyond their tolerances; food for foraging waders	salinities remain within tolerance range, water level more important
Insect larvae	Mortality	1-138 ppt	None	*Lx, Lb*		D	2	3	projected salinities within tolerance ranges	

Scenario: Seawater pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
No negative impacts in Lakes. Salinities inside of the barrages may exceed tolerance ranges, but transport further into Lx possible and salinities suitable for most species.										
Ficopomatus enigmaticus	Mortality	1.5 - 60 ppt	Jan-Mar, annually	MM	80	B	2	4	Mundoo channel likely to survive spike in salinity,hypermarine conditions (~>40 ppt) will persist, possibly risking exceeding upper tolerance limit of tubeworms. Water level drawdown over summer futher issue threatening their population	worm reefs have been identified as important biogenic structures; structure as such remaining if worms die; annual die-offs in site 2 and 3

Scenario: Seawater pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Simplisetia aequisetis	Mortality	7-88 ppt range; <50 optimal	Jan-Mar, annually	MM	80	B	2	4	seawater discharge into Lx ove summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; possilbe pocket in Mundoo channnel holding on	important prey for shorebirds. Numbers have decreased as salinity increased over last few years
Capitella spp./ Oligochaeta	Mortality	1-138 ppt range Cap; 0-93 ppt range Oligo; <60 ppt optimal for both	Jan-Mar, annually	MM	80	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	about the only abundant macroinvertebrate left in sediments
Nephtys australiensis	Mortality	15-50 ppt range	Jan-Mar, annually	MM	80	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; respond to any loss in lower trophic levels	was very abundant worm in most mudflats, also occurring in subtidal sediments; annual die-offs in site 2 and 3
Boccardiella limnicola	Mortality	4-60 ppt	Jan-Mar, annually	MM	80	B	4	3	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; takes advantage of salinity between 50-60 ppt when it colonises empty tubeworm tubes.	abundances have increased in recent years. Found in sediment and empty tubes of Ficopomatus reefs.

Scenario: Seawater pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Amphipods	Mortality	1-125 ppt range, <45 ppt optimal	Jan-Mar, annually	MM	80	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	mix of several species. Populations have almost collapsed in recent years
Paragrapsus gaimardii	Mortality	brackish/marine	Jan-Mar, annually	MM	60	B	3	2	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; dependent on vertical salinity gradient	crabs also affected by epigrowth of tubeworms. Crabs aggregate near MM in ~Dec, possibly to spawn
Arthritica helmsi, large bivalves	Mortality	1-129 ppt range. <45 ppt optimum	Jan-Mar, annually	MM	80	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; cyclical compounding effect	was probably an important food item for short-billed shorebirds
large bioturbators	Mortality	brackish/marine	Jan-Mar, annually	MM	70	B	2	4	salinites at or above likely threshold. Distribution restricted mainly to area between Goolwa barrage and MM, were less effects are expected.	bioturbation important for sediment biogeochemistry and as biogenic structure. Food items for long-billed shorebirds
Insect larvae	Mortality	1-138 ppt	Aug09-Aug11	SL 9-14	100	B	3	3	about only macroinvertebrates left in SL	adult life stages independent of water due to mobility
Ficopomatus enigmaticus	Mortality	1.5 - 60 ppt	Aug 09	NL 4-7	100	B	1	4	if seawater pumping into Lx, salinities increase in summer plus reduced water levels will negatively affect theis species	worm reefs have been identified as important biogenic structures; structure as such remaining if worms die.

Scenario: Seawater pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Simplisetia aequisetis	Mortality	7-88 ppt range; <50 optimal	Aug 09	NL 4-6	100	B	3	4	seawater discharge into Lx ove summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; possilbe pocket in Mundoo channnel holding on	important prey for shorebirds may be lost
Capitella spp./ Oligochaeta	Mortality	1-138 ppt range Cap; 0-93 ppt range Oligo; <60 ppt optimal for both	Aug 09	NL 4,5	100	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	about the only abundant macroinvertebrate left in sediments
Nephtys australiensis	Mortality	15-50 ppt	Aug09	NL 4	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; respond to any loss in lower trophic levels	not recorded in Dec 09
Boccardiella limnicola	Mortality	4-60 ppt	Aug 09	NL 4	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; takes advantage of salinity between 50-60 ppt when it colonises empty tubeworm tubes.	Present prior to 2009
Amphipoda	Mortality	1-125 ppt range, <45 ppt optimal	Aug09	NL 4-6	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL, salinity likely to already exceep upper tolerance limit	Present prior to 2009

Scenario: Seawater pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Paragrapsus gaimardii	Mortality	brackish/marine	Aug 09	NL 4-6	100	B	3	3	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; dependent on vertical salinity gradient; salinity likley to already exceed upper tolerance limit	Present prior to 2009, possibly since 2009 (?)
Arthritica helmsi, large bivalves	Mortality	1-129 ppt range. <45 ppt optimum	Aug 09	NL 4	100	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; cyclical compounding effect	
Insect larvae	Mortality	1-138 ppt	Jan10-Mar10, Jan15-Mar15	NL 4-8	60	B	3	3	projected salinities outside of tolerance range	adult life stages independent of water due to mobility
large bioturbators	Mortality	brackish/marine	Aug 09	NL 4	100	C	3	2	sediment conditions may prevent establishment in subtidal. SIngle Australonereis found at some site	Australonereis present prior to 2009 and low numbers after 2009

Scenario: Freshwater pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	<2 ppt	31/07/2013	Lx	100	A	1	2	Waters become fresh	

Scenario: Do-Nothing cease pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Oligochaeta	*Mortality*	*0-93 ppt*	None	*Lx*		*E*	*3*	*2*	salinity remains suitable for oligochaetes, occur in low numbers only	
Oligochaeta	*Mortality*	*0-93 ppt*	None	*Lb*		*E*	*3*	*2*	projected salinities would not decrease oligochaetes, water level and sediment properties more important	
Amphipoda	*Mortality*	*1-125 ppt*	None	*Lx, Lb*		*D*	*3*	*3*	amphipods occurring in low numbers at present, salinities not changing beyond their tolerances; food for foraging waders	salinities remain within tolerance range, water level more important
Insect larvae	*Mortality*	1-138 ppt	None	*Lx, Lb*		D	2	3	projected salinities within tolerance ranges	

Scenario: Seawater cease pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
No negative impacts in Lakes. Salinities inside of the barrages may exceed tolerance ranges, but transport further into Lx possible and salinities suitable for most species.										
Insect larvae	Mortality	1-138 ppt	Sept09-June11	SL 9-14	100	B	3	3	about only macroinvertebrates left in SL	adult life stages independent of water due to mobility
Ficopomatus enigmaticus	Mortality	1.5 - 60 ppt	Jan-Mar Annually	MM	65	B	2	4	Mundoo channel likely to survive spike in salinity,hypermarine conditions (~>40 ppt) will persist, possibly risking exceeding upper tolerance limit of tubeworms. Water level drawdown over summer futher issue threatening their population	worm reefs have been identified as important biogenic structures; structure as such remaining if worms die; annual die-offs in site 2 and 3
Simplisetia aequisetis	Mortality	7-88 ppt range; <50 optimal	Jan-Mar Annually	MM	65	B	2	4	seawater discharge into Lx ove summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; possilbe pocket in Mundoo channnel holding on	important prey for shorebirds. Numbers have decreased as salinity increased over last few years

Scenario: Seawater cease pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Capitella spp./ Oligochaeta	Mortality	1-138 ppt range Cap; 0-93 ppt range Oligo; <60 ppt optimal for both	Jan-Mar Annually	MM	65	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	about the only abundant macroinvertebrate left in sediments
Nephtys australiensis	Mortality	15-50 ppt range	Jan-Mar Annually	MM	65	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; respond to any loss in lower trophic levels	was very abundant worm in most mudflats, also occurring in subtidal sediments; annual die-offs in site 2 and 3
Boccardiella limnicola	Mortality	4-60 ppt	Jan-Mar Annually	MM	65	B	4	3	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; takes advantage of salinity between 50-60 ppt when it colonises empty tubeworm tubes.	abundances have increased in recent years. Found in sediment and empty tubes of Ficopomatus reefs.
Amphipods	Mortality	1-125 ppt range, <45 ppt optimal	Jan-Mar Annually	MM	65	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	mix of several species. Populations have almost collapsed in recent years
Paragrapsus gaimardii	Mortality	brackish/marine	Jan-Mar Annually	MM	40	B	3	2	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; dependent on vertical salinity gradient	crabs also affected by epigrowth of tubeworms. Crabs aggregate near MM in ~Dec, possibly to spawn
Arthritica helmsi, large bivalves	Mortality	1-129 ppt range. <45 ppt optimum	Jan-Mar Annually	MM	65	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; cyclical compounding effect	was probably an important food item for short-billed shorebirds

Scenario: Seawater cease pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
large bioturbators	Mortality	brackish/marine	Jan-Mar Annually	MM	65	B	2	4	salinites at or above likely threshold. Distribution restricted mainly to area between Goolwa barrage and MM, were less effects are expected.	bioturbation important for sediment biogeochemistry and as biogenic structure. Food items for long-billed shorebirds
Ficopomatus enigmaticus	Mortality	1.5 - 60 ppt	Aug 09	NL 4-7	100	B	1	4	if seawater pumping into Lx, salinities increase in summer plus reduced water levels will negatively affect theis species	worm reefs have been identified as important biogenic structures; structure as such remaining if worms die.
Simplisetia aequisetis	Mortality	7-88 ppt range; <50 optimal	Aug 09	NL 4-6	100	B	3	4	seawater discharge into Lx ove summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; possilbe pocket in Mundoo channnel holding on	important prey for shorebirds may be lost
Capitella spp./ Oligochaeta	Mortality	1-138 ppt range Cap; 0-93 ppt range Oligo; <60 ppt optimal for both	Aug 09	NL 4,5	100	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL	about the only abundant macroinvertebrate left in sediments
Nephtys australiensis	Mortality	15-50 ppt	Aug09	NL 4	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; respond to any loss in lower trophic levels	not recorded in Dec 09
Boccardiella limnicola	Mortality	4-60 ppt	Aug 09	NL 4 (check report)	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; takes advantage of salinity between 50-60 ppt when it colonises empty tubeworm tubes.	Present prior to 2009

Scenario: Seawater cease pumping (Salinity: Marine macroinvertebrates) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Amphipoda	Mortality	1-125 ppt range, <45 ppt optimal	Aug09	NL 4-6	100	A	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL, salinity likely to already exceep upper tolerance limit	Present prior to 2009
Paragrapsus gaimardii	Mortality	brackish/marine	Aug 09	NL 4-6	100	B	3	3	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; dependent on vertical salinity gradient; salinity likley to already exceed upper tolerance limit	Present prior to 2009, possibly since 2009 (?)
Arthritica helmsi, large bivalves	Mortality	1-129 ppt range. <45 ppt optimum	Aug 09	NL 4	100	B	2	4	seawater discharge into Lx over summer will increase salinity and water level stressors in the MM and NL, in particular if concurrent pumping of SL; cyclical compounding effect	
Insect larvae	Mortality	1-138 ppt	Jan10-Mar10, Jan15-Mar15	NL 4-8	60	B	3	3	projected salinities outside of tolerance range	adult life stages independent of water due to mobility
large bioturbators	Mortality	brackish/marine	Aug 09	NL 4	100	C	3	2	sediment conditions may prevent establishment in subtidal. SIngle Australonereis found at some site	Australonereis present prior to 2009 and low numbers after 2009

Scenario: Freshwater cease pumping (Salinity: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Oligochaeta	Mortality	0-93 ppt	None	Lx		E	3	2	salinity remains suitable for oligochaetes, occur in low numbers only	
Oligochaeta	Mortality	0-93 ppt	None	Lb		E	3	2	projected salinities would not decrease oligochaetes, water level and sediment properties more important	
Amphipoda	Mortality	1-125 ppt	None	Lx, Lb		D	3	3	amphipods occurring in low numbers at present, salinities not changing beyond their tolerances; food for foraging waders	salinities remain within tolerance range, water level more important
Insect larvae	Mortality	1-138 ppt	None	Lx, Lb		D	2	3	projected salinities within tolerance ranges	

Dissolved oxygen Risk Assessment: Marine macroinvertebrates

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (Dissolved oxygen: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	<5mg/l	26/06/2019	Lx	95	B	1	4	Response may vary with each taxa.	

Dissolved oxygen was not assessed as having any impacts in any other scenarios or locations

pH Risk Assessment: Marine macroinvertebrates

Completed by: Workshop **Date:** 23/06/2010

Scenario: Do-Nothing pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	lethal if pH<6	March/ May 2012 start; all habitat by Oct 2012	Lx	100	A	1	5	Habitat is 30% 0f Lake. As not many marine/estuarine macroinvertebrates in the lake sediments, they remain unaffected, apart from areas on the lake side of the barrage and up to Pt Stury were they already occur	
Insect larvae	Mortality	lethal if pH<4	~May 2012	Lx	100	A	1	4	as adults can fly, populations as such not threatened as long as other breeding sites found.	

Scenario: Seawater pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	lethal if pH<6	Mar 2012	Lx	25	A	1	3	as not many marine/estuarine macroinvertebrates in the lake sediments, they remain unaffected, apart from areas on the lake side of the barrage and up to Pt Stury were they already occur	affected areas between barrages and Pt Sturt, but acidification reverses in model. Otherwise isolated pockets around lake shore, but no larger scale acidification; low confidence b/c of questionable modelling outputs
Insect larvae	Mortality	lethal if pH<4	Mar 2012	Lx	10	A	1	3	as adults can fly, populations as such not threatened as long as other breeding sites found.	affected areas between barrages and Pt Sturt, but acidification reverses in model. Otherwise isolated pockets around lake shore, but no larger scale acidification; low confidence b/c of questionable modelling outputs

Scenario: Freshwater pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Insect larvae	Mortality	lethal at pH<4	June 2010	Lx	5	A	1	2	as adults can fly, populations as such not threatened as long as other breeding sites found.	isolated pockets around lake shore, but no larger scale acidification

Scenario: Do-Nothing cease pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	lethal if pH<6	May2016	Lx	40	B	2	3	as not many marine/estuarine macroinvertebrates in the lake sediments, they remain unaffected, apart from areas on the lake side of the barrage and in the top east corner	isolated pockets around lake shore, but no larger scale acidification
Insect larvae	Mortality	lethal if pH<4	May2016	Lx	10	A	2	3	as adults can fly, populations as such not threatened as long as other breeding sites found.10% relates to fringe areas with MBO	isolated pockets around lake shore, but no larger scale acidification

Scenario: Seawater cease pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All marine invertebrates	Mortality	lethal if pH<6	March 2012 near barrages; Oct 2012 southern lake	Lx	100	A	1	4	areas affected inside barrages contain estaurine macroinvertebrates	affecting mainly area inside barrages were discharge into lake occurs; low confidence in model outputs
Insect larvae	Mortality	lethal if pH<6	March 2012 near barrages; Oct 2012 southern lake	Lx	100	A	1	4	as adults can fly, populations as such not threatened as long as other breeding sites found.	affecting mainly area inside barrages were discharge into lake occurs; low confidence in model outputs
Insect larvae	Mortality	lethal if pH<6	July 2011	Lb	95	A	1	4	as adults can fly, populations as such not threatened as long as other breeding sites found.	rapid switch of conditions to acidification

Scenario: Freshwater cease pumping (pH: Marine macroinvertebrates)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Insect larvae	Mortality	lethal if pH<6	June 2011	Lx	95	A	1	5	Narrows remain habitable until Dec 2011 when pH drops below 4. Relatively quickly switch to acidification	

Salinity Risk Assessment: Fish
Completed by: Workshop

Scenario: Do-Nothing pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All species	All effects			Lx	0				Thresholds not reached during action period.	
Murray Cod	Mortality	>13,200 mg/L	Mar-12	Lb	80	A	1	4	Majority of lake above tolerance of all life stages (published literature). Percentages based on total lake area.	Barriers to migration away from highly saline areas. Narrung Narrows not considered sufficient habitat, similar conditions reoccur in March 2013
Golden perch	Mortality	>14,400 mg/L	Mar-12	Lb	80	A	1	4	Majority of lake above tolerance of all life stages (published literature). Percentages based on total lake area.	Barriers to migration away from highly saline areas, similar conditions reoccur in March 2013
Common carp	Mortality	>13,000 mg/L	Mar-12	Lb	80	A	1	4	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas, similar conditions reoccur in March 2013
Short-headed lamprey	Recruitment failure: limited sperm motility, loss of eggs or larvae	>10,000 mg/L	Mar-12	Lb	80	A	1	4	majority of lake over tolerance of early life stages (ammocoetes). Spawning occurs in freshwater, ammocoetes develop in freshwater.	First occurs in Jan 2011, but Mar 2012 is worst case.

Scenario: Seawater pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Murray Cod	Mortality	>13,200 mg/L	Mar-13	Lx	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.

Scenario: Seawater pumping (Salinity: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Golden perch	Mortality	>14,400 mg/L	Mar-13	Lx	75	A	2	4	Wellington weir in place therefore may be potential for avoidance; nevertheless, fish will be lost from the lake	Barriers to migration away from highly saline areas.
Australian smelt	Mortality	>30,000 mg/L	Feb-13	Lx	10	B	4	3	Only small portion of lake above tolerance. Minor loss of adult habitat.	Whilst this salinity is below tolerance 30,000 mg/L seems high
Bony herring	Mortality	>30,000 mg/L	Feb-13	Lx	10	B	4	3	Only small portion of lake above tolerance. Minor loss of adult habitat.	Whilst this salinity is below tolerance 30,000 mg/L seems high
Murray hardyhead	Mortality	>30,000 mg/L	Feb-13	Lx	10	B	4	3	Only small portion of lake above tolerance (published literature)	
Yarra pygmy perch	Mortality	>10,000 mg/L	Feb-13	Lx	100	A	1	5	Whole lake above predicted tolerance, Not considered a mobile species	
Common carp	Mortality	>13,000 mg/L	Mar-13	Lx	90	A	1	5	Whole lake above tolerance of all life stages	
Congolli	Loss preferred habitat (females & juv)	>2,000 mg/L	Feb-13	Lx	100	B	3	3	Loss of prefered freshwater habitats for females and juveniles but within salinity tolerances of these lifestages	
Common galaxias	Loss of preferred habitat (all)	>2,000 mg/L	Feb-13	Lx	100	B	3	3	Loss of preferred habitats for adults but flexible reproductive strategies.	
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Mar-13	Lx	100	A	1	5	Whole lake above tolerance of ammocoetes (published literature). Spawning occurs in freshwater, ammocoetes develop in freshwater.	Ammocoetes only life-stage resident in lakes. Adults transient.
Murray Cod	Mortality	>13,200 mg/L	Mar2011 onwards	Lb	100	A	1	5	Whole of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.

Scenario: Seawater pumping (Salinity: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Golden perch	Mortality	>14,400 mg/L	Mar2011 onwards	Lb	100	A	1	5	Whole lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Australian smelt	Mortality	>30,000 mg/L	Feb2012 onwards	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	
Bony herring	Mortality	>30,000 mg/L	Feb2012 onwards	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	
Common carp	Mortality	>13,000 mg/L	Mar2011 onwards	Lb	100	A	1	5	Whole lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Congolli	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar2012; Mar2013	Lb	90	B	1	3	Tolerance is high but prefer lower salinities. Whilst this does not mean mortality it would impact population. Mar2012 55%; Mar2013 90%	
Common galaxias	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar2012; Mar2013	Lb	90	B	1	3	Tolerance is high but prefer lower salinities. Whilst this does not mean mortality it would impact population. Mar2012 55%; Mar2013 90%	
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Dec-10	Lb	100	A	1	5	Whole lake above tolerance of ammocoetes (published literature). Spawning occurs in freshwater, ammocoetes develop in freshwater.	Ammocoetes only life-stage resident in lakes. Adults transient.

Scenario: Freshwater pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All species	All effects			Lx	0				Thresholds not reached during action period.	
Murray Cod	Mortality	>13,200 mg/L	Mar-12	Lb	70	A	2	4	majority of lake over tolerance of adults. Occurs again in Mar 2013.	Barriers to migration away from highly saline areas.
Golden perch	Mortality	>14,400 mg/L	Mar-12	Lb	60	A	2	4	majority of lake over tolerance of adults. Occurs again in Mar 2013.	Barriers to migration away from highly saline areas.
Common carp	Mortality	>13,000 mg/L	Mar-12	Lb	70	A	2	4	majority of lake over tolerance of adults. Occurs again in Mar 2013.	Barriers to migration away from highly saline areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Mar-12	Lb	80	A	1	4	majority of lake over tolerance of early life stages (ammocoetes). Spawning occurs in freshwater, ammocoetes develop in freshwater.	First occurs in Jan 2011, but Mar 2012 is worst case.

Scenario: Do-Nothing Cease pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All species	All effects			Lx	0				Thresholds not reached during action period.	
Murray Cod	Mortality	>13,200 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Golden perch	Mortality	>14,400 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.

Scenario: Do-Nothing Cease pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Australian smelt	Mortality	>30,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Bony herring	Mortality	>30,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Common carp	Mortality	>13,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Congolli	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence.	Barriers to migration away from highly saline areas.
Common galaxias	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence	Barriers to migration away from highly saline areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Mar-11	Lb	90	A	1	4	Majority of lake above tolerance of ammocoetes (published literature). Spawning occurs in freshwater, ammocoetes develop in freshwater.	Barriers to migration away from highly saline areas.

Scenario: Seawater Cease pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Murray Cod	Mortality	>13,200 mg/L	Feb-12	Lx	90	A	1	5	Whole of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas. Wellington weir may be potential for avoidance; nevertheless, fish will be lost from the lake

Scenario: Seawater Cease pumping (Salinity: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Golden perch	Mortality	>14,400 mg/L	Feb-12	Lx	75	A	2	5	Majority of lake above tolerance of all life stages (published literature). Salinities are very close to tolerance in most of lake	Wellington weir may be potential for avoidance; nevertheless, fish will be lost from the lake
Australian smelt	Mortality	>30,000 mg/L	Feb-12	Lx	10	B	4	3	Only small portion of lake above tolerance, Minor loss of adult habitat	Whilst this salinity is below tolerance 30,000 mg/L seems high
Bony herring	Mortality	>30,000 mg/L	Feb-12	Lx	10	B	4	3	Only small portion of lake above tolerance, Minor loss of adult habitat	Whilst this salinity is below tolerance 30,000 mg/L seems high
Murray hardyhead	Mortality	>30,000 mg/L	Feb-12	Lx	10	B	4	3	Only small portion of lake above tolerance (published literature)	
Yarra pygmy perch	Mortality	>10,000 mg/L	Feb-12	Lx	>95	A	1	5	Whole lake above predicted tolerance, Majority of lake above tolerance of all life stages (published literature)	Not considered a mobile species
Common carp	Mortality	>13,000 mg/L	Feb-12	Lx	90	A	1	5	Whole lake above tolerance of all life stages, Much of lake above tolerance of all life stages (published literature)	
Congolli	Loss of preferred habitat (females and juveniles)	>2,000 mg/L	Oct-09	Lx	100	B	3	3	Loss of prefered freshwater habitats for females and juveniles but within salinity tolerances of these lifestages	
Common galaxias	Loss of preferred habitat (all adults)	>2,000 mg/L	Oct-09	Lx	100	B	3	3	Loss of preferred habitats for adults but flexible reproductive strategies.	
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Feb-12	Lx	90	A	1	5	Whole lake above tolerance of ammocoetes (published literature), Spawning occurs in freshwater, ammocoetes develop in freshwater	

Scenario: Seawater Cease pumping (Salinity: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Murray Cod	Mortality	>13,200 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Golden perch	Mortality	>14,400 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Australian smelt	Mortality	>30,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Bony herring	Mortality	>30,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Common carp	Mortality	>13,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Congolli	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence.	Barriers to migration away from highly saline areas.
Common galaxias	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence	Barriers to migration away from highly saline areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Mar-11	Lb	90	A	1	4	Majority of lake above tolerance of ammocoetes (published literature). Spawning occurs in freshwater, ammocoetes develop in freshwater.	Barriers to migration away from highly saline areas.

Scenario: Freshwater Cease pumping (Salinity: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All species	All effects			Lx	0				Thresholds not reached during action period.	
Murray Cod	Mortality	>13,200 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Golden perch	Mortality	>14,400 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Australian smelt	Mortality	>30,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Bony herring	Mortality	>30,000 mg/L	Mar-11	Lb	91	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Common carp	Mortality	>13,000 mg/L	Mar-11	Lb	90	A	1	5	Majority of lake above tolerance of all life stages (published literature)	Barriers to migration away from highly saline areas.
Congolli	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence.	Barriers to migration away from highly saline areas.
Common galaxias	Loss of preferred habitat (all life-stage)	>40,000 mg/L	Mar-11	Lb	90	B	1	3	Majority of lake above tolerance of all life stages. This species is highly tolerant however, preferred habitat is not hypersaline water. The tolerance of this species is reflected in the Low confidence	Barriers to migration away from highly saline areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	>10,000 mg/L	Mar-11	Lb	90	A	1	4	Majority of lake above tolerance of ammocoetes (published literature). Spawning occurs in freshwater, ammocoetes develop in freshwater.	Barriers to migration away from highly saline areas.

Water level Risk Assessment: Fish

Completed by: Workshop **Date:** 17/06/2010

Scenario: Do-Nothing pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Bony herring	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Yarra pygmy perch	Mortality	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced spawning & recruitment; Mortality	minus 1.5 m AHD,	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure likely to lead to total loss of individuals.
Common galaxias	Reduced available	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009

	habitat area								

Scenario: Do-Nothing pumping (Water level)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD,	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure likely to lead to a reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Short-headed lamprey	Reduced spawning & recruitment.	minus 1.5 m AHD,	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs upstream spawning movements into Lx and RM. Furthermore, lack of outflows results in a lack of navigational or migrational cues. Ammocoets live for ~3yrs prior to metamorphosising and migrating downstream. Continued disconnection will result in loss of species. Barrage closure likey to lead to total loss of individuals.
Short-headed lamprey	Loss of all individuals	Lake drying	2015	Lb	100	A	1	5	Total lake drying. Cease pumping scenario??
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.

Scenario: Seawater pumping (Water level: Fish) Same as Do-Nothing - must be wrong???

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.

Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.

Scenario: Seawater pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Bony herring	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Yarra pygmy perch	Loss of all individuals	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Congolli	Reduced spawning & recruitment; Mortality	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure, total loss of individuals.
Common galaxias	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure maylead to reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.

Scenario: Seawater pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Short-headed lamprey	Reduced spawning & recruitment. Mortality.	minus 1.5 m AHD,	length of scenario, 2015	Lx	100	A	1	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. Continued lack of outflows results in a lack of navigational or migrational cues. Whilst adults may move upstream during seawater delivery (unlikely due to limited attraction), newly metamorphosed juveniles cannot migrate to the ocean. Barrage closure may lead to total loss of individuals.
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Short-headed lamprey	Mortality.	Lake drying	2015	Lb	100	A	1	5	Total lake drying.

Scenario: Freshwater pumping (Water level: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Bony herring	Reduced available habitat area	minus 1.5 m AHD	2016	Lx	~26	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats.
Yarra pygmy perch	Loss of all individuals	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with wetlands, sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats

Scenario: Freshwater pumping (Water level: Fish) Cont.

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Congolli	Reduced spawning & recruitment; Mortality	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure, total loss of individuals.
Common galaxias	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure maylead to reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Short-headed lamprey	Reduced spawning & recruitment. Mortality.	minus 1.5 m AHD, barrage closure, total loss of individuals	length of scenario, 2015	Lx	100	A	1	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. Continued lack of connectivity obstructs upstream spawning movements into Lx and RM. Furthermore, lack of outflows results in a lack of navigational or migrational cues. Ammocoets live for ~3yrs prior to metamorphosising and migrating downstream. Continued disconnection will result in loss of species
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Short-headed lamprey	Mortality.	Lake drying	2015	Lb	100	A	1	5	Total lake drying

Scenario: Do-Nothing Cease pumping (Water level: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Bony herring	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Yarra pygmy perch	Mortality	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced spawning & recruitment; Mortality	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure, total loss of individuals.
Common galaxias	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009

Scenario: Do-Nothing Cease pumping (Water level: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure maylead to reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009.
Short-headed lamprey	Reduced spawning & recruitment. Mortality.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. Continued lack of connectivity obstructs upstream spawning movements into Lx and RM. Furthermore, lack of outflows results in a lack of navigational or migrational cues. Ammocoets live for ~3yrs prior to metamorphosising and migrating downstream. Continued disconnection will result in loss of species
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
All species	Mortality	Lake drying	2015	Lb	100	A	1	5	Total lake drying. Likely to affect Murray Cod, Golden perch, Australian smelt, Bony herring, Common carp, Common galaxias, Short-headed lamprey and Small-mouthed hardyhead.

Scenario: Seawater Cease pumping (Water level: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009

Scenario: Seawater Cease pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Yarra pygmy perch	Mortality	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced spawning & recruitment; mortality	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure, total loss of individuals.
Common galaxias	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure maylead to reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009

Scenario: Seawater Cease pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Short-headed lamprey	Reduced spawning & recruitment. Mortality.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. Continued lack of connectivity obstructs upstream spawning movements into Lx and RM. Furthermore, lack of outflows results in a lack of navigational or migrational cues. Ammocoets live for ~3yrs prior to metamorphosising and migrating downstream. Continued disconnection will result in loss of species
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
All species	Mortality	Lake drying	2015	Lb	100	A	1	5	Total lake drying. Likely to affect Murray Cod, Golden perch, Australian smelt, Bony herring, Common carp, Common galaxias, Short-headed lamprey and Small-mouthed hardyhead.

Scenario: Freshwater Cease pumping (Water level: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Murray Cod	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Golden perch	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Australian smelt	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Bony herring	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Murray hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats

Scenario: Freshwater Cease pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
Yarra pygmy perch	Mortality	minus 1.5 m AHD	2015	Lx	~90	A	1	3	This species is associated with sheltered areas and littoral zones and thus a water level of -1.5 m AHD results in the absence of these habitats
Common carp	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Congolli	Reduced spawning & recruitment; mortality	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong obstructs migratory movements for spawning and later recruitment into Lx. Potential loss of species from Lx. Barrage closure, total loss of individuals.
Common galaxias	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Common galaxias	Reduced spawning & recruitment.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	B	3	3	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. This species, unlike congolli, may recruit within freshwater environments although it is normally catadromous. In absence of connectivity recruitment is likely to be significantly reduced. Barrage closure maylead to reduction in recruitment success.
Short-headed lamprey	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009
Short-headed lamprey	Reduced spawning & recruitment. Mortality.	minus 1.5 m AHD	length of scenario, 2015	Lx	100	A	1	5	Lake level as a proxy for connectivity. This is a highly important primary stressor. Continued lack of bi-directional connectivity between Lake and Coorong. Continued lack of connectivity obstructs upstream spawning movements into Lx and RM. Furthermore, lack of outflows results in a lack of navigational or migrational cues. Ammocoets live for ~3yrs prior to metamorphosising and migrating downstream. Continued disconnection will result in loss of species
Small-mouthed hardyhead	Reduced available habitat area	minus 1.5 m AHD	2015	Lx	~25	A	4	4	Potential habitat area reduced by ~25% due to receded water level as compared to October 2009

Scenario: Freshwater Cease pumping (Water level: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale & Considerations
All species	Mortality	Lake drying	2015	Lb	100	A	1	5	Total lake drying. Likely to affect Murray Cod, Golden perch, Australian smelt, Bony herring, Common carp, Common galaxias, Short-headed lamprey and Small-mouthed hardyhead.

pH Risk Assessment: Fish

Completed by: Workshop **Date:** 17/06/2010

Scenario: Do-Nothing pumping (pH: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All fish	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Jul-13	Lx	70	A	3	3	Below tolerance of early life stages/sperm motility for majority/whole lake. Highly likely that sub-lethal injuries occur before death. Thresholds unknown.	
All fish	Mortality.	<5	Jul-13	Lx	50	A	2	4	Below adult tolerance for majority/whole lake. Highly likely that sub-lethal injuries occur before death. Thresholds unknown.	Barriers to migration away from acidic areas.
Yarra pygmy perch	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	90	B	1	2	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Yarra pygmy perch	Mortality.	<5	Sep-12	Lx	90	B	1	2	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.

Scenario: Seawater pumping (pH: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Murray Cod	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Murray Cod	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. Not as big an issue in this example
Murray hardyhead	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Murray hardyhead	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of all life stages in a portion of lake Note: littoral species will be impacted by decreased pH around the edges of Lake Alex on 15th Aug 2008?? whilst the Lakes doesn't broadly acidify spp that reside in littoral zones may be affected. Would likely impact early life stages also	Barriers to migration away from acidic areas.
Yarra pygmy perch	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	50	B	2	2	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater pumping (pH: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Yarra pygmy perch	Mortality.	<5	Sep-12	Lx	50	B	2	2	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Common carp	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Common carp	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Australian Smelt	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Australian Smelt	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Congolli	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater pumping (pH: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Congolli	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Common galaxias	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Common galaxias	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Short-headed lamprey	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Yellow-eyed mullet	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater pumping (pH: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Yellow-eyed mullet	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH
Yellow-eyed mullet	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Oct 2012	Lx	10	B	4	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-oct 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, *so it is an obvious negative impact but uncertain about scoring. Note: does not persist as long in this scenario as in SW_CP. Assumed that only 20% of the time that seawater entering over 2012-13 that pH is hostile*	Consequence needs to be considered as acidification may exclude fish from the entire lake
Small-mouthed hardyhead	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	10	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Small-mouthed hardyhead	Mortality.	<5	Sep-12	Lx	5	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.

Scenario: Seawater pumping (pH: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Black bream	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Black bream	Mortality.	<5	Sep-12	Lx	30	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH
Black bream	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Oct 2012	Lx	10	B	4	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-oct 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, so it is an obvious negative impact but uncertain about scoring. Note: does not persist as long in this scenario as in SW_CP	
Mulloway	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Sep-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake	

Scenario: Seawater pumping (pH: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mulloway	Mortality.	<5	Sep-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH
Mulloway	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Oct 2012	Lx	10	B	4	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-oct 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, so it is an obvious negative impact but uncertain about scoring. Note: does not persist as long in this scenario as in SW_CP	

Scenario: Freshwater pumping (pH: Fish)

pH does not constitute a stressor under this scenario

Scenario: Do-Nothing Cease pumping (pH: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All fish	Mortality.	<5	*NA*	Lx						
All fish	Mortality.	<5	Jul-11	Lb	>90	A	1	5	Below tolerance for majority/whole lake. Highly likely that sub-lethal injuries occur before death. Thresholds unknown.	Barriers to migration away from acidic areas.

Scenario: Seawater Cease pumping (Ph: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Murray Cod	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake; Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct.	
Murray Cod	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of all life stages in a portion of lake; Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct.	Barriers to migration away from acidic areas.
Golden perch	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Golden perch	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Australian smelt	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Australian smelt	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Murray hardyhead	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Murray hardyhead	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Yarra pygmy perch	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	90	B	1	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Yarra pygmy perch	Mortality.	<5	Oct-12	Lx	90	B	1	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Common carp	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Common carp	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Congolli	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Congolli	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Common galaxias	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Common galaxias	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Short-headed lamprey	Recruitment failure: limited sperm motility, loss of eggs or larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Short-headed lamprey	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.
Yellow-eyed mullet	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Yellow-eyed mullet	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Yellow-eyed mullet	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Nov 2012	Lx	30	B	3	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-Nov 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, so it is an obvious negative impact but uncertain about scoring. Assumed that only 30% of the time that seawater entering over 2012-13 that pH is hostile.	
Small-mouthed hardyhead	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Small-mouthed hardyhead	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas.

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Black bream	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	
Black bream	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH
Black bream	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Nov 2012	Lx	30	B	3	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-Nov 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, so it is an obvious negative impact but uncertain about scoring.Assumed that only 30% of the time that seawater entering over 2012-13 that pH is hostile.	
Mulloway	Recruitment failure: limited sperm motility, loss eggs/larvae	<6	Oct-12	Lx	35	B	4	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	

Scenario: Seawater Cease pumping (Ph: Fish) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Mulloway	Mortality.	<5	Oct-12	Lx	30	B	3	3	Below tolerance of early life stages in a portion of lake;Low pH (3) progresses from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct	Barriers to migration away from acidic areas. This has different interpretation to freshwater species, basically there may be an initial increase in available habitat due to increased salinity but some of this will be taken away due to low pH
Mulloway	Mortality of entrained individuals that must pass through acidic portion of Lake immediately post filling phases	<5	Sept - Nov 2012	Lx	30	B	3	2	Estuarine and marine fish that move in with seawater (entrained or otherwise) have to pass through an acidified (~3) area of water between the barrage and approximately point Macleay. This 'plug' of water remains from sept-Nov 2012 and may result in significant mortality of entrained fish. These fish would probably have been better staying in Coorong, so it is an obvious negative impact but uncertain about scoring. Assumed that only 30% of the time that seawater entering over 2012-13 that pH is hostile.	
All fish	Mortality.	<5	Jul-11	Lb	>90	A	1	5	Below tolerance for majority/whole lake. Highly likely that sub-lethal injuries occur before death. Thresholds unknown.	Barriers to migration away from acidic areas.

Scenario: Freshwater Cease pumping (pH: Fish)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
All fish	Mortality.	<5	Jun-11	Lb	>90	A	1	5	Below tolerance for majority/whole lake. Highly likely that sub-lethal injuries occur before death. Thresholds unknown.	Barriers to migration away from acidic areas.

Salinity and water level Risk Assessment template: Southern Bell Frog

Completed by: Nick Souter
Date: 10-Jul-10

Scenario: All scenarios for Lake Alexandrina only
pH has no effect prior to disconnection and salinity

Scenario	Effect	Measures of effect	Worse-case Timing	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
DDN pump	Mortality; Local extinction	disconnection and salinity > 9 ppt	02-Feb-11	100	B	1	3	disconnection to main lake body and increase in salinity	proxy for adjacent swamps drying of adjacent terrestrial habitat, initial disconnection and restablishment frogs assumed to be able to avoid salinity > 7 ms/cm or 9 ppt (tadpoles)
Seawater pump	Mortality; Local extinction	salinity > 9 ppt then disconnection	20-Dec-10	100	B	1	3	increase in salinity followed by disconnection of main lake body	
Freshwater pump	Mortality; Local extinction	disconnection and salinity > 9 ppt	02-Mar-11	100	B	1	3	disconnection to main lake body and increase in salinity	
DDN cease pump	Mortality; Local extinction	disconnection and salinity > 9 ppt	05-Jan-11	100	B	1	3	disconnection to main lake body and increase in salinity	
Seawater cease pump	Mortality; Local extinction	salinity > 9 ppt then disconnection	17-Nov-10	100	B	1	3	increase in salinity followed by disconnection of main lake body	
Freshwater cease pump	Mortality; Local extinction	disconnection and salinity > 9 ppt	09-Mar-11	100	B	1	3	disconnection to main lake body and increase in salinity	

Salinity Risk Assessment template: Birds

Completed by: Dan Rogers
Date: 8/07/2010

Scenario: Do-Nothing Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/abundance/foraging performance	Nov-10	Lb	50-75	B	2	3	decline in foraging performance, habitat avoidance below 'giving-up density'	salinity above tolerance of remaining submerged/floating veg. Possible food source for generalist waterfowl through remaining zooplankton while water remains

Scenario: Seawater Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds				Lx	salinity remains below threshold for insect larvae (primary food source for this receptor group) throughout. Some minor reductions in water level unlikely to have major impact on distributjon of foraging habitat.					water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.
Generalist shorebirds				Lb	salinity presumably remains below threshold for insect larvae (primary food source for this receptor group), although salinity values unknown from model when >40g/L.					water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.

Scenario: Seawater Pumping (Salinity: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Estuarine shorebirds				Lx	Some minor reductions in water level unlikely to have major impact on distributjon of foraging habitat. Potentially some benefits with importation of marine/estuarine infauna (larger polychaetes)					water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.
Estuarine shorebirds				Lb	not relevant				water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.	
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Feb 2013	Lx	15	B	4	2	salinity thresholds for bony herring reached in parts of lake. Other large bodied fish affected more severely, impacting on prey redundancy. However, introduction of estuarine/marine species may offset losses and result in some improved habitat (but see pH). Smallmouth hardyhead tolerance not reached during action.	decline in foraging performance, habitat avoidance below 'giving-up density'
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Feb 2012	Lb	65 (up to 95 for some species)	A	1	5	salinity thresholds for larger fish (bony herring) largely reached end of Summer 2012, resulting in impacts to piscivores that depend on larger fish (Australian Pelican, White-bellied Sea-eagle, Caspian Tern). Smallmouth hardyhead salinity thresholds not reached, although cannot determine maximum salinity for salinities > 40g/L from model.	species that depend on larger bodied fish likely to give up before total extirpation of these species (therefore, 90% loss of fish habitat may result in 100% loss of these bird species)

Scenario: Seawater Pumping (Salinity: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Oct 2010, Mar 2013	Lx	60	B	3	4	salinity above tolerance of remaining submerged/floating veg by 2013. Although freshwater zooplankton lost, likely to be replaced by estuarine/marine zooplankton - predict null-positive effect for species that can survive on zooplankton (e.g. teal, pink-eared duck, shoveler)	
Waterfowl	Reduced foraging, Habitat avoidance	presence/abundance/foraging performance	Oct 2010, Mar 2013	Lb	60	B	3	4	salinity above tolerance of remaining submerged/floating veg by 2013. Although freshwater zooplankton lost, likely to be replaced by estuarine/marine zooplankton - predict null-positive effect for species that can survive on zooplankton (e.g. teal, pink-eared duck, shoveler)	

Scenario: Freshwater Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl				*Lx*	salinity below tolerance of remaining submerged/floating veg. Also below tolerance of remaining zooplankton (food source for generalist waterfowl)				*no assessment done for other submerged veg species (presumed absence of submerged macrophytes from lake body in Oct-09). Habitat still available in managed wetlands (Narrung, GC, Coorong). Does not account for possible macrophyte recruitment events during action*	

Scenario: Freshwater Pumping (Salinity: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Nov-10, Mar-13	Lb	50-75	B	3	3	salinity above tolerance of remaining submerged/floating veg. Possible food source for generalist waterfowl through remaining zooplankton	no assessment done for other submerged veg species (presumed absence of submerged macrophytes from lake body in Oct-09). Habitat still available in managed wetlands (Narrung, GC, Coorong). Does not account for possible macrophyte recruitment events during action

Scenario: Do-Nothing Cease Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds				Lx	salinity remains below threshold for insect larvae (primary food source for this receptor group) throughout				*water level regime will be important if suitable mudflats are not periodically inundated or saturated*	
Generalist shorebirds			Feb 2011	Lb	100	A	1	2	salinity remains below threshold for insect larvae (primary food source for this receptor group) until lake goes (essentially) dry - risk assessment from water level decline	massive loss of habitat as shoreline recedes and mudflats dry out (water level impact). Spatial variation of mudflat quality unknown at different water levels
Estuarine shorebirds				Lx	not relevant - landlocked habitat				water level regime will be important if suitable mudflats are not periodically inundated or saturated	
Estuarine shorebirds				Lb	not relevant - wrong habitat				massive loss of habitat as shoreline recedes and mudflats dry out (water level impact). Spatial variation of mudflat quality unknown at different water levels	
Fish-eating birds				Lx					salinity thresholds for all fish species not reached during action period	

Scenario: Do-Nothing Cease Pumping (Salinity: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	June 2011	Lb	75	B	1	4	salinity thresholds for abundant, large-bodied prey species(bony herring; Bice pers. comm.) reached March 2011, resulting in loss of larger piscivores (Australian Pelican, White-bellied Sea-eagle, Caspian Tern). Smallmouth Hardyhead probably persist while water is available (maximum salinity of model unknown beyond ~40 g/L)	loss of prey species redundancy and larger size classes (smallmouth hardyhead only remaining species)
Waterfowl				Lx	salinity below tolerance of remaining submerged/floating veg. Also below tolerance of remaining zooplankton (food source for generalist waterfowl)				no assessment done for other submerged veg species (presumed absence of submerged macrophytes from lake body in Oct-09). Habitat still available in managed wetlands (Narrung, GC, Coorong). Does not account for possible macrophyte recruitment events during action	
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Nov-10	Lb	90	A	2	3	salinity above tolerance of remaining submerged/floating veg. Possible food source for generalist waterfowl through remaining zooplankton while water remains	habitat lost completely when lake dries (March 2013)

Scenario: Seawater Cease Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds				Lx	salinity remains below threshold for insect larvae (primary food source for this receptor group) throughout. Some minor reductions in water level unlikely to have major impact on distribution of foraging habitat. Water level regime important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.					

Scenario: Seawater Cease Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Jan 2011, Jan 2012	Lb	95	A	1	2	salinity presumably remains below threshold for insect larvae (primary food source), although salinity values unknown from model when >40g/L. However water levels drop significantly from Jan 2011 - almost complete loss of habitat from Jan 2012	water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.
Estuarine shorebirds				Lx	Possibly improvements in habitat for some species with introduction of estuarine/marine infauna. Water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.					
Estuarine shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Jan 2011, Jan 2012	Lb	95	A	1	2	water levels drop significantly from Jan 2011 - almost complete loss of habitat from Jan 2012	water level regime will be important if suitable mudflats are not periodically inundated or saturated. Mudflat habitat quality unknown at low water levels.
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Feb 2012	Lx	15	B	4	2	salinity thresholds for bony herring reached in small parts of lake (near barrages). Other freshwater fish affected more severely, impacting on prey redundancy. However, introduction of estuarine/marine species may offset losses and result in some improved habitat (but see pH). Smallmouth hardyhead may benefit from action resulting in improved food resources for smaller species (Greenshank, small terns).	
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Mar 2011	Lb	100	A	1	2	salinity thresholds for bony herring reached in March 2011. Other fish affected more severely, impacting on prey redundancy. Smallmouth hardyhead tolerance not reached until lake dries. Small waterbody may increase pressure on remaining fish to extirpation	species that depend on larger bodied fish likely to give up before total extirpation of these species (therefore, 90% loss of fish habitat may result in 100% loss of these bird species)

Scenario: Seawater Cease Pumping (Salinity: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/abundance/foraging performance	September 2010: March 2013	Lx	60	A	3	2	salinity above tolerance of remaining submerged/floating veg by 2013. Although freshwater zooplankton lost, likely to be replaced by estuarine/marine zooplankton - predict null-positive effect for species that can survive on zooplankton (e.g. teal, pink-eared duck, shoveler)	
Waterfowl			December 2010: March 2013	Lb	100	A	1	2	salinity above tolerance of remaining submerged/floating veg by 2013. Zooplankton food resource (in spite of community change) will remain ok until water body dries out.	

Scenario: Freshwater Cease Pumping (Salinity: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	March 2011	Lb	75	A	2	3	salinity thresholds for larger fish (bony herring) largely reached end of Summer 2011, resulting in impacts to piscivores that depend on larger fish (Australian Pelican, White-bellied Sea-eagle, Caspian Tern). Smallmouth hardyhead salinity thresholds not reached during action period.	species that depend on larger bodied fish likely to give up before total extirpation of these species (therefore, 90% loss of fish habitat may result in 100% loss of these bird species)
Waterfowl				Lx	salinity below tolerance of remaining submerged/floating veg. Also below tolerance of remaining zooplankton (food source for generalist waterfowl). No assessment done for other submerged veg species (presumed absence of submerged macrophytes from lake body in Oct-09). Habitat still available in managed wetlands (Narrung, GC, Coorong). Does not account for possible macrophyte recruitment events during action					
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	March 2011	Lb	100	B	2	3	salinity above tolerance of remaining submerged/floating veg. Possible food source for generalist waterfowl through remaining zooplankton while water remains, but habitat completely lost by March 2012	

pH Risk Assessment template: Birds

Completed by: Dan Rogers
Date: 8/07/2010

Scenario: Do-Nothing Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	May 2012	Lx	100	A	1	4	Loss of prey items (chironomid larvae) from when pH crashes. Birds will move to alternative habitats for period (though remaining high quality mudflats are affected, so move will be to suboptimal habitats). Recolonisation by chironomidae likely after pH improves	see salinity notes on water level impacts. Uncertainty around physiological impacts of pH
Generalist shorebirds				Lb	pH remains above threshold for prey species.					
Estuarine shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	May 2012	Lx	100	A	1	4	not relevant in landlocked system	see salinity notes on water level impacts
Estuarine shorebirds				Lb	not relevant - wrong habitat					
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	July 2013	Lx	80	A	3	2	pH falls below threshold of key prey species July 2013. Birds may give up on site when fish density drops below certain level (before local fish extinction)	
Fish-eating birds				Lb	pH remains above threshold for prey species.					

Scenario: Do-Nothing Pumping (pH: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/abundance/foraging performance	June 2013	Lx	75	C	3	1	lake falls below pH threshold of food species.	vegetation dynamics in response to short-term acidification unknown. Distribution of physical foraging habitat quality unknown.
Waterfowl				Lb	pH remains above threshold for macrophytes and zooplankton food species.					

Scenario: Seawater Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Jan 2011	Lx	10	B	4	3	pH remains above threshold for key prey species (chironomid larvae), although some seasonal drops around fringes and particularly near barrages (recently good habitat for shorebirds)	
Generalist shorebirds				Lb	pH remains above threshold for key prey species (chironomid larvae)					
Estuarine shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Jan 2011	Lx	5	B	4	3	pH remains above threshold for key prey species (estuarine macroinverts), although some seasonal drops around fringes and particularly near barrages (recently good habitat for shorebirds)	
Estuarine shorebirds				Lb	pH remains above threshold for key prey species (estuarine macroinverts, and, with marine influence, estuarine and marine infauna)					
Fish-eating birds				Lx	pH generally remains above threshold for key fish species					

Scenario: Seawater Pumping (pH: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Fish-eating birds				Lb	pH generally remains above threshold for key fish species					
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	seasonal (Summertime); end of Summer 2012	Lx	15	C	3	1	seasonal minor pH drops at fringes. Estuarine zooplankton may be affected by pH drops near barrages	vegetation dynamics in response to short-term acidification unknown. Distribution of physical foraging habitat quality unknown.
Waterfowl				Lb	pH remains above threshold for key plant species while salinity is under tolerance level					

Scenario: Freshwater Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	June 2010	Lx	30	A	3	3	Loss of prey items (chironomid larvae) from habitat transient. Birds will move to alternative habitats for period (though remaining high quality mudflats are affected, so move will be to suboptimal habitats). Recolonisation by chironomidae likely after pH returns to tolerant levels.	
Estuarine shorebirds			June 2010	Lx	30	A	3	3		

Scenario: Do-Nothing Cease Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance		Lx	10	C	3	1	some fringing habitat below pH threshold of aquatic macrophyte food species. If best foraging sites are lost, transient pH effects may be drawn out (slow recruitment of macrophytes). Zooplankton food species unlikely to be affected.	vegetation dynamics in response to short-term acidification unknown. Distribution of physical foraging habitat quality unknown.

Scenario: Do-Nothing Cease Pumping (pH: Birds) (cont.)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	June 2011	Lb	100	A	1	4	pH thresholds for all prey species reached June 2011. Loss of all vegetation and zooplankton habitat Summer 2011, but waterfowl likely to have given up before then (particularly if alternative off-site habitats are available).	habitat lost completely when lake dries (March 2013)

Scenario: Seawater Cease Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Generalist shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	seasonal	Lx	10	B	4	3	pH remains above threshold for key prey species (chironomid larvae), although some seasonal drops around fringes and particularly near barrages (recently good habitat for shorebirds)	seasonal nature of pH fluctuations should mean rapid recolonisation of prey (chironomids)
			July 2011	Lb	100	A	1	4	pH drops below threshold of prey for entire lake	
Estuarine shorebirds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	seasonal	Lx	10	B	4	3	pH remains above threshold for key prey species (estuarine macroinverts), although some seasonal drops around fringes and particularly near barrages (recently good habitat for shorebirds). Low pH at barrages may limit introduction of estuarine/marine invertebrate prey	seasonal nature of pH fluctuations should mean rapid recolonisation of prey (chironomids)
			July 2011	Lb	100	A	1	4	pH drops below threshold of prey for entire lake	

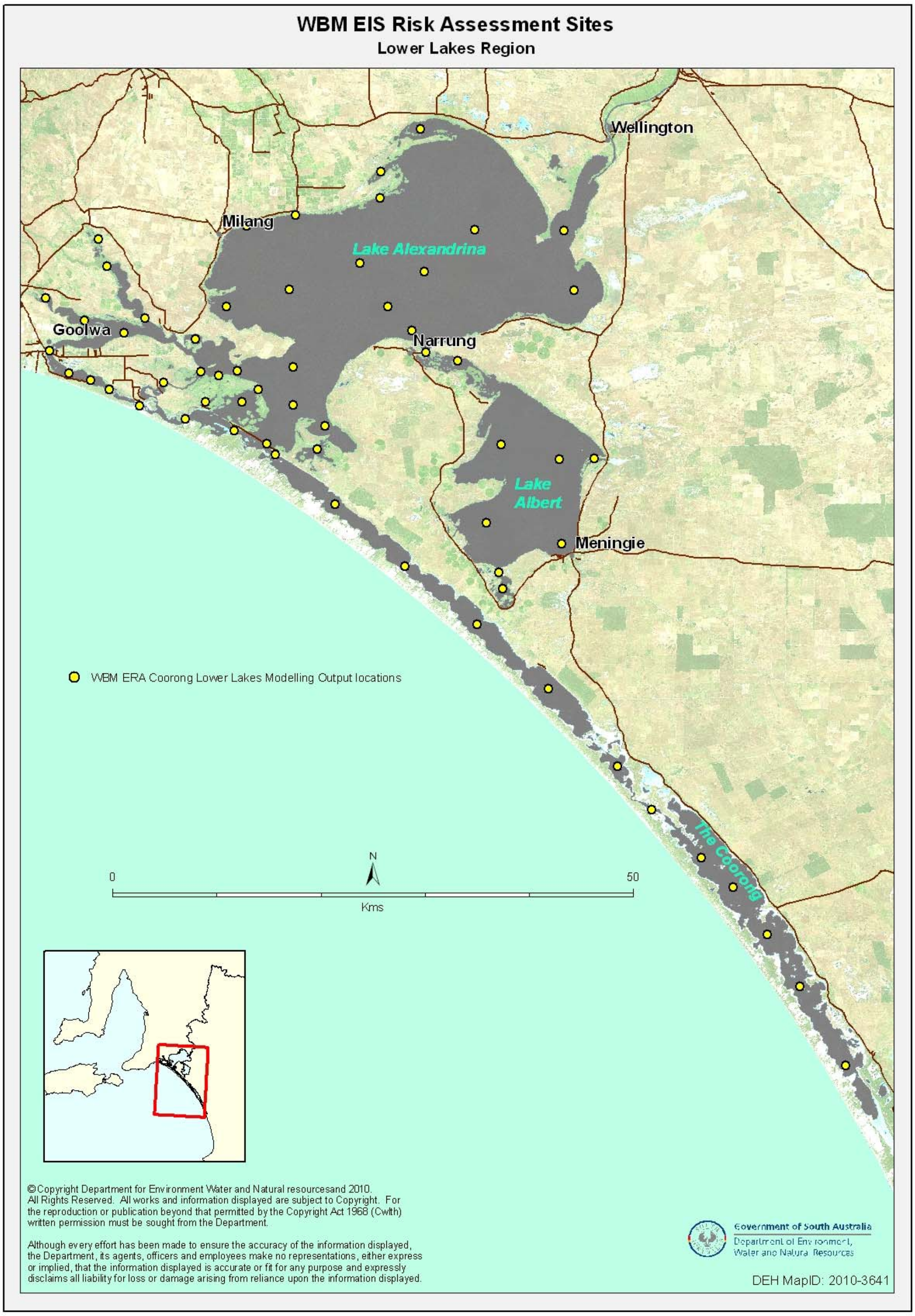
Scenario: Seawater Cease Pumping (pH: Birds) Cont.

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance	Sep 2011	Lx	35	C	3	2	pH below tolerance of prey species from immed u/s Tauw barrage in late Sept to approx third of the lake in mid-late Oct 2011. pH at barrages may form barrier to introduction of marine/estuarine prey species into lakes	
Waterfowl	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance		Lx					pH only drops below threshold after salinity has exceeded threshold of remaining aquatic plants. pH may affect any estuarine/marine food plant/algal species - unknown. Seasonal loss of zooplankton due to pH post Spring 2011	vegetation dynamics in response to short-term acidification unknown. Distribution of physical foraging habitat quality unknown.
			July 2011	Lb	100	A	2	5	pH only drops below threshold after salinity has exceeded threshold of remaining aquatic plants. pH may affect any estuarine/marine food plant/algal species - unknown. Loss of zooplankton due to pH Winter 2011	

Scenario: Freshwater Cease Pumping (pH: Birds)

Receptor list	Effect	Measures of effect	Worse-case Timing	Location	Habitat (%)	Likeli.	Consq.	Conf.	Rationale	Considerations
Fish-eating birds	Reduced foraging, Habitat avoidance	presence/ abundance/ foraging performance		Lx	pH remains above threshold for key species (aquatic veg. & zooplankton)					
			June 2011	Lb	>90	A	1	5	pH falls below threshold of key prey species July 2011. Birds may give up on site when fish density drops below certain level (before local fish extinction)	
Waterfowl				Lx	pH remains above threshold for key species (aquatic veg. & zooplankton)					
			June 2011	Lb	100	A	1	4	pH thresholds for all prey species reached June '11. Loss of all vegetation and zooplankton habitat Summer 2011, but likely to have given up before then (part. if alternative off-site habitats are available). habitat lost completely when lake dries (March '13)	

Attachment E: Hydrological Modelling Sites for Lakes Alexandrina and Albert, Murray Mouth and Coorong



Attachment F: Assessment of alternative acidification control treatments

F.1: Introduction

Acid sulfate soils (ASS) that are kept in a reducing state do not generate sulfuric acid and thus do not represent an environmental hazard. Site managers can maintain reducing conditions by keeping the ASS inundated. Reducing conditions stimulate sulfate-reducing bacteria to convert the damaging sulfuric materials to the more benign sulfidic materials.

Reducing conditions are typically induced by:

15. 1) re-wetting the ASS, thereby greatly reducing diffusivity of oxygen in the inundated soils compared to exposed soils (10,000 times less; Zehnder 1988), and/or
16. 2) adding sufficient organic matter to the ASS (via living plants or mulch) to increase oxygen demand beyond the rate of oxygen supply (Revsbech *et al*. 1980; Reimers and Smith 1986).

The other management option is to treat the problem by neutralising the acid as it is being generated. Prevention of ASS formation is not generally considered here as an alternative management option because extensive areas of ASS have already been formed. However, the possibility of increased ASS formation via seawater introduction should be addressed in another study given that seawater contains significant quantities of sulfate. Thus the various management techniques can be categorised as:

- Prevention (i.e. keep ASS inundated and prevent oxidation);
- Control (e.g. planting or mulching); and/or
- Treatment (e.g. neutralising acid with limestone).

Figure F.1 shows a diagram of the different management techniques for prevention, control and treatment along with their key objectives.

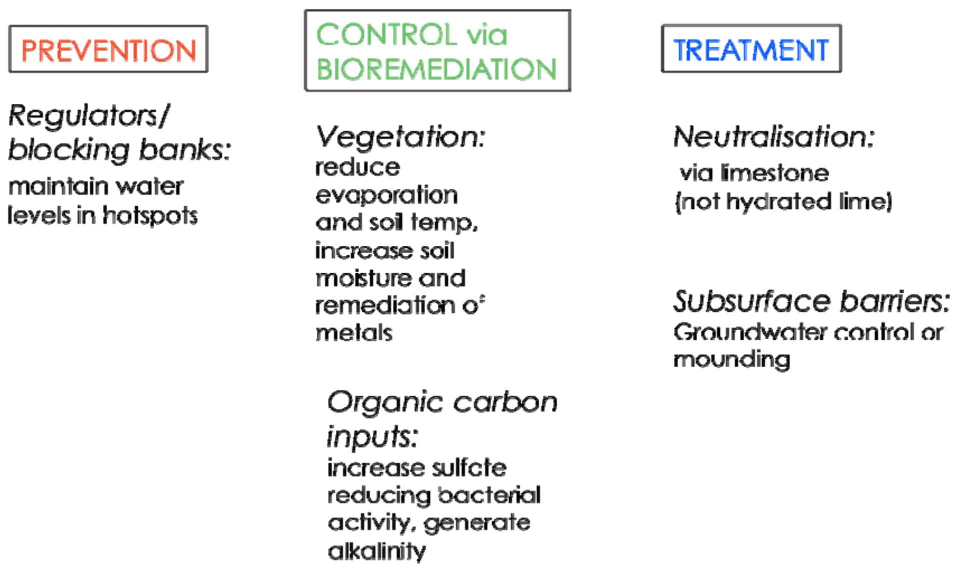


Figure F.1: Overview of the Acid Sulfate Soils Management techniques used within the Lakes Alexandrina and Albert site. Adapted from Barnett (unpubl.)

At a whole-of-site scale there is the option of *prevention* of ASS exposure across the lakes by keeping lake levels above the acidification tipping points with either freshwater or seawater inflows. Within the site, exposure of ASS can be prevented using regulators or blocking banks to maintain water levels in parts of the system (e.g. Clayton and Narrung Narrows regulators shown on Figure 1.1). *Control* of ASS occurs through increasing the cover of vegetation) or the amount of organic matter to provide conditions which stimulate activity of sulfate reducing bacteria, converting sulfate to sulfide. *Treatment* involves neutralising the acid using limestone or other chemical ameliorants or wetting the ASS via groundwater mounding or irrigation. The different management strategies are discussed more fully in Section F.3.

Prevention of acidification of Lakes Alexandrina and Albert through regional water management is the key objective of the Seawater and Freshwater pumping scenarios being assessed in this Ecological Risk Assessment. Inundation with either seawater or freshwater was shown to prevent widespread exposure and oxidation of acid sulfate soils (ASS) by keeping lake levels higher than the acidification trigger levels of -1.5m AHD in Lake Alexandrina and -0.5 mAHD in Lake Albert. Maintenance of lakelevels above those tipping points was modelled as preventing widespread acidification. When ASS hot spots were exposed at lake levels higher than those tipping points then localised acidification events were predicted.

The hydrological model outputs analysed in preceding chapters showed that widespread acidification was successfully avoided in both lakes under the Seawater and Freshwater pumping scenarios. In the Do-nothing scenario, widespread acidification occurred in Lake Alexandrina when pumping to Lake Albert continued. When pumping to Lake Albert ceased in the Do-nothing scenario, localised acidification occurred around the fringes of Lake Alexandrina. Areas equivalent of up to 5% of the lake margin and 5% of the open water acidified each autumn for intermittent periods (one to two weeks at a time). In the Seawater and Freshwater scenarios localised acidification occurred in Lake Alexandrina with <1 % to 5% of the fringes acidified for short periods each autumn (one to two weeks at a time), regardless of whether pumping to Lake Albert ceased or not. Pumping between the two lakes prevented acidification in Lake Albert in all scenarios. However if pumping ceased, water levels in Lake Albert rapidly dropped and widespread acidification of the remaining water occurred in all of the cease-pumping scenarios. These widespread acidification events lasted for up to 12 months before the lake completely dried out.

This chapter assesses the capacity of alternative localised strategies to treat or control the widespread and isolated acidification events that occurred in Lake Alexandrina (widespread in Do-nothing pumping and isolated in other scenarios) and Lake Albert (widespread in all cease-pumping scenarios). Control strategies assessed below include bioremediation (vegetation or mulching) and moisture retention (regulators or moisture barriers). The key treatment strategy under assessment is neutralisation (adding limestone).

F.2: Alternative acidification management strategies

In the scenarios where acidification occurred, the following strategies could be employed to manage acidification:

- Prevention through surface water regulators/blocking banks
- Control through revegetation with native plants or crops such as perennial rye grass;
- Control through mulching;
- Treatment with limestone dosing, and/or subsurface barriers (groundwater mounding/control).

These strategies can be deployed individually or simultaneously as a suite of interrelated actions for managing ASS and acidification risk in the lakes. Control through mulching was not considered further because it had not been trialled at the lakes due to prohibitive expense and logistical constraints.

The nature of the ASS materials dictates the relative effectiveness of the treatment and/or control efforts required. A strong factor in management success is whether the ASS materials are predominately sand or clay. Sandy soils around the lake fringes can be acidic (low pH) but contain relatively low acid stores compared to clay soils (Sullivan *et al.*

unpubl. data). This means that relatively small amounts of alkalinity (e.g. limestone applications) are required to raise the pH to biologically acceptable levels (> 6.5). The areas dominated by sands and clays have been mapped by Fitzpatrick et al. (2010) and are shown below in Figure F.2. These maps can be used to guide selection of different localised ASS treatment or control actions for different sites as well as for determining the likely magnitude and effectiveness of those actions.

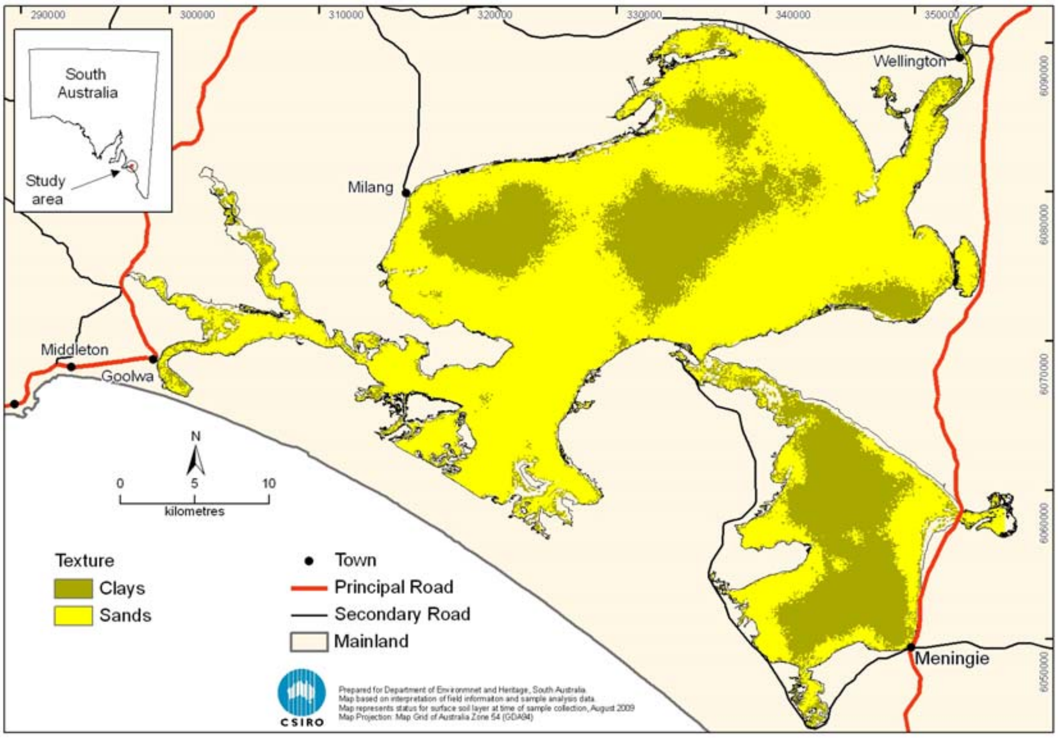


Figure F.2: Soil Maps of Lakes Alexandrina and Albert showing areas of clay and sand.

F.2.1: Installation of surface water regulators/bunding - prevention

Surface water regulators are built to facilitate pumping or ponding of water in contained water bodies. Water levels are maintained so that ASS within those contained areas remains inundated which prevents oxidation and acid generation. Regulators were built in Lake Alexandrina during 2009 near Clayton to contain Goolwa Channel and across Narrung Narrows that separate the two lakes (Figure 1.1). The Clayton and Currency Creek regulators were designed to pond water downstream of Clayton, including Goolwa Channel and the mouths of the Finniss River and Currency Creek, areas of high ASS risk and also high ecological significance. The Narrung Narrows bund effectively uncoupled water level management between the two lakes so that lake levels could be independently managed around their different acidification tipping points (-1.5 mAHD and -0.5 mAHD, respectively). It was used as a barrier across which water could be pumped into Lake Albert from Lake Alexandrina and ponded at different levels in each lake.

There are no reports that show that the regulators were successful, however the ASS research program (DENR 2010) showed that if nothing was done to maintain water levels and prevent further ASS oxidation, areas such as Currency Creek and Finniss River would have become acidic or more acidic. Monitoring following the construction of the regulators showed that water quality in Currency Creek, Finniss River and the Goolwa Channel improved (EPA 2011).

The hydrological modelling conducted for ERA (Wainwright and Hipsey 2010) showed the predictions for widespread acidification as water levels dropped in Lake Albert (Chapters

4 to 6). In the pumping scenarios, acidification did not occur in Lake Albert because water levels were maintained above the tipping point. By contrast, the hydrological outputs from the cease-pumping scenarios clearly show acidification as water levels drop shortly after pumping ceased in all scenarios. This suggests that the prevention strategy of using blocking banks and regulators can only be successful if sufficient freshwater is available in Lake Alexandrina to continue pumping and maintain water levels above the acidification tipping point. Maintenance of the integrity of the surface water regulators and good working order of associated pumps and pipelines is also essential for this action to be successful.

F.2.2: Revegetation – control

Revegetation of exposed ASS works by providing organic matter to the sediments, which fuels the decompositional activity of sulfate reducing bacteria. Sulfate reduction is the process by which microbes convert sulfate to sulfide minerals, effectively consuming acid. Sulfate-reduction and other associated biogeochemical processes (e.g. ferric reduction) essentially reverse the pyrite/iron monosulfide oxidation reactions that generated acidity when the ASS was exposed to air (Muller 2000; Fitzpatrick *et al.* 2010).

Vegetative cover also reduces or prevents the mobilisation of heavy metals and metalloids from the exposed ASS to the water body by physically binding these toxins, thus reducing probable toxic effects on fish, frogs and other aquatic life. This process of uptake by plants is referred to as phytoremediation, which can be a successful technique to extract heavy metals from contaminated soils (Choram and Karimi 2008). It may be necessary to remove plants from the site if concentrations of heavy metals are high to ensure the heavy metals are not recycled back into the ecosystem when the plant tissue decomposes.

Sullivan et al. (2011) conducted a project that assessed bioremediation techniques, as the lakes re-filled during 2010 and 2011. They looked at effects of bioremediation on sulfate reduction and associated processes in the acidified lake sediments that were exposed between 2007 and 2010. The field studies assessed changes in lake sediments to refilling and bioremediation activities and the laboratory component involved controlled inundation of intact sediment cores with synthetic River Murray water.

Field locations at Waltowa, Poltalloch, Tolderol and Campbell Park each had a range of revegetation treatments (in terms of both the vegetation species and timing of plantings), as well as unvegetated control sites. Revegetation produced substantial reductions in acidity of surficial lake sediments (e.g. Figure F.3). Figure F.3 shows that pH levels were near neutral under vegetative cover (pH ~ 7) compared to highly acidic levels in bare soil (pH ~3) suggesting that establishment of appropriate plant cover atop exposed ASS can stimulate sulfate-reducing bacteria which consume acid and thus can be an effective management strategy for *controlling* acidification. The pH raising effect is greatest at the surface where sulfate-reduction is greatest and drops off with increasing soil depth. It is likely that this increase in pH occurred via a combination of ecosystem processes associated with vegetation, such as, alkalinity leaking from plant roots as well as minimising soil erosion which in turn prevented exposure of deeper ASS. Deeper ASS were often exposed by erosion in unvegetated sites which remained more acidic. Plants may also reduce soil temperature and evaporation, which reduces the rate and depth of ASS oxidation.

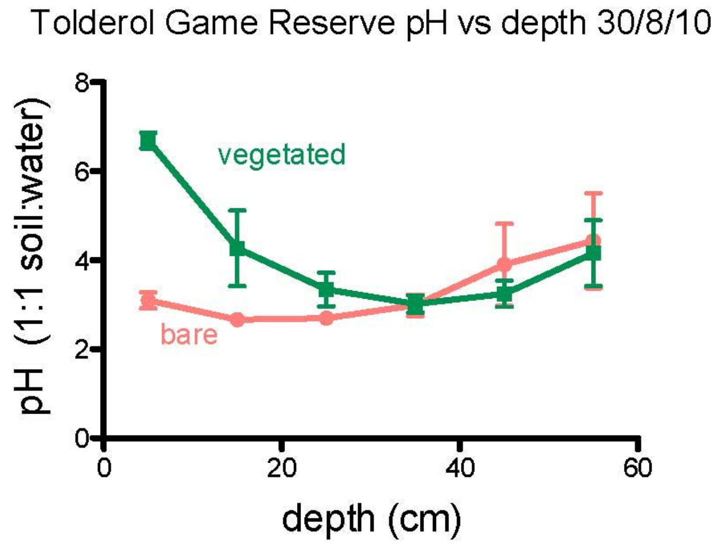


Figure F.3: Sulfate-reduction under vegetation compared to bare soils at Tolderol Game Reserve in the western edge of Lake Alexandrina.
Source: Sullivan *et al.* (publ. data).

Sulfide minerals such as monosulfides and pyrite did not appear to accumulate in surficial lake sediments. Thus their associated hazards of acidification, metal and metalloid mobilisation, and deoxygenation appear to have been avoided (Sullivan et al. 2011). This study has only looked at the first six months of inundation and thus their findings may not apply to on-going organic matter cycling or longer-term recovery.

The two main factors remediating the acidified sediments appear to be alkalinity from lake water entering the sediments and processes associated with the vegetation (Sullivan et al. 2011). It is not known what would have happened if inundation did not occur and the plants were the only remediating factor.

Vegetation can be established by various methods: aerial seeding, direct machine seeding and hand planting of speedlings (advanced seedlings). A mixture of locally sourced native and exotic species would be chosen for the vegetation program. Native species may include wetland species for the lakebeds and terrestrial (dryland) for the margins of the lakes. Exotic species may be used for specific situations, for example, if no local seed or plants are available (or not in sufficient quantities) or where the immediate need is remediation of highly degraded areas prior to establishment of native plants. Exotic species such as cereal crops would be seeded from the air to provide rapid cover of large areas of exposed ASS (DENR 2010b). These crops promote the subsequent establishment of native species by providing protection from sun and wind as well as enhancing nutrient uptake. Moisture retention by crops can help establishment of subsequent vegetation although crops may compete for moisture, if limited, and reduce the establishment success of subsequent vegetation.

As well as treating exposed ASS, vegetation actions can also promote natural establishment of other plants and can assist in the recovery of the lakes ecosystem, particularly if appropriate native species are used to enhance lakeshore biodiversity. Plant selection for acidification treatment is critical. Annual plants produce significant quantities of organic matter then die off, whereas, perennial plants can provide a on-going supply. An on-going supply of organic matter is likely to be important in the lake sediments because organic matter availability is a major factor limiting sulfate-reduction along with extremely low pHs (Sullivan *et al.* 2010). Sulfate-reducers like other microbes are strongly opportunistic and will grow in patterns that follow organic matter inputs and availability of sulfate. In sulfate-rich environments, sulfate reduction can dominate organic matter catabolism and be the major decomposition pathway (e.g. Reeburgh and Heggie 1977; Hines *et al.* 1993).

Some aquatic plants (e.g. *Phragmites australis,* Common reed) have the capacity to 'pump' oxygen into the root zone (Brix *et al.* 1999) potentially promoting ASS oxidation and increasing the rate of acid generation, which would be counter-productive, particularly in dry conditions. However, *Phragmites australis* can also grow under prolonged inundation and thus continues to supply organic matter to fuel sulfate reduction when terrestrial plants have died and ceased to produce additional carbon. Therefore it may be beneficial for bioremediation as well as habitat provision if its growth is adaptively managed. it is, however, highly unlikely that when lake levels are within their normal operating window (+0.3 to +0.6 mAHD) that mangers will be abel to control growth of *Phragmites australis* which was the dominant reed around the lakes prior to the 2006 – 2010 drawdown (Gehrig and Nicol 2010).

Vegetation actions are best suited to small-scale acidification events around water bodies that are well buffered and thus have the capacity to neutralise some mobilised acid. Bioremediation using vegetation is most successful on sandy soils or sandy-clay loams where a variety of plants can be used and germination/establishment rates are high. Dense clays or deeply cracked soils present a greater challenge for vegetation actions because germination rates are poor and fewer plants are suitable. It is possible to vegetate dense clays during the drawdown phase with reeds (e.g. *Phragmites australis*). However, reeds as mentioned above liberate oxygen into the soils promoting oxidation of deeper ASS and thus generation of heavy metals and acid. In addition, reeds may more rapidly dry out soils via evapotranspiration compared if left those soils were left bare.

F.2.3: Limestone dosing - Treatment

Ultra-fine limestone dosing is the preferred treatment method when prevention through water level management and control through bioremediation are no longer options (DENR 2011). Ultra-fine limestone ($CaCO_3$) can be applied as dry powder from aircraft flying low over the water. It can also be applied as limestone embankment barriers or mounds across water channels. The limestone acts to neutralise acidic water flowing over or around the barriers/mounds and increases the alkalinity of non-acidic watercourse water and overland flow such that the alkaline water will neutralise acid when it comes in contact with exposed ASS. Limestone barriers or mounds are suitable for small, flowing watercourses such as Currency Creek and Finniss River (DENR 2011). Wet limestone slurry can also be prepared and added to the water/sediment surface using land-based pumps or watercraft. Dosing with limestone involves sourcing, transport, storage (stockpiling), application (e.g. using aircraft or earthmoving equipment), monitoring, evaluation, implementation of alterations to actions (if needed) and site remediation (DENR 2011).

For greatest efficacy the limestone is added directly to the water body rather than to the sediment where it could be iron coated and where mixing is more difficult. The limestone is best added to acidic or low alkalinity water where it will rapidly dissolve and increase the pH or neutralising capacity of the standing water. Therefore timing of application is critical and is based around monitoring the alkalinity of a given water body. The management trigger for limestone application used in Currency Creek and Finniss River was alkalinity level of < 50 mg/L $CaCO_3$ and increasing rates of change (DENR 2011).

Calculations of the amount of limestone needed are based on results from soil and water research and monitoring programs as well as from the results of field trials in Goolwa Channel and Boggy Lake (see DEH 2010). Just as too much acidity in water bodies can have adverse ecological impacts, too much alkalinity can be problematic for some aquatic biota. The aim is to maintain circum-neutral pH levels (around pH of 7).

In order to determine the volumes of $CaCO_3$ required for treatment, it is necessary to calculate the acidity load: that is, acidity multiplied by water volume.

For example, 1.0 ML of water with an acidity of 100 mg $CaCO_3$/L has a total acidity load of: 100 mg $CaCO_3$/L x 1,000,000 L = 100 kg $CaCO_3$

It can be assumed that available limestone is not pure $CaCO_3$ nor will it be homogenously mixed or completely dissolved, therefore limestone application rates need to be greater than theoretically calculated. Alternatively, the mass of acidity produced can be measured in terms of H_2SO_4. The neutralisation reaction is:

$$H_2SO_4 + CaCO_3 + H_2O \Rightarrow CaSO_4.2H_2O + CO_2$$

This shows that 1 mole of H_2SO_4 is neutralised by 1 mole of $CaCO_3$. Given that the atomic weight of H_2SO_4 (98) is almost equal to the atomic weight of $CaCO_3$ (100), "acidity load" of the water body can be quoted in terms of H_2SO_4 generated or $CaCO_3$ required.

Aerial application was found to be the most effective and efficient from the 2009 limestone dosing trials in Currency Creek. This involved aircraft flying at around 20 – 50 metres above the water body delivering over 200 tonnes per day to a given ASS hot spot (Rural Solutions SA 2009). Aerial application can only be done during the day and when wind conditions are suitable.

ASS hot spot areas that need to be treated with limestone are determined by lake water levels and the results of the soil and water research and monitoring program and a risk assessment process (DENR 2010c). In general terms the lower the lake levels, the greater the area of ASS likely to be exposed and the greater the amount of limestone needed to treat the water and restore or maintain circum-neutral pH levels. Access to sufficient quantities of fine-grade limestone may become problematic if dosage rates and areas are large and thus it is unlikely to be feasible to add limestone to open lake areas.

F.2.4: Installation of subsurface barriers - Treatment

Subsurface barriers can be installed in exposed hazardous ASS areas to retard groundwater discharge to the lake water body from sandy soils, and thereby mound groundwater and partially submerg ASS up the hydraulic gradient. If the subsurface barriers effectively saturate the sulfidic materials, then sulfide oxidation, acid generation and transport from these sands should be minimised (Earth Systems 2010). Barriers are designed for specific areas of sulfidic sands and, if successfully installed, are expected to achieve effective saturation at least 30 cm above the lowest piezometric surface.

Three trial subsurface barriers were installed at Waltowa Swamp on the north-east side of Lake Albert. Two of these barriers were vertical trenches filled with either bentonite slurry or dry bentonite powder mixed with backfill. The third used an auger to distribute dry bentopnite powder into sandy sediments (Earth Systems 2010). Sustained hydraulic gradients were achieved behind the trenches showing they could successfully mound groundwater but the auger-derived barrier leaked and was unsuccessful.

The hydrological modelling shows that substantial acid is likely to have already been generated and stored in the sediment by the time lake levels drop and subsurface barriers installed (Wainwright and Hipsey 2010). Significant rainfall could flush this stored acid into the water body thereby inducing waterbody acidification. Installation of subsurface barriers should reduce the rate of acid flux and by mounding groundwater reduce the rate of ASS oxidation. Coupling subsurface barrier installation to actively pumping groundwater from Quaternary or Tertiary aquifers or irrigation of ASS hotspots behind the barriers may be needed in summer to improve their efficacy. Earth Systems (2010) found that the cost vs. benefit analysis was low for installation, maintenance and removal of the barriers and there were also unacceptable adverse ecological outcomes so this method of treatment has not been pursued further.

F.3: Capacity to reduce acidification in modelled scenarios

Isolated acidification events

The hydrological modelling predicted that isolated acidification events would occur in Lake Alexandrina in the Do-nothing cease-pumping and both Seawater and Freshwater scenarios. Acidification events (pH less than 4) occurred around the fringes of Lake Alexandrina each autumn and sometimes in early winter. In any one of these acidification events approximately 1 to 5 % of the littoral zone (lake fringes) had a pH < 4 for periods of two weeks or less. The main areas of low pH in autumn were in the north-western corner of Lake Alexandrina (Dog and Boggy Lakes) and on the sandy flats near the property known as Kindarua (between Pt. Sturt and Milang) as shown by the blue patches in Figure F.4. The extent and duration of these events was greatest in the Do-nothing cease-pumping scenario and least in the two Freshwater scenarios.

After 2010, the lake receded (to approximately 76% of the October 2009 baseline) in the Do-nothing cease-pumping scenario and the location of the lake margin shifted inwards by several kilometres. This means that the fringing areas that acidified in the early years (Boggy Lake, Dog Lake and sandy flats near Kindarua) became dry and new fringing areas were affected. When lake levels were lower (post-2010) the main areas to be affected were in the eastern corner of Lake Alexandrina where up to 25% of the habitat of River-sourced plankton was affected (see Figure F.5). An isolated pool of water on the Polltaloch Plains along the eastern shore acidified in this and the Seawater cease-pumping scenario. It is important to note here that the hydrological models only predict acidification events in the water and it is most likely that the acidified areas such as Boggy Lake will remain acidic when dry and disconnected from the lake water body and will continue to pose a risk to the Ecological Character of those areas. In general the acidified patches in the Do-nothing scenario were larger and persisted for longer than those in the Seawater and Freshwater scenarios.

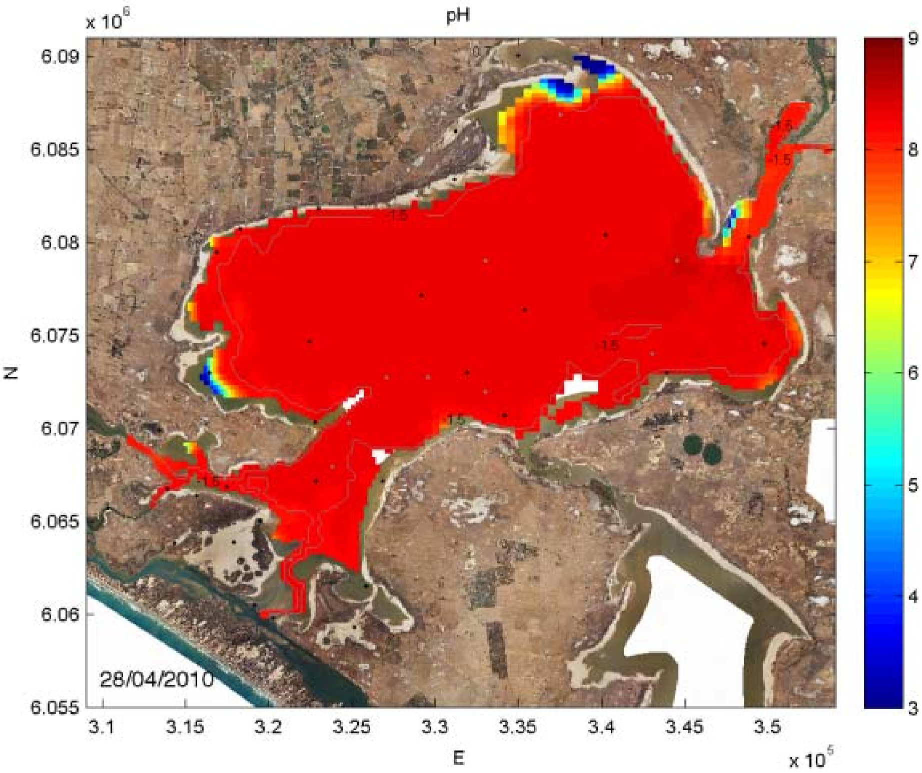


Figure F.4: Isolated acidification event in Boggy Lake, Dog Lake and near Kindarua around the fringes of Lake Alexandrina in the Do-Nothing cease-pumping scenario in March 2015.
Note: acidified patches (low pH) show as blue and teal.

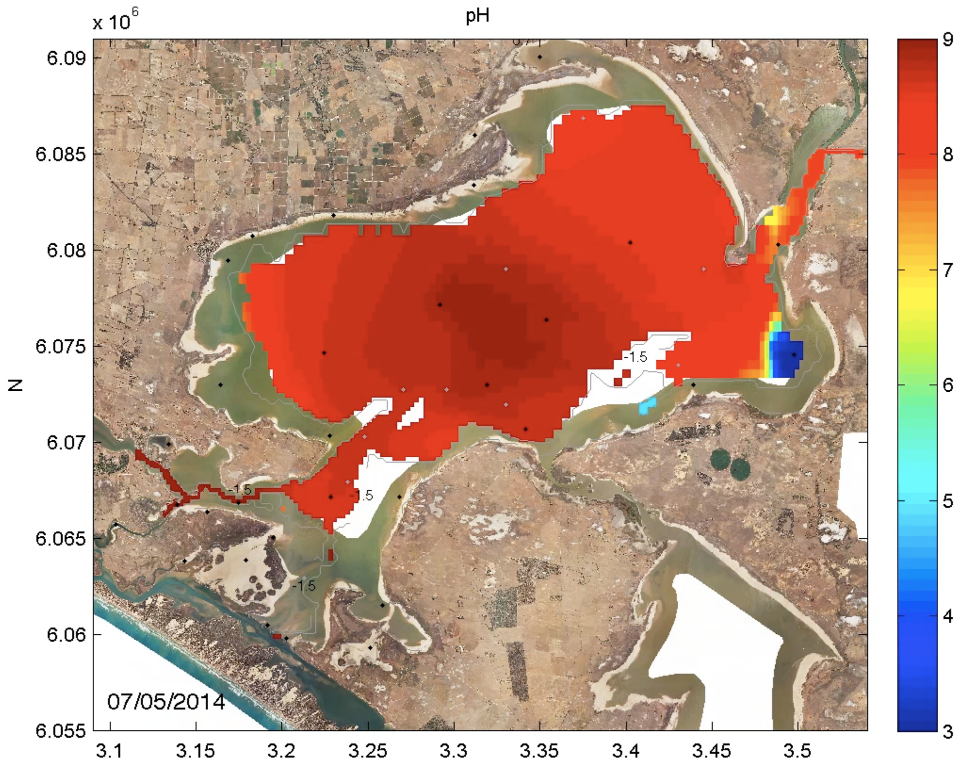


Figure F.5: Localised acidification event in the eastern corner of Lake Alexandrina in the Do-nothing ceasepumping scenario in May 2014. The acidified isolated pool on the Polltaloch Plains is also shown.
Note: acidified patches (low pH) show as blue and teal.

Boggy and Dog Lakes

In the Do-nothing cease-pumping, both Seawater and both Freshwater scenarios, Boggy Lake acidifies early in the hydrological modelling sequence. The extent and duration of acidification is greatest in the Do-nothing cease-pumping scenario when Boggy and Dog Lakes acidify in May 2010 and are then disconnected from the main lake body for the rest of the action period. This means that alkaline lake water is not predicted to circulate into Boggy and Dog Lakes and therefore alternative treatment methods such as vegetation and limestone dosing would be sole treatment agents.

Large areas of Boggy and Dog Lakes are heavy cracking clays that are not easy to establish dense plant cover over. The best revegetation action is likely to be planting out reeds as the water level is receding (Seaman pers. comm.), however as described above, some reeds have the capacity to pump oxygen excess to their respiratory requirements in their root zones and this may enhance ASS oxidation as well as their evapotranspiration increasing the rate of drying in Boggy and Dog Lakes and thus increasing the rate of ASS exposure (oxidation and acid generation). Alternatively, the organic matter provided by the reeds may stimulate sulfate-reduction to a greater extent than the oxygen transport and evapotranspiration promote ASS oxidation so there may be a net gain in sulfate-reduction and slower ASS oxidation upon exposure. It is difficult to predict. Remediation of acidified clays with vegetation is considered difficult due to extremely low pH (Sullivan *et al.* 2011), metal availability and extensive cracking within the clay profile (Seaman pers. comm.). Areas within Boggy and Dog Lakes that comprise of sand would be suitable for active remediation with appropriate vegetation cover to promote sulfate reduction.

The amount of limestone required to neutralise acidification in these areas would depend on the ponding of water in Boggy and Dog Lakes from rainfall and/or groundwater as well as the specific acidity loading. In the Do-nothing cease-pumping scenario the lake level does not recover sufficiently to inundate the ASS in Boggy and Dog Lakes until 2016 when the River Murray inflows recover therefore substantial quantities of limestone, far greater than that applied in DENR trials to date, would need to be applied on an annual basis.

In the Seawater and Freshwater scenarios, Boggy and Dog Lakes are exposed and acidify in 2010 but there are occasional periods when winter lake levels refill and thus alkaline lake water is likely to circulate and assist in neutralising the acid stores and preventing further oxidation of ASS, therefore limestone dosing may not be required every year or the amounts required may be lower.

Boggy Lake is a shallow bay situated within the north-western corner of Lake Alexandrina. It is connected to the main water body on its eastern side. Water quality monitoring in 2010 showed waterbody acidification was occurring at the site. During the summers 2008/09 and 2009/10 a large proportion of Boggy Lake dried due to water levels dropping to approximately – 0.5 m AHD, exposing acid sulfate soils (predominantly cracking clays with high net acidity to atmospheric oxygen and allowing the oxidation of pyrite to occur). It was identified as a priority hotspot with a risk rating of 2 out of a possible 3 in the rapid assessment (DENR 2010), due to it having:

- high levels of net acidity,
- large amounts of surface efflorescences (mineralogy),
- expansive connection to the mainwater body,
- strong wind seiching across the water body,
- medium ecology value, and
- low socio-economic/cultural value as it was not located near a high residential area.

On-going monitoring showed that increased lake levels were not sufficient to neutralise the water body and increase pH to near 7 therefore a three-staged aerial limestone dosing treatment was applied.

Four hundred and twenty tonnes (420 tonnes) of limestone was applied in stage 1 which decreased the acidity and increased the pH, however the lake remained acidic, with the highest acidity around the western margin of the bay (EPA 2010). Another 400 tonnes of limestone was applied in stage 2. Monitoring showed that the number of acidic sites decreased and that there was an overall decrease in acidity and an increase in pH due to direct limestone applications as well as water with high levels of soluble alkaline circulating into Boggy Lake from the main body of Lake Alexandrina when lake levels increased (- 0.2 m to 0 m AHD) which inundated most of the high sulfate cracking clay. Some sites within Boggy Lake remained acidic as a result of passivation of limestone (coating that reduces reactivity), ongoing flux of acid from the lake margins and/or flux of acid from recently inundated sediment. This suggests that the stage 1 and 2 limestone treatments did not apply sufficient limestone to completely neutralise Boggy Lake.

Stage 3 of the aerial limestone treatment used 175 tonnes of calcium carbonate. Following this monitoring showed that the water body of Boggy Lake was alkaline with all sites having a pH above the ANZECC water quality guideline levels (pH > 6.5 but less than 9). The limestone treatments (total 985 tonnes) were not the sole treatment agent given that during stage 3 the water level in Lake Alexandrina increased from -1 mAHD to +0.65 m AHD, which effectively covered all exposed ASS in Boggy Lake with highly alkaline lake water. Inundation of the ASS with alkaline lake water prevented further oxidation of ASS as well as acid fluxes from rainfall or seiching. This suggests that a major neutralising factor was inundation of Boggy Lake by alkaline lake water when the lake levels increased. Limestone alone may not have resulted in neutralisation.

Overall, there is a moderate to high chance that isolated acidification of Boggy and Dog Lakes could be treated in the Seawater and Freshwater scenarios in some, or most years, but a low chance of treatment in the Do-nothing scenario primarily because of the probably very high quantities of limestone required each year, the likely failure of revegetation to control acid transport to the water body and the lack of even periodic inundation with lake water that would provide a major neutralising driver. It may be that vegetation would improve conditions during the recovery phase by providing organic matter to fuel sulfate reduction but once the water has acidified it would be unlikely that any alternative methods could neutralise it. Installation of subsurface barriers would be very costly due to the need to mound groundwater around kilometres of wetland fringe. Such barriers would most likely need to be installed under samphire and other floodplain vegetation that would be provided significant habitat value when the lake was dry and thus barrier installation would have a very high negative ecological impact.

Widespread acidification

Widespread acidification occurred in Lake Alexandrina in the Do-nothing pumping scenario and in Lake Albert under all three cease-pumping scenarios. It is not probable that any alternative prevention, treatment or control methods could be successfully employed to reduce acidification in spatial or temporal extent given that the lake water alkalinity was overwhelmed in these scenarios (DENR program summary). If regional water management fails to keep lake levels above tipping points then widespread acidification will occur and full extent of ecological damage described in chapters 3 to 5 would occur without possible abatement.

Attachment G: Receptor responses to Entitlement and Average flow during the recovery period

Lake Alexandrina pumping Entitlement flows:

Probable Receptor effects:

- River-sourced plankton will be likely to recover to pre-action condition (pre-2009) given that the volumes of lake water under direct River Murray influence will be similar to the pre-action period in Do-Nothing and Freshwater scenarios even though the lake water levels will not be restored to pre-2006 levels.
- The relatively low lake levels mean that Low salinity plankton and Floating plants will have much reduced habitat compared to when the lakes are at typical operating levels and thus they will be unlikely to recover under the Do-Nothing and Freshwater scenarios. They are, however, likely to become more abundant in the available water because salinities are very fresh and river flows keep bringing new recruits into the lake populations.
- In the Seawater scenario, River-sourced plankton are likely to become more abundant in areas directly influenced by River Murray flows but not recover because of the delayed reductions in salinities in the main lake body and the higher salinities for the first part of the recovery period compared to pre-2006 conditions.
- Low salinity plankton and Floating plants for the same reasons are likely to increase in abundance during periods of high River Murray flows and in the latter years of the Seawater recovery period because the river flows bring in new recruits.
- If Floating plants do recover they are highly unlikely to form dense floating mats that cover significant areas of the lakes due to resource constraints and being moved around by wind.
- Spiny rush may colonise the exposed lakebed along with a range of invasive terrestrial plants. If Spiny rush does invade the lakebed it is likely to become the dominant aquatic plant given the poor recovery of other plants predicted above.
- All other vegetation will be unlikely to recover because they will remain disconnected and desiccated at the modelled lake level of -0.75 mAHD.
- Floating plants and Spiny rush will not replace the ecological functions (e.g. shelter, nutrient cycling, erosion control) that diverse littoral vegetation perform, upon which most of the other lake receptors depend either directly (e.g. Lacustrine macroinvertebrates) or indirectly (e.g. predatory fish).
- Given this, it is unlikely that Lacustrine macroinvertebrates and Southern bell frog will re-establish or persist.
- Lacustrine macroinvertebrates will persist through the action periods for the Do-Nothing cease-pumping and Freshwater scenarios but will be unlikely to persist because of sustained food and habitat limitations and high levels of predation.
- Insect larvae and Generalist shorebirds will be likely to recover. The value of the Insect larvae receptor group as food for the Generalist shorebird group and other predators (e.g. fish) may change over time if the communities change in composition and palatability. Thus recovery of Generalist shorebirds and other predator may not be as strong as suggested by the recovery of Insect larvae based solely on salinity and water levels.
- If Tube worms re-colonise, they will proliferate in the Do-nothing pumping and Seawater scenarios. The salinity regime in the Seawater scenarios will be optimal for Tube worms across the whole of the lake whereas in the Do-nothing pumping scenario salinities will freshen towards their lower salinity threshold, therefore, proliferation will be greatest in the Seawater scenarios.

- All fish will have reduced viability during the recovery period compared to their pre-action condition in all scenarios and many will not to recruit, thus recovery will not occur for any fish receptors.
- In the Do-Nothing pumping scenario all fish will be strongly affected by acidification during the action period causing loss or severe population damage. Even though widespread acidification will not occur in the Do-Nothing cease-pumping and Freshwater scenarios, all fish receptors will decline due to food and habitat limitations.
- Murray Cod, Australian smelt, Bony herring, Common galaxias and Murray Hardyhead will be lost.
- Short-headed lampreys, Congolli and Yarra pygmy perch will be unlikely to recolonise.
- In the Do-Nothing and Freshwater scenarios, Golden perch and Common carp populations may change through migration, however, it is unlikely that they will significantly increase in abundance.
- Small-mouthed hardyhead will persist through the action period for Do-Nothing and Freshwater but their recruitment will be severely restricted. They are an adaptable species but food resources and shelter will ultimately limit survivorship.
- If Redfin perch recover, from migration and recruitment within the lakes, they may come to dominate the fish community.
- No fish will recovery under the Seawater scenario. The exceptions could be fish that re-establish after migrating into the lakes with River Murray during the latter five years of the Seawater recovery period. Of these Golden perch and the introduced Redfin perch and Common carp are the most likely to survive but even then they will be severely limited by the scarcity of food and habitat resources and may not form permanent populations.
- The different bird receptors will come and go with changes in food supplies in all scenarios.
- Generalist shorebirds will have the highest chance of recovery based on likely Insect larvae recovery and Waterfowl will have the lowest chance of recovery because of the lack of aquatic vegetation and Lacustrine macroinvertebrates.

Lake Alexandrina Average recovery flows – pumping

Plankton and vegetation effects:

- It is expected that the typical Lake Alexandrina plankton communities will recover within the first 1-2 years of the 10-year recovery period in all scenarios. River-sourced plankton will occur in the northern parts of the lake under River Murray influence and Low-salinity plankton will dominate the remaining parts of the lake.
- Floating Plants are also expected to recover, mainly because of their high dispersive potential from incoming river water.
- Floodplain vegetation receptors will decline during the recovery period because of the lack of floodplain inundation, unless significant floods also occur during the recovery period that are not apparent in the hydrological modelling outputs.
- By contrast, the introduced Spiny rush will proliferate around the lake edge and may become dominant in certain parts of the riparian zone, particularly if the seed bank for the former vegetation has declined in viability.
- The remaining vegetation receptors will begin recovering from spring 2017 onwards when water levels reach approximately +0.7 mAHD and the former littoral/riparian zone is re-connected. It is unlikely that the resident seedbank will be able to support recruitment of the full diversity or abundance of aquatic plants that were present prior to 2006 because by 2017 when the water levels inundate the seedbank, the seed will

have been subjected to twelve years of desiccation in salinised and acidified sediments.

- Reed beds (dominated by *Phragmites australis*) will increase in abundance but not recover to pre-2006 condition with respect to diversity and littoral/riparian band width.
- Water ribbons and Ribbonweed may re-establish later in the vegetation sequence once *P. australis* stands provide shelter.
- Samphire and Paperbark woodlands will decline over time.
- Lignum will increase in abundance near the shoreline where inundation will occur.
- *Gahnia* sedgelands are not as widespread as Lignum, therefore they are likely to have lower dispersal success and consequently decline over the recovery period except for those plants that have access to Lake Alexandrina water, fresh groundwater or rainfall run-off.
- Therefore, the aquatic vegetation community is predicted to improve but not recover to pre-2006 diversity or abundance. The reduction in seedbank viability and diversity was likely to be greatest in the Seawater and Do-Nothing cease-pumping scenarios because of very high salinities and low pH, respectively.

Lacustrine macroinvertebrates

- Recovery of Lacustrine macroinvertebrates populations will be dependent upon new incoming recruits rather than recruitment within the lakes until the latter 3 to 5 years of the 10-year recovery period.
- The exception is the Insect larvae receptor group, the species composition and therefore palatability of which may vary over time, but are expected to recover to baseline conditions within 18 months to 2 years of the recovery period starting.
- Freshwater macroinvertebrates and Yabbies will be unlikely to recover although populations may re-establish towards the end of the recovery period.
- Littoral and Brackish macroinvertebrates will be in better condition at the end of the action period than the other Lacustrine macroinvertebrates, particularly in the Do-nothing cease-pumping and Freshwater scenarios. They will be, therefore, more likely to increase in abundance although recovery is not likely to be possible until several years after the vegetation has developed (i.e. from 2020's). By this stage, individuals surviving the action period may have perished or no longer be fertile.
- Recovery under the Do-nothing pumping and Seawater scenarios will be likely to be less and take longer because resident macroinvertebrates will perish during the action periods in these scenarios and thus will be entirely dependent on migration for re-colonisation.
- Tube worms will be likely to decrease in abundance in the Do-nothing cease-pumping because of freshening and inundation.
- If Tube worms can recolonise during recovery in the Seawater scenarios, then they be likely to proliferate because salinities will be suitable throughout the recovery period. Tube worms will not colonise or re-establish in the Freshwater cease-pumping because they will perish during the action period and salinities will be at or near their lower salinity threshold.

Fish

- It is difficult to predict the likely effects on the Murray Cod population during recovery. They will perish in the lake during the Seawater action period but may have avoided acidification in the Do-nothing cease-pumping scenario if they sought refuge in deep, non-acidified water. If they did survive the Do-nothing treatment, they will be most likely to continue to decline during the recovery period due to limited food resources and inability to recruit.

- Golden perch, Common carp and Redfin perch will be likely to increase in abundance in all scenarios but abundance will be lower in the Do–nothing cease-pumping and Seawater scenarios in the first few years after recovery begins due to greater impacts during the action period.
- Redfin perch may come to dominate the fish population during the recovery period.
- Common carp will increase in abundance.
- Of the three diadromous fish, Common galaxias will be only ones likely to still be present and they may increase in abundance.
- Short-headed lamprey, Congolli and Yarra pygmy perch will be highly unlikely to re-establish. If they do it will be more likely in the Do-Nothing and Freshwater scenarios than the Seawater scenario.
- Small-mouthed hardyhead, Australian smelt, Bony herring and Murray hardyhead will be delayed in their recovery until the submerged plants recover (i.e. from 2017). Again, their recovery is expected to be less complete and take longer in the Do-nothing cease-pumping and Seawater scenarios because adverse impacts during the action period will be greater than in the other scenarios.

Southern Bell Frog

- These frogs may re-establish from incoming adult frogs, eggs or tadpoles but this is quite uncertain and will be delayed until submerged plants have recovered after 2017, if it occurs at all.

Birds

- Generalist shorebirds will have the highest chance of recovery because they feed on Insect larvae which are highly tolerant and dispersive as a group.
- Fish-eating birds may also increase in abundance during the recovery period due to fish entering the lakes and having little cover in the early years of recovery in particular and by feeding around the barrages once barrage flows recommence (from 2017).
- Waterfowl will be also likely to increase in abundance because they depend on Floating plants that will come in with river flows. Waterfowl may recover to pre-2006 condition, if Lacustrine macroinvertebrates also increase but that is highly unlikely.
- It is unlikely that Terrestrial birds and Fringe-dwelling birds will recover.

Lake Albert Average pumping

- Brackish plankton will recover within the first 2 years of the recovery period in all scenarios.
- Hypersaline plankton that will have established during the action period will decline as salinities freshen.
- It is likely that there will be a cascade of different plankton communities as salinities drop, which may mean that overall primary productivity by the plankton community is poor, compared to pre-2006 levels and to plankton recovery in Lake Alexandrina, particularly if the plankton species are highly palatable.
- Floating plants will re-establish in the Freshwater scenario after 2017 when the Narrung Narrows bund is removed. Salinities in the Do-Nothing scenario will be on the border of their upper salinity tolerance and therefore they may survive but will be unlikely to recover strong and vigorous populations. They are not expected to recover in the Seawater scenario because salinities will remain too high throughout the recovery period.
- The aquatic plant seedbank will most likely have been severely damaged by desiccation, soil acidification and then inundation with relatively saline water when lake levels returned to near +0.6 mAHD. Therefore it is unlikely that Water milfoil, Water ribbons or Ribbonweed will return to the main Lake Albert littoral zone during the recovery period, particularly in the more-saline Seawater scenario. Their chances of recovery are greatest in the Freshwater scenario because salinities will be lower at earlier times during recovery and they will be likely to also re-establish in Lake Alexandrina in the Freshwater scenario (and therefore have a population in close proximity from which to colonise Lake Albert).
- Plant species that occur in the lakes but not in the river (e.g. *Myriophyllum caput-meusae*) may not re-establish due to a lack of incoming propagules and probable loss of viable seed in the seedbank.
- Over time reed beds will re-establish around the edges of the lake but they will be highly likely to be simple and dominated by few species, taking until at least the early 2020's to form a continuous band. *Phragmites australis* and *Typha domingensis*, will re-establish readily, increasing in cover from 2017 onwards.
- Full recovery of diverse reed beds and floodplain vegetation will be highly unlikelybefore 2025.
- All Lacustrine macroinvertebrates will be lost from Lake Albert during the recovery period except for Insect larvae and possibly Brackish macroinvertebrates in the Freshwater pumping scenario. As was observed in 2010/11, the recovering macroinvertebrates communities will probably be more simple and sparse than prior to 2006 and full recovery may take several decades after recovery of the littoral and riparian vegetation.
- The likelihood for re-establishment will be greatest for the Littoral and Brackish macroinvertebrates in the Freshwater pumping scenario but it is unlikely strong populations will recover by 2025.
- Recovery in the Seawater scenario will be extremely unlikely because of the combined impacts of extreme salinisation and the longer period required for the salinity level to decay in the Seawater scenario compared to the Do-Nothing and Freshwater scenarios. If any macroinvertebrate re-establish in Lake Albert in the Seawater scenarios it will most likely be the Brackish macroinvertebrates and Insect larvae.
- It is highly unlikely that Murray Cod will re-establish in Lake Albert.
- Golden perch, Small-mouthed hardyhead, Common carp and Redfin perch may increase but will be limited by the on-going lack of food resources, in particular

macroinvertebrates. Likelihood of re-establishment in the Seawater scenario is extremely low given that very high salinities will persist for longer than in Do-Nothing and Freshwater and the on-going lack of prey. Small-mouthed hardyhead and Redfin perch will be the most likely to re-establish and may co-dominate in whatever fish communities occur.

- Short-headed lamprey, Congolli and Yarra pygmy perch will be highly unlikely to re-establish. If they do it will be more likely in the Do-Nothing and Freshwater scenarios than the Seawater scenario.
- Small-mouthed hardyhead, Australian smelt, Bony herring, Murray hardyhead and Common galaxias may re-establish after 2017. Most fish coming in from Lake Alexandrina will tolerate the salinity regime after six months in the Do-Nothing and Freshwater scenarios and after five years in the Seawater scenario. Fish are likely to enter the less saline Narrung Narrows channel but avoid entering the main lake body due to high salinities in the Seawater scenario. Again, viability is expected to be significantly lower in the two Seawater scenarios than in the others.
- Generalist shorebirds have the highest chance of recovery, Fish-eating birds may increase in abundance but Waterfowl, Terrestrial birds and Fringe-dwelling will be unlikely to recover strong populations.

References

Glossary of Terms

Acidification: the process of becoming more acid. A pH value of less than 7 is acidic and the lower the pH value the more acidic the environment.

Acidification tipping points: hydrological and biogeochemical models predict that incoming acid from exposed acid sulfate soils will exhaust the neutralising capacity of the lake water and cause pH to drop to less than 6 at the approximate levels of -1.5 and -0.5 mAHD in Lakes Alexandrina and Albert, respectively.

Acidophiles: organisms, typically bacteria, plankton or other microbesthat thrive in acidic conditions (typically pH < 5 although some require pH < 3.5 or 2).

Bioremediation: the use of biological agents, such as bacteria and/or plants, to remove or neutralize contaminants, as in polluted soil or water.

Biotic group: a group of organisms commonly considered to belong to one biological unit such as plankton, macroinvertebrates (lacustrine or estuarine), fish, birds, frogs or vegetation.

Consequence: outcome of an event affecting objectives. Notes: 1. An event can lead to a range of consequences, 2. A consequence can be certain or uncertain and can have positive or negative effects on objectives, 3. Consequences can be expressed qualitatively or quantitatively, 4. Initial consequences can escalate through knock-on effects (Section 2.18, AS/NZS ISO 31000:2009).

Diadromous fish: fish that migrate between fresh and saline waters during their life cycle.

Driver: major external factors that have large-scale effects (either positive or negative) on the ecosystem.

Ecological Character: The Ramsar Convention defines ecological character as the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time (Ramsar Convention Resolution IX.1 Annex A).

Ecological viability: the effects of interwoven ecological interactions and processes on receptor viability, such as the receptors': baseline condition, ability to avoid stressors, dispersal mechanisms, critical life history requirements, indirect trophic effects or level of dependence on specific habitat or food resources.

Effect: Something brought about by a cause or agent (stressor); a result; an impact. Examples: mortality, major changes in community composition, loss of preferred habitat, recruitment failure.

Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act):is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as *Matters of National Environmental Significance* (taken from http://www.environment.gov.au/epbc on 23rd August 2011).

Estuarine: of, or relating to, the area where the sea meets a freshwater river, stream or lake. An organism that is typically tolerant of salinities found within estuarine areas. Generally such areas are less saline than the sea (approximately 36 g/L) but more saline than fresh or brackish (1 – 10 g/L) water. Typically salinities in estuarine waters are within the range of 7-35 g/L but as can be seen above, there is often overlap in salinity concentrations applied to various common descriptors of waters. It is possible, where freshwater inputs are ephemeral or very low, for estuarine areas to have salinities greater than the sea (e.g. the Southern Lagoon of the Coorong). In such cases these areas are sometimes referred to as hyper-saline lakes or "reverse estuaries". For the purposes of this ecological consequences assessment, some receptor groups have been named based on their typical habitat (e.g. estuarine macroinvertebrates are found downstream of the barrages in the Ramsar state). Specific salinity thresholds and ranges for each receptor in Table 1.1 over-ride these more generic descriptors of waters.

Event: occurrence or change of a particular set of circumstances (Section 2.17, AS/NZS ISO 31000: 2009).

Extremophiles: an organism that lives under extreme environmental conditions (e.g. pH < 3.5, hypersalinity)

Fishways: are structures that allow fish and other biota to move across hydrological barriers (e.g. barrages). There are currently five fishways in the barrages at Goolwa, Tauwitcherie and Hunter's Creek.

Hydrological modelling: hydrology is the study of the movement, distribution, and quality of water. Hydrological models are simplified, conceptual representations of a part of the hydrologic cycle. They are primarily used for hydrologic predictions under defined scenarios and for understanding hydrologic processes.

Lacustrine: of, or relating to, lakes. Living or growing in or along the edges of lakes.

Littoral: the edge or shallow area of water. Living or growing near the edges of lakes; Living or growing in the shallows.

Macroinvertebrates: invertebrates visible to the naked eye, such as insect larvae.

Matters of National Environmental Significance: nationally and internationally important flora, fauna, ecological communities and heritage places that are listed and defined under the EPBC Act 1999. There are eight Matters of National Environmental Significance protected under the EPBC Act including wetlands of international importance (listed under the Ramsar Convention), listed threatened species and ecological communities and migratory species protected under international agreements.

*No directional impact:*Phrase used in reference to insect larvae and Generalist birds to describe the condition where the overall impact of the given stressor on the receptor is neither positive nor negative, although there may be changes in the specific taxa present within the given receptor group. For example, Insect larvae as a receptor group can tolerate salinities from 1 to 138 g/L therefore populations will be present across that salinity range although the taxa present may change as salinities change.

Physiological viability: a receptor's capacity to withstand a certain magnitude of a stressor in a given area of habitat (assuming the receptor remains in that habitat).

Propagules: a seed or a vegetative part of a plant, such as a stem, bud or rhizome, that is a dispersal agent for that plant and from which a new plant can grow.

Receptor: a species, assemblage or group of organisms (functional, tolerance or other) that respond to a stressor. Examples: River-sourced plankton, Murray cod, *Ruppiatuberosa.*

Ramsar: the Ramsar Convention is an international treaty for the conservation and sustainable utilization of wetlands, i.e. to stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.

Ramsar-state: the recognizable, stable, resistant and resilient abiotic/biotic complexes that occurred across the Coorong and Lakes Alexandrina and Albert at the time of listing as a Wetland of International Importance under the Ramsar Convention (1985), as described in Phillips and Muller (2006), Souter (2009) and Souter and Stead (2010). The

Ramsar-state encompasses a certain amount of variation in time and space, which are referred to as the Acceptable Limits of Change (Phillips and Muller, 2006).

Scenario: a hypothetical or predicted set of events or circumstances.

Stressor: any agent, condition or stimulus that causes stress to an organism. Examples: salinity, water level or pH.

List of Abbreviations

EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
EMLR	Eastern Mount Lofty Ranges
ECA	Ecological Consequences Assessment
DN_P	Do-nothing pumping
DN_CP	Do-nothing cease pumping
DENR	South Australian Department for Environment and Natural Resources
FW_P	Freshwater pumping
FW_CP	Freshwater cease-pumping
GL	gigalitres – one thousand, million litres
GC	Goolwa Channel
ha	hectares
Lb	Lake Albert
Lx	Lake Alexandrina
MM	Murray Mouth (Goolwa Channel to Pelican Point to Murray Mouth)
MNES	Matters of National Environmental Significance
mAHD	metres in Australian Height Datum
NL	North Lagoon of the Coorong
SL	South Lagoon of the Coorong
SW_P	Seawater pumping
SW_CP	Seawater cease-pumping