

Curdies River 2017

Estuary Management Plan



Together we will make a difference



Curdies River



Total Catchment: 1,245 km²
River Length: 66 km
Estuary Length: 17 km
Location: 38.4504° S
 142.9439° E



Scale: 1:40,000

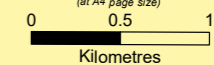


Legend

- Curdies Inlet and River
- Other watercourses
- Roads and Tracks

Scale 1:40,000

(at A4 page size)



Kilometres

Sources: DELWP-Roads, 2011 Imagery
 Filename: 1051_Curdies EMP_Location_Map.mxd

Map Created:
 16/08/2017

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Curdies River Estuary Management Plan.
Prepared by RM Consulting Group for the
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SECTION A

1. Introduction

The Curdies River estuary is defined by the Curdies Inlet lagoon, surrounding areas of floodplain habitat, an opening to the wild southern ocean, excellent fishing and its position on the Great Ocean Road. The diversity of estuarine and wetland habitats support a range of flora and fauna species, both aquatic and terrestrial and the estuary was once an important resource for Indigenous populations. The raw and natural aesthetic of the estuary is synonymous with the township of Peterborough and today the estuary continues to support recreational fishing, tourism and agriculture.

This Estuary Management Plan (EMP) addresses the main management issues that were identified by the Working Group (refer to Appendix 1) and does not seek to reiterate the full suite of threats that are already well documented in past plans, including the last *Curdies River Estuary Management Plan 2008*. A review of the existing literature occurred as a preliminary piece of work to this EMP, and provides a more detailed account of the main values and threats associated with the estuary, as well an overview of estuary management in Victoria*.

Of particular pertinence to the future management of the Curdies River estuary are challenges associated with climate change and impacts such as storm surges and sea level rise. Similarly, a whole of catchment approach has been taken in developing the EMP, recognising that what occurs upstream will ultimately affect downstream. Therefore, this EMP is strongly aligned to, and supports, the *Corangamite Waterway Strategy 2014-2022*. Further, this EMP is not limited to a geographic area defined as the “estuary”, given the very dynamic nature of estuarine environments; this is evidenced by a salt wedge that continually moves in response to freshwater and saltwater influences and the nature of the river mouth.

Another challenge this EMP aims to address is the competing values and uses surrounding the estuary. While the community highly value the estuary, the way in which it is valued is not equally shared and there are differing opinions about how it should be protected and enhanced. For example, the natural estuarine flooding regime required to sustain certain aquatic flora and fauna, can be at odds with what is required to protect built infrastructure.

It is important that all stakeholders and the community work together to achieve the objectives and goal of this EMP, so that the environmental values are protected and enhanced, and that the social and economic uses expected by the community can be sustainably supported.



Aerial image of the Curdies River estuary at Peterborough

*The *Curdies River Literature Review (2016)* can be accessed on the CCMA Knowledge Base www.ccmaknowledgebase.vic.gov.au

2. The Estuary

The Curdies River begins near Lake Purrumbete to the south of Camperdown, and flows in a southwestern direction where it meets the sea at Peterborough. The river and its tributaries, Scotts Creek and Coorimungle Creek, traverse coastal plains with agricultural land covering a catchment area of 1,245km² (Water Technology 2008).

Curdies Inlet is the estuarine lagoon of the Curdies River. The seawater penetrates 17km inland from the estuary mouth at Peterborough to the confluence of the Curdies River with A'Becketts Creek north of Curdievale. The lower reach of the Curdies Inlet is a broad, shallow sandy tidal delta, which is linked to the Southern Ocean by an intermittently open tidal channel of approximately 1km (Figure 1).

Figure 1: Map of the Curdies estuary showing the 1 in 100 year flood extent and the area of estuarine waters and wetland.



3. The Plan

3.1 Scope

The Curdies River EMP has been prepared to provide a clear picture of the main management activities required to maintain or improve the condition of the estuary. The EMP has been prepared in consideration of the social, economic and environmental values of the estuary, as well as the current and emerging threats. At the time of preparing this EMP, the guidance from the Victorian Government was for an eight-year plan.

It is intended that the EMP will be used to seek funding, strengthen coordination amongst stakeholders responsible for estuary management and increase community understanding and appreciation for the natural values of the estuary.



3.2 Planning context

There are two policies that guide estuary management in Victoria, these being the *Victorian Coastal Strategy 2014 (VCS)* and the *Victorian Waterway Management Strategy 2013 (VWMS)*. Figure 2 outlines the legislative and planning framework for estuary management in Victoria.

The VCS is the statewide policy for coastal management and planning, prepared in accordance with the *Coastal Management Act 1995**. The VCS and associated plans address use and development issues related to estuaries in Victoria, particularly issues that require planning responses; however, they do not comprehensively include management of the environmental condition of estuaries (DEPI 2014). The VWMS is the responsible document providing statewide direction on the management of the environmental condition of estuaries. Regional Waterway Strategies translate the statewide direction into regional priorities and the *Corangamite Waterway Strategy 2014-2022* identifies the

The Corangamite CMA will work with the Victorian Government, the Victorian Coastal Council, Coastal Boards and regional partner organisations within the framework of the VWMS and VCS to effectively manage the environmental condition of estuaries within the Corangamite region.

EMPs are one tool to prioritise management activity and guide the improvement of environmental condition at the local level. The “review and update of current EMPs” or development of “new plans as required” is identified as an action (Action 13.2) in the VWMS. In response, the *Corangamite Waterway Strategy* identifies the development of the Curdies River EMP as a priority management activity. The Curdies River EMP also aligns with the strategic intent of the *Corangamite Regional Catchment Strategy 2013-2019* which is the region’s blueprint for catchment health and is recognised in the Corangamite and Moyne Shire Local Planning Policy Frameworks.

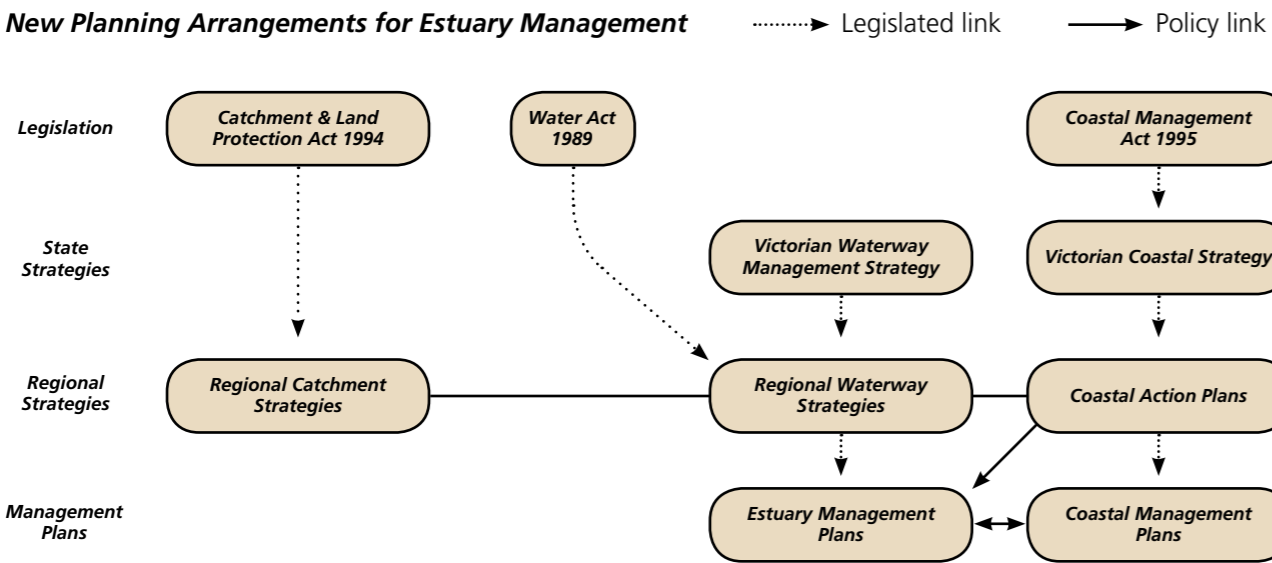
4. Partners and their Roles and Responsibilities

The Corangamite CMA is the responsible authority tasked with the management of waterways, drainage and floodplains under the *Water Act 1989*. Land tenures and management arrangements around estuaries are particularly complex and many other agencies also play a role, as highlighted in Table 1. Figure 3 provides a map of the land management boundaries surrounding the Curdies estuary.

Table 1: Roles and responsibilities of key stakeholders

Group or Agency	Regional responsibility
Corangamite Catchment Management Authority (CCMA)	Regional caretaker of water health, including the development of the Corangamite Waterway Strategy and Estuary Management Plan; implementation of waterway work programs; authorisation of works on waterways, including estuary mouth openings, responding to natural disasters and incidents affecting waterways.
Local Government (Corangamite and Moyne, Shire councils)	Council has responsibilities under the <i>Planning and Environment Act 1987</i> to administer the planning scheme, under the <i>Road Management Act 2004</i> to maintain local infrastructure and under the <i>Emergency Management Act 1986</i> to coordinate emergency management at a municipal scale. Council also has statutory responsibilities under the <i>Environmental Protection Act 1970</i> to regulate septic systems on private land.
Department of Environment, Water, Land & Planning (DELWP)	Development of waterway policy, coordination of regional delivery and prioritisation of government investment in waterways.
Department of Economic Development, Jobs, Transport & Resources (DEDJTR)	To create the conditions to sustainably develop the Victorian economy and grow employment. Fisheries Victoria, which is responsible for the management of fisheries, including recreational fishing, sits within DEDJTR. Agriculture Victoria also sits within DEDJTR.
Parks Victoria (PV)	Management of the Port Campbell National Park and Bay of Islands Coastal Park. Management of ‘bed and banks’ of Curdies River estuary. Holds permit for artificially opening Curdies estuary. Issues tour operator licenses for activities associated with parks and reserves managed by Parks Victoria (excluding water-based activities).
Environmental Protection Authority (EPA)	Responsible for the protection and improvement of Victoria’s environment by establishing environmental standards, regulating and working with organisations to meet these standards. The EPA also provides guidance on wastewater management to minimise health and environmental risk.
Western Coastal Board	Strategic coastal and marine planning and preparation of regional coastal plans.
Traditional Owners (TOs)	Traditional Owners have rights and interests to lands and waters within their recognised region, including participation in decision-making on how land and/or waters are used. The Eastern Maar Aboriginal Corporation operate in the area around the Curdies River estuary.
Water users (Southern Rural Water, irrigators and farm dam owners)	Southern Rural Water regulates irrigation, domestic supply and farm dams in the catchment.
Maritime Safety Victoria	Enforces regulations regarding Marine Safety. The <i>Marine Act (1988)</i> establishes boat speeds for inland waters.
Victorian State Emergency Services	Responsible for the emergency management response related to flooding events including riverine flooding, flash flooding and storm surge.

Figure 2: Key legislation and planning arrangements for estuary management in Victoria (DEPI 2014)



Influencing: Other relevant State legislation eg. *Flora & Fauna Guarantee Act 1988*, *Environment Protection Act 1970*. Other relevant State strategies eg. *Victorian Biodiversity Strategy*, *SEPP (WoV)*.

Source: *Victorian Waterway Strategy (2013)*

*The *Coastal Management Act 1995* is to be superseded by a new *Marine and Coastal Act* scheduled for release in 2017.



Figure 3. Land Management Map



4.1 EstuaryWatch

An EstuaryWatch group was established at the Curdies River estuary during 2013. EstuaryWatch is a successful citizen science program that supports community members to actively participate in the monitoring of estuary health. The data collected by EstuaryWatch volunteers makes a valuable contribution to informing better estuary management.

Since 2013, the EstuaryWatch group has collected water quality data, as well as photo point data, at various locations along the estuary. This information provides is important in observing condition change over time.

More information about EstuaryWatch can be accessed at: www.estuarywatch.org.au

Right & Below: EstuaryWatch volunteers play an important role in monitoring water quality at the Curdies estuary



4.2 Waterwatch

Waterwatch is a national community water monitoring program, supporting local community members to test the quality of their local stream or waterway so action can be taken to maintain or improve the water quality.

There is an active group of volunteers undertaking water quality monitoring at the Curdies as part of the Waterwatch program, which is supported by the Corangamite CMA. Monitoring occurs at various points upstream along the Curdies River, as well as along tributaries including Scotts Creek and Coorimungle Creek.



4.3 Landcare

The Heytesbury and District Landcare Network provide overarching support to local Landcare and other community based conservation groups in the district. They support groups to facilitate programs in habitat restoration, pest plant and animal management and environmental education, and work closely with government agencies such as the Corangamite CMA and Corangamite Shire.

The Curdies Valley Landcare Group is an active group operating in the Curdies Valley region.

5. The Curdies River Estuary

5.1 Values

The natural environment of the Curdies River estuary underpins many social and economic uses that are highly valued by locals and visitors alike. The rich natural resources of the estuary and floodplain have sustained populations both past and present. Prior to European settlement, two Indigenous clans, the Barath gundidji and the Ngaragurd gundidj, occupied the estuary and surrounding coastal area where resources such as birds, fish and terrestrial mammals were abundant. Since the 1860s the fertile estuarine floodplains have supported agriculture, predominately dairy and beef grazing. Agriculture continues to be an important part of the landscape at the Curdies River estuary and many of the original farming families remain in the area today. The estuary also supports a commercial eel fishery.

The identity of Peterborough and the local community is strongly influenced by the estuary. It is greatly valued for recreation, in particular the excellent fishing opportunities both at the estuary and nearby at the coast. The estuary and adjoining shallow waters provide significant habitat that support the lifecycle of many fish species, including migration, spawning and rearing of juveniles. The Yarra Pygmy Perch (*Nanoperca obscura*) has been recorded in the estuary and is listed as vulnerable at state and national level.

During the summer months, visitors are drawn to Peterborough and the banks of the Curdies Inlet to swim, fish, boat and relax. Bird watching opportunities abound at the estuary and this reflects the range and size of habitats available in and around the estuary that support both migratory and non-migratory birds. The Curdies estuary is located on the prominent Great Ocean Road and is nearby the internationally renowned 12 Apostles Marine National Park, Port Campbell National Park, the Arches Marine Sanctuary and the Bay of Islands Coastal Park. The area forms part of the broader Shipwreck Coast which attracts 2.6 million visitors annually (Parks Victoria 2015). The *Shipwreck Coast Masterplan 2015* is the current document guiding tourism investment along this stretch of coast over the next 20 years, and the protection and conservation of the coast's natural values is a primary objective of the plan.

Several significant vegetation communities are represented at the Curdies River estuary, including a stand of Estuarine Wetland (EVC 10), which is noted as one of the largest in southeast Australia and is listed as depleted across the Warrnambool Plain bioregion (DELWP 2016).

The values identified here are consistent with those outlined in the *Corangamite Waterway Strategy* for the Curdies landscape zone, and were also identified by the Working Group during the development of this EMP.

5.2 Threats

Estuaries are exposed to pressures from all directions, including from the catchment, the immediate surrounds as well as coastal and marine influences. Agriculture, in particular dairy farming, is the predominate land use surrounding much of the estuary and the catchment of the Curdies River. Parts of the Curdies River and associate tributaries and estuary have been subjected to grazing pressures. Livestock access to waterways can erode banks, damage riparian vegetation and reduce water quality through sedimentation and effluent contamination.

Over 50 species of introduced flora have been reported at the Curdies River estuary, including a number of common agricultural weeds that dominate the landscape in places where native vegetation is cleared (DELWP 2016). Livestock grazing, resulting in the reduction of indigenous vegetation cover, spread of weeds, particularly Tall Wheat Grass (*Lophopyrum ponticum*) and pugging has been identified as the main threats to remnant estuarine vegetation at the Curdies (Osler & Cook 2010). The encroachment of domestic garden plants into surrounding native vegetation has also been identified as a threat. Infestations of weeds can out-compete native species, resulting in changes to the structure, species composition and abundance of native vegetation communities. The *Corangamite Waterway Strategy* identifies the red fox (*Vulpes vulpes*), as a significant threat to bird species inhabiting or visiting the estuary and wetlands of the lower Curdies River.

Surface and groundwater extraction in the catchment for domestic and irrigation supply reduces the amount of water reaching the estuary, however little is known about the flow requirements for the Curdies River estuary and the impact of current extraction. Climate change and the predicted reduction in annual rainfall is likely to result in even less freshwater inflows reaching the lower river and estuary.

The coastal impacts associated with climate change also pose a significant threat to the Curdies River estuary. Sea level rise of 0.8-1.1m is forecast by 2100, as well as an increase in storm surge events. According to the Corangamite NRM Plan for Climate Change these influences, combined with a reduction in rainfall, create a high climate change risk for the Curdies estuary. In recent years, storm surge events

have occurred at the Curdies estuary providing an insight into the impacts that may be experienced more frequently in the future. Appendices 2 and 3 provide further detail on the predicted climate change impacts and opportunities at the Curdies estuary.

Under natural conditions, the Curdies River estuary intermittently opens and closes in response to prevailing conditions such as freshwater inflows, weather changes or tidal movements. Floodplain inundation associated with the closure of the river mouth is a natural process and one that is necessary to support the lifecycle of many species, as well as the cycle of nutrients. Artificial estuary openings now occur to minimise the impact of flooding on adjacent land and infrastructure, however doing so can cause adverse impacts to the natural environment and the species that live there.

The township of Peterborough at the mouth of the Curdies estuary is a popular tourist destination and the estuary is utilised for a range of recreational activities. Increased usage of the estuary may have negative impacts if not carefully planned for and managed. Potential impacts may include littering, trampling of vegetation and habitat disturbance, bank erosion due to inappropriate access, the introduction and spread of weeds and illegal shooting and camping. Urban encroachment and inappropriate development around the estuary also has the potential to impact on the natural values of the estuary and the installation of hard infrastructure may restrict the ability for a more natural flood regime to be achieved; this too must be carefully managed and planned for.

Many of the threats described here also pose issues for emergency management. Agencies such as the SES and EPA are responsible for responding to natural events (such as riverine flooding, flash flooding, storm surge, landslides and debris resulting from bushfire) and well as other events (such as pollution, boating incidents and drownings). Peterborough has a history of being impacted by flooding from the Curdies River when the mouth is closed, with impacts including flooding of the caravan park and dwellings and inundation of roads. Documents such as local government *Municipal Emergency Management Plans* and the *Regional Floodplain Management Strategy* (currently under development) provide detail on emergency management and associated risks.



The Curdies estuary supports many environmental, social and economic values

6. Goals, Objectives and Management Actions

6.1 Goal

The environmental condition of the Curdies River estuary is maintained or improved, promoting a healthy, rich and diverse estuarine ecosystem and supporting long-term sustainable use.

6.2 Objectives

Six objectives have been identified to help achieve the goal for the Curdies River estuary.

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They are:

1. The diverse native vegetation communities and wildlife of the estuary are protected and enhanced
2. Water flows support estuary values, and the quality of water entering the estuary improves over time
3. Tourism and recreational use is environmentally sensitive and available for all
4. Indigenous and heritage values are respected and conserved
5. Management of the estuary is coordinated and knowledge gaps addressed
6. Future development has no, or minimal, impact on the variable hydrology of the intermittently open estuary.



Aerial image of the of the Curdies estuary mouth open to the sea

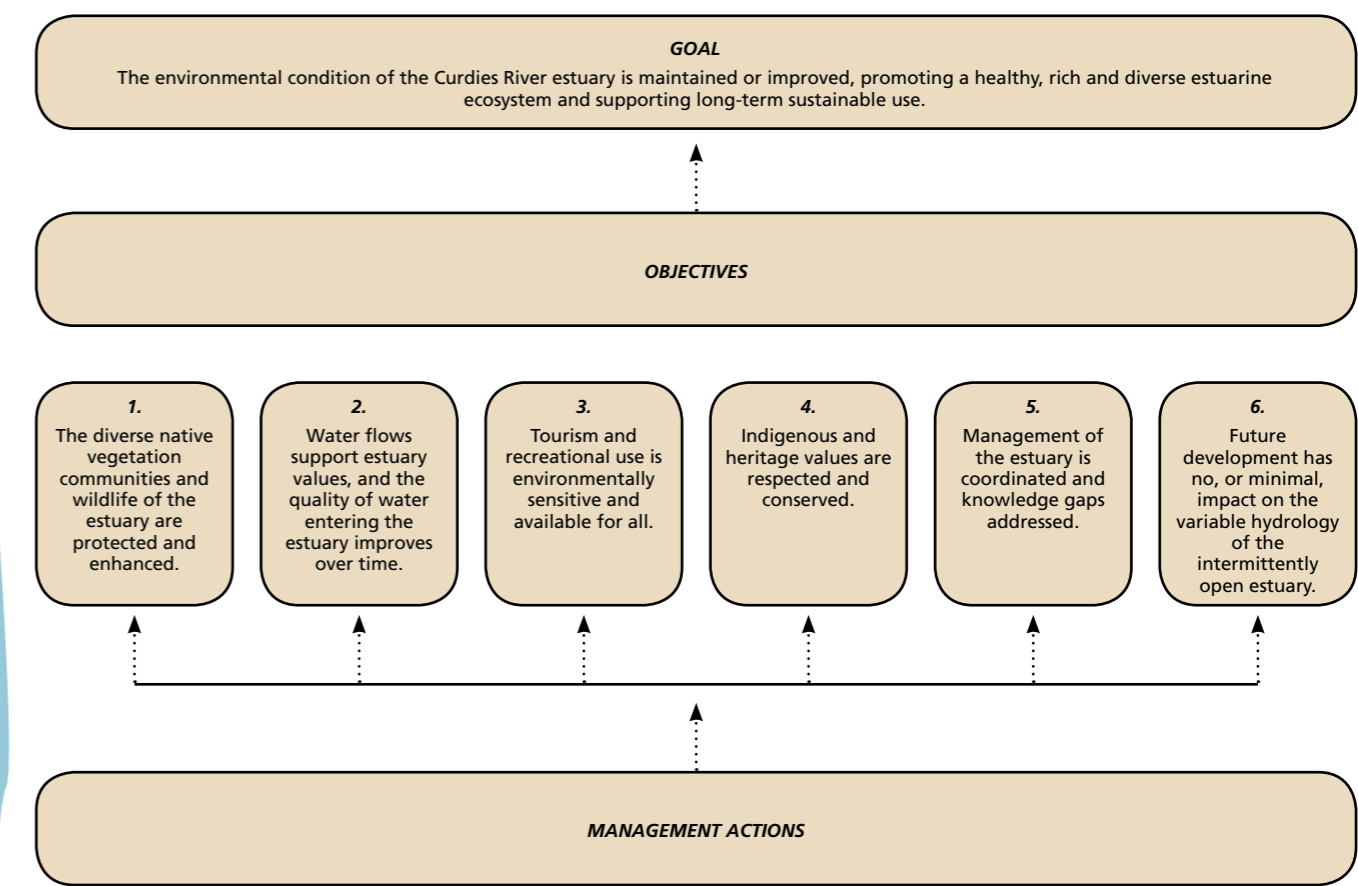
6.3 Management Actions

The management actions for the Curdies River have been informed by existing research and relevant plans, and prepared in consultation with a Working Group of stakeholders including agency representatives and local landholders.

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The management actions are presented in Table 2. Collectively, these actions will contribute towards the achievement of the six objectives and ultimately the goal for the Curdies River estuary (Figure 4).

Figure 4. Hierarchy of goal, objectives and management actions for the Curdies River estuary



Timelines and costing have not been included, to allow the CCMA and other stakeholders flexibility to deliver actions as funding becomes available.

7. Implementation of Actions

This EMP has been written for all stakeholders who have an influence on the Curdies River estuary. The Corangamite CMA has taken a lead role in the development of the EMP, although it is only one stakeholder that has a role in the implementation of the actions identified in Table 2. For instance, the CMA has a high level of control and influence in the continuing support of EstuaryWatch and the delivery of river health programs for riparian restoration work in the catchment of the Curdies estuary. There are other actions, such as the maintenance and potential upgrades to built infrastructure, where the CMA will play more of a supporting role to other agencies and stakeholders, in this case local government.

The lead agency, or agencies, has been identified for each action as well as project partners. A Stakeholder Reference Group will be established for the Curdies River estuary and will meet annually to oversee the delivery and monitoring of actions.

Another key role of the CMA and the relevant stakeholders will be to seek funding opportunities as they arise to deliver the actions.

Table 2: Management actions for the Curdies River estuary

Action	Detail of Action	Lead	Project Partners
Water quality			
1*	Work with landholders to find opportunities to install riparian fencing to exclude livestock.	CCMA	Landcare, landholders
2	Continue to support and encourage riparian restoration works in the Curdies River catchment.	CCMA	Landcare, landholders
3	Pilot approaches to riparian fencing for stock exclusion on the floodplain that are flexible and meet the needs of farming systems, whilst providing sound ecological outcomes for the investment.	CCMA	Landcare, landholders
4	Support and encourage whole-farm planning initiatives with dairy farmers in the Curdies River catchment to reduce nutrient runoff to the river and tributaries.	CCMA, DEDJTR	WestVic Dairy, EPA, Landcare
Freshwater flows			
5	Undertake investigations to better understand the flow requirements for the Curdies River estuary.	CCMA	DELWP, SRW, research institutions
6	Undertake investigations to increase understanding of groundwater interactions with the Curdies River estuary.	CCMA	SRW, DELWP, research institutions
7	Work with the water users in the Curdies catchment, such as irrigators and farm dam owners, to increase understanding and encourage more responsible water use.	SRW, CCMA	LG, Landcare

* These actions are also identified as key management activities for the Curdies River estuary in the Corangamite Waterway Strategy 2014-2022.

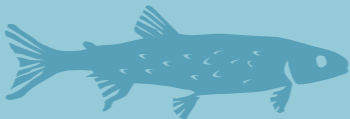


Table 2: Management actions for the Curdies River estuary (continued)

Action	Detail of Action	Lead	Project Partners
Biodiversity			
8*	Establish stewardship/management agreements to support landholders to undertake sustainable land management practices.	CCMA	Landholders, DELWP, PV
9	Establish terrestrial pest animal control (especially feral and domestic cat and fox control) as part of a large scale coordinated program to protect biodiversity values.	DEDJTR, LG	PV, Landcare, landholders, CCMA, DELWP
10*	Work with public and private land managers to implement weed control works on the floodplain and surrounding land.	DEDJTR	Landcare, landholders, CCMA, DELWP, PV
11	Increase community education about the impact of garden plants encroaching surrounding native vegetation.	DEDJTR	PV, LG
12*	Establish native indigenous vegetation at the estuary, in accordance with the appropriate Ecological Vegetation Classes (EVCs).	CCMA	DELWP, PV, Landcare, landholders
13	Protect and enhance stands of remnant EVCs on private and public land at the estuary, with a particular focus on those that are threatened e.g. Swamp Scrub (EVC 53).	CCMA	DELWP, PV, Landcare, landholders
14	Increase the participation of landholders in the CCMA Coastal Tender and Saltmarsh Tender programs.	CCMA	Landcare, landholders, PV
15	Increase the extent and protection of habitat for known rare and endangered bird species including the Hooded Plover, Rufous Bristlebird and Orange Bellied Parrot.	DELWP	PV, Landcare, landholders, CCMA
16	Undertake a survey of native fish species utilising the estuary	CCMA	Research institutions, EstuaryWatch, Fisheries Victoria
17	Build on existing surveys of in-stream vegetation, through further research and/or implementation of in-stream structures where appropriate, to support native fish populations in particular the vulnerable Yarra Pygmy Perch	CCMA	ARI, Fisheries Victoria
18	Use existing monitoring of estuary vegetation to inform future management of the estuary.	CCMA	DELWP, PV, Landcare, landholders
19	Support research on bird species utilising the wetlands and build this knowledge into the future management of the estuary.	DELWP	Research institutions, CCMA
Climate change			
20	Support the PhD research project titled 'Mitigating Climate Change with Blue Carbon Ecosystems' and incorporate the findings of into the management of the Curdies River estuary where appropriate.	CCMA	Deakin University, LG, DELWP, PV, landholders
21	Undertake investigations to further understand the implications of storm surge events and sea level rise on the Curdies River estuary, and in particular the ability for the natural environment to adapt.	LG, CCMA	DELWP, PV, SES
22	Continue to document case studies on storm surge events, and other extreme climatic events, as they occur.	LG, CCMA	EstuaryWatch, PV, SES
23	Consider local estuary monitoring data alongside Municipal Emergency Response Plans for all flooding events including estuarine and riverine flooding, as well as storm surge events.	LG, SES	EstuaryWatch, BoM, PV, CCMA
24	Prepare a coordinated approach to collating storm surge data and issuing alerts to the community and stakeholders.	LG, SES	PV, CCMA
25	Support the guiding adaptation responses identified for the Curdies River estuary in the Corangamite Natural Resource Management Plan for Climate Change, in particular actions that will support the estuary to adapt naturally to the impacts of climate change.	CCMA	DELWP, PV, LG, Landcare, EstuaryWatch, landholders

* These actions are also identified as key management activities for the Curdies River estuary in the Corangamite Waterway Strategy 2014-2022.

7. Implementation of Actions (continued)

Table 2: Management actions for the Curdies River estuary (continued)

Action	Detail of Action	Lead	Project Partners
Artificial estuary openings			
26*	Continue to adopt a risk based approach to estuary mouth opening.	CCMA, PV	LG
27	Prepare a Memorandum of Understanding between the relevant agencies and stakeholders to ensure a coordinated approach to the management of artificial estuary openings.	CCMA, DELWP	DELWP, PV, LG, landholders
28	Ensure EEMSS contains up-to-date information.	CCMA	PV, LG
29*	Investigate opportunities for blue carbon projects on the floodplain to support landholders adapt land management to support estuarine inundation.	CCMA	DELWP, landholders, LG, research institutions
30	Assess the costs and benefits of investing in modifications to existing public assets and infrastructure at risk of flooding e.g. Old Ocean Road.	LG, CCMA	DELWP, PV
31	Assess the suitability of local government planning controls e.g. overlays, to ensure they acknowledge the variable inundation regime of intermittently open estuaries.	LG	CCMA, PV
Cultural and European heritage			
32	Ensure future works, planning and strategies consider Indigenous and European heritage values for the Curdies River estuary.	All	TOs
33	Identify and incorporate cultural risks in EEMSS.	CCMA, PV	TOs, LG, DELWP
Community			
34	EstuaryWatch volunteers continue to be supported in the collection and analysis of water quality monitoring data at the Curdies River estuary.*	CCMA	EstuaryWatch
35	Support Landcare and EstuaryWatch (e.g. through funding, resource provision and sharing expertise and knowledge) so that they can continue to promote the natural values of the estuary to the wider community.	DELWP, CCMA	Landcare, EstuaryWatch
36	Increase community education about the impact of upstream activities on the estuary.	Landcare	EPA
37	Ensure research and information relating to the management of the estuary is communicated and made accessible to interested community organisations and members.	CCMA	Landcare, EstuaryWatch, PV
Tourism and recreation			
38	Conduct studies to understand the economic value of recreational fishing in the Curdies River estuary.	DEDJTR	DELWP, VRFish, research institutions, CCMA
39	Support initiatives arising from relevant tourism strategies that are environmentally sensitive and promote the natural values of the Curdies River estuary.	LG	PV, CCMA, DELWP
40	Advocate for management approaches that protect and enhance the natural values of the estuary and wetlands, particularly in high use areas.	DELWP, CCMA	PV, LG, MSV
41	Advocate opportunities for passive recreation at the estuary, in particular bird watching.	DELWP, PV	LG, CCMA, Birdlife Australia
42	Support research that increases the understanding of the value and impact of recreation (e.g. fishing and boating) on the ecology of the estuary.	All	Research institutions, VRFish, DEDJTR, DELWP, PV, CCMA

* These actions are also identified as key management activities for the Curdies River estuary in the Corangamite Waterway Strategy 2014-2022.

ARI	Arthur Rylah Institute	DELWP	Department of Environment, Land, Water & Planning	PV	Parks Victoria
BoM	Bureau of Meteorology	EPA	Environment Protection Authority	SES	State Emergency Services
CCMA	Corangamite Catchment Management Authority	LG	Local Government (Corangamite Shire)	SRW	Southern Rural Water
DEDJTR	Department of Economic Development, Jobs, Transport & Resources	MSV	Maritime Safety Victoria	TOs	Traditional Owners
				VRFish	Victorian Recreational Fishing

8. Estuarine Processes and Characteristics

8.1 Physical characteristics

A complex set of interacting factors influences the characteristics and functioning of an estuary, particularly the formation of the sand bar at the mouth (Figure 5).

The key influencing factors are:

- Ocean tides
- Wave activity
- Storm surges
- Freshwater inflow
- Geomorphology e.g. rock headlands.

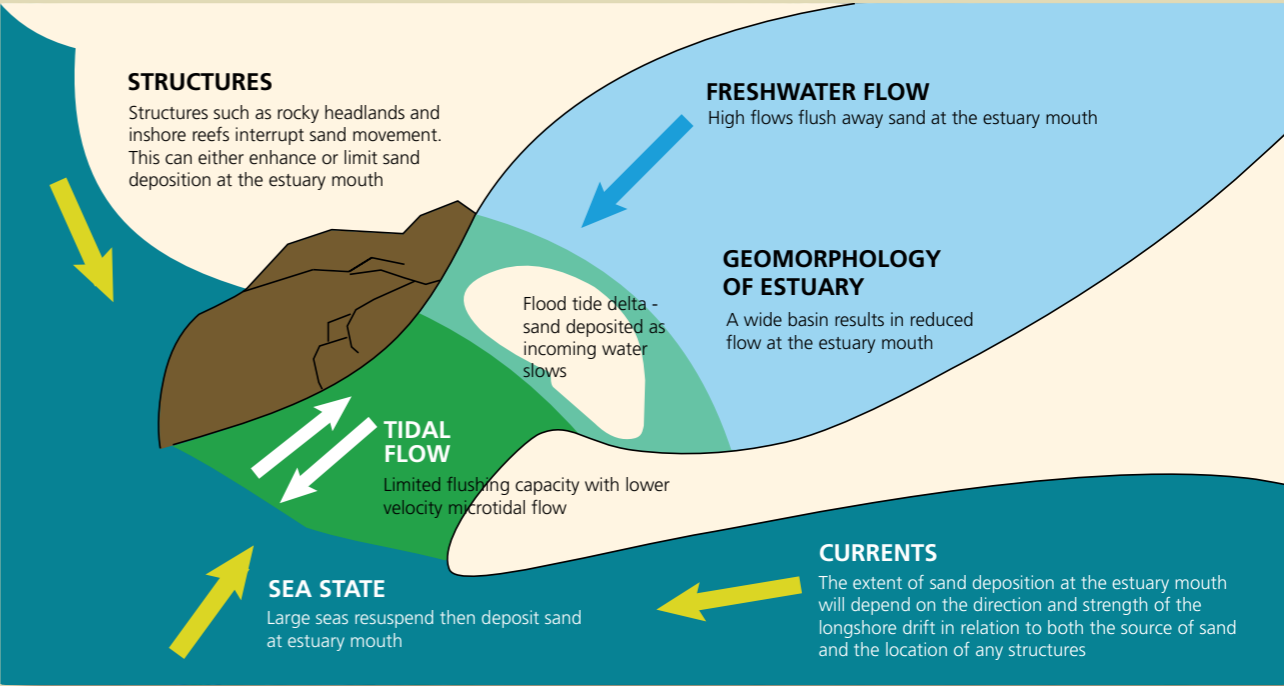
The Curdies River is the dominant source of freshwater for the Curdies River estuary and the main stream of the river originates at Lake Purrumbete. The estuary intermittently opens to the ocean, closing mainly as a result of the accumulation of wave and wind blown sand and less frequently due the high freshwater flows.

The estuary is predominantly shaped by the prevailing southwesterly ocean swell causing infilling and is classified as a Wave Dominated Estuary (WDE) (OzCoasts 2016). The rocky headland to the west of the estuary combined with easterly currents, common in the summer months, promotes the accumulation of sand at the estuary entrance.

The lagoon at the head of the estuary is well defined by a narrow river channel, which opens up via a reed-fringed delta. The delta is gradually reclaiming the estuary, converting the lowland areas into riverine floodplain. The lower coastal reaches of the lagoon are being converted into a tidal delta as a result of sand infill caused by flood tides and storm surges.

The estuary catchment has an annual rainfall of 700mm. River discharges are variable both annually and seasonably and have an impact on estuary dynamics. Winter floods may flush salt water from the estuary completely, whilst low flows in summer can constrict tidal exchange resulting in higher concentrations of salt water.

Figure 5. Factors that influence the characteristic and functioning of an estuary, particularly the mouth (Arundell 2006)



8.2 Water quality

Mixing of salt and freshwater is a key feature of estuaries defining both the extent of an estuarine environment and the biota that inhabit it. The availability of dissolved oxygen, sediments supplying carbon, nutrients and presence of pollutants are other key aspects of water quality that determine the suitability of an estuarine environment for biota.

The Curdies River has been identified as having exceptionally high nutrient levels, consistently exceeding state objectives (DEPI 2005). These high nutrient levels have been responsible for numerous toxic algal blooms in the estuary which impact on ecological values including birds, fish and macrophyte communities. Following a risk assessment completed in 2005, sewage systems at Peterborough, Cobden and Timboon have been built, reducing nutrient inflows to the system. Despite this reduction, agricultural and industrial sources of nutrients appear to still impact the system (Water Technology 2008).

Water quality parameters are monitored at several sites along the Curdies River estuary system, from the estuary mouth to the upper reaches of the Curdies River. The EPA, DELWP and EstuaryWatch currently undertake monitoring for the Curdies River estuary (Table 3).

Table 3. Key water quality parameters collected by various monitoring sources.

Parameter	Unit
Dissolved oxygen (DO)	mg/l & % saturation
Salinity	Parts per thousand (ppt)
Electrical conductivity (EC) (measure of salinity)	micro Siemens per cm (µS/cm)
pH	pH units
Temperature	Degrees Celsius (°C)
Turbidity	Nephelometric Turbidity Units (NTU)

The extent of stratification (separation of salt and freshwater) in estuarine systems is highly dynamic, largely driven by intermittent opening of the estuary mouth and variability in freshwater flows (Water Technology 2008). Generally freshwater flows are low in summer and autumn and stratification is higher, than in winter (Figure 6). In the Curdies River estuary, water has been reported to range from fresh during high river flows to highly saline during period of low flow.

This variability is typical of an open estuary system with variable flows (DEPI 2005).

Dissolved oxygen (DO) is also influenced by mouth closures and shows the greatest variation when there is stratification of the water column. Measurements of percent saturation of DO will typically range from 0% to 100%, but can exceed 100% at times when plants and algae are producing large amounts of oxygen.

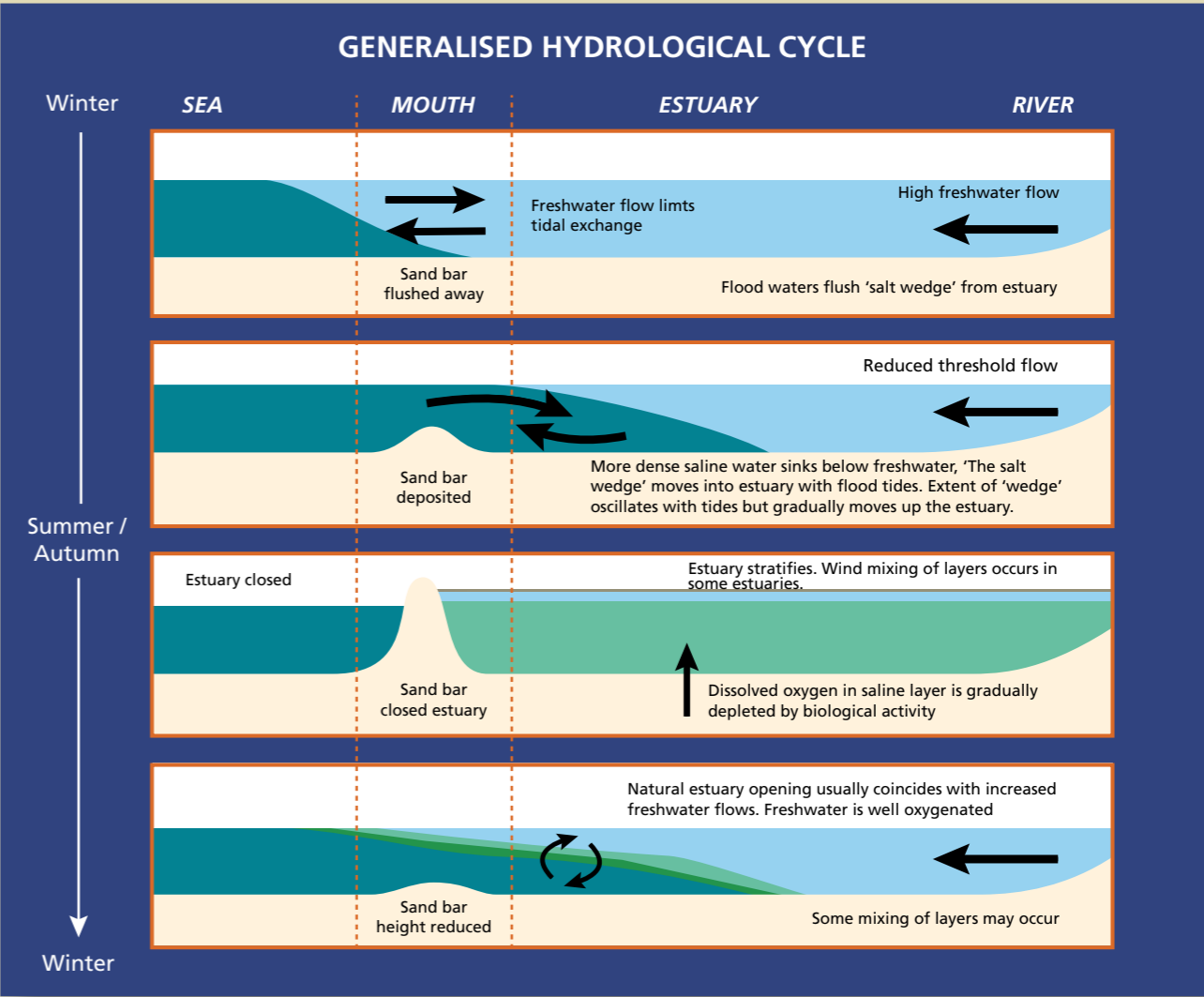
Fluctuations in DO is a natural occurrence in salt wedge estuaries, such as the Curdies. Most animals and plants can grow and reproduce unimpaired when DO levels exceed 80%. While some living organisms can become stressed when DO drops to less than 80%, there are other species that have adapted to depleted oxygen conditions. For example, some zooplanktonic estuarine species have been found to occur in the deeper oxygen depleted regions of estuaries (Newton-McKay 1994). Zooplankton are the foundation of the estuarine food web and their ability to survive in low DO conditions is very important and they play a vital role in sustaining a diverse estuarine ecology.

Levels of DO in the Curdies River estuary are highly variable and dependant on where in the system the measurement is taken. Close to the estuary mouth DO saturation is most variable ranging from almost zero (in the salty bottom layer which is isolated from the atmosphere), to greater than 300% (in the top freshwater layer where oxygen exchange can occur with the atmosphere). Low DO levels in this section of the estuary are also potentially exacerbated by high nutrient inputs (Water Technology 2008).

Other parameters, including salinity, pH, temperature and turbidity also provide important indicators of water quality.

Salinity in particular plays a major role in the functioning of estuarine ecology and salinity dynamics can influence other parameters such as dissolved oxygen, turbidity, pH and colour. Salinity is the amount of salt dissolved in the water and is commonly measured as the units of electrical conductivity (EC) expressed as micro Siemens per centimetre (µS/cm) or parts per thousands (ppt). The overriding influence on salinity in estuaries is from marine inflows; catchment inflows will influence the freshwater surface layer e.g. from geology, urban and agricultural runoff, sewage and industrial effluent and groundwater which can often have very high salt concentrations. Salinity can influence stratification within an estuary, as heavy salt water sinks beneath freshwater causing a tidal salt wedge to move backwards and forwards with the tides (EstuaryWatch Victoria 2012).

Figure 6. Generalised hydrological cycle of intermittently open estuaries in Victoria such as the Curdies River estuary (DEPI 2005).



Other factors such as wind, geology (depth and width of an estuary), velocity of freshwater and tidal inflows and temperature also influence stratification and mixing in an estuary. Temperature, for example, can change the density of water leading to thermal stratification. Warm water is less dense than cold water, and will therefore float above cold water. The density difference between warm and cold water can inhibit mixing in the same way that salinity does (EstuaryWatch Victoria 2012). Temperature is also a key factor controlling the rate of biological processes such as algal growth (the rate of growth will increase with temperature increases) and also influences oxygen concentrations (as temperature increases, the amount of oxygen water can hold will decrease). The pH of water is another important parameter, measuring acidity or alkalinity. Freshwater pH is generally lower than seawater. When the entrance closes, water in the estuary will essentially be marine and therefore the pH will be generally higher than 7. During high river inflows, freshwater will begin to dominate and estuary pH will decrease at the surface.

Bottom water however may remain saline and the pH is likely to be higher (EstuaryWatch Victoria 2012).

Turbidity is a measure of the clarity of water. As suspended particulate matter including clay, silt, detritus and plankton in the water increases, the clarity decreases and the water takes on a muddy appearance. Most of the sediment in an estuary originates from catchment, river, streambed and bank erosion which can be exacerbated by agriculture, forestry and urban developments. Sewerage effluent, industrial and septic tank discharges can also influence the turbidity of an estuary. During periods of high river inflows, turbidity can be very high, conversely when the entrance is closed and water is more marine, the turbidity will be low (<10NTU) (EstuaryWatch Victoria 2012).

Further information relating to water quality monitoring parameters in estuaries, can be found on the EstuaryWatch Portal: www.estuarywatch.org.au

8.3 Condition reporting

Estuaries across Victoria vary greatly. To effectively report on estuary condition it is important to have a standard set of data to report against.

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The Index of Estuary of Condition (IEC), currently under development, is designed to complement the existing Index of Stream Condition (ISC). This provides a consistent statewide assessment of the environmental condition of estuaries that is completed every eight years. The assessment is conducted across six themes:

- Water quality
- Physical form
- Hydrology
- Sediment
- Flora, and
- Fauna.

This enables the condition of the Curdies River estuary to be reported at regional, state and national levels, prioritising resource allocation, and providing a way to assess estuary management interventions. The IEC is only intended to provide a snapshot of condition. Therefore, it is important to have long-term datasets to track condition over time and account for different hydrological states.

The Environment Protection Authority (EPA) water quality guidelines provide a framework and tools for assessing the environmental condition of riverine estuaries. The guideline values describe the condition of quality estuaries, and these can be used as an indicator for assessment of other estuaries (EPA 2011).

8.4 Current condition

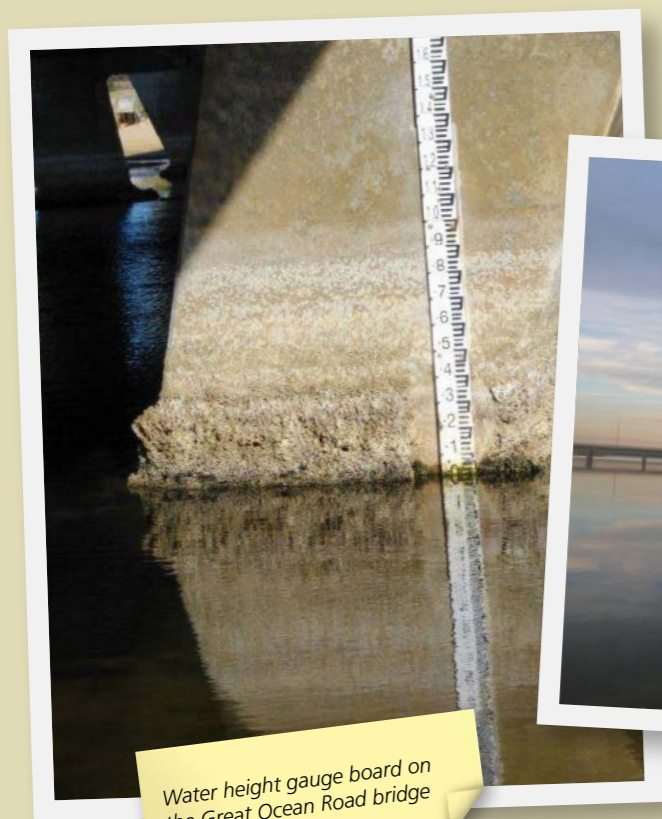
The Curdies River estuary scored moderately to poorly based on the 2011 EPA assessment guidelines and in comparison to other estuaries in Victoria. The scores were influenced by poor freshwater quality and catchment and estuary modification. The assessment assumed the condition of the inflowing stream i.e. the Curdies River, was a key predictor of estuarine health (EPA 2011).

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The third ISC report for the Corangamite Region (based on data from 2004-2010) assessed the lower reaches of the Curdies River as being in very poor condition (DEPI 2010). The low score was partially attributed to drought conditions causing flow stress in the Curdies that affected much of the Corangamite basin during this period. This condition rating is worse than previous ISC condition ratings for the Curdies River in 1999 and 2004, which classified the lower reaches as 'moderate' for these years.

More information regarding the ISC and studies relating to the condition of the estuary can be located here:

- Corangamite CMA Knowledge Base: www.ccmaknowledgebase.vic.gov.au
- EstuaryWatch Portal: www.estuarywatch.org.au



Water height gauge board on the Great Ocean Road bridge



Where the Curdies estuary meets the sea



Looking west across Curdies Inlet

9. Estuarine Values

9.1 Fish Species

Fish are managed throughout Victoria for various reasons.

Broadly speaking the *Victorian Guide to Native Fish Management* (Drew et al. 2008) prioritises the following:

- Freshwater and estuarine species recognised as threatened*
- Freshwater and estuarine species that are targeted by recreational and commercial fishers# or are of cultural significance
- Remaining freshwater species for which we have good knowledge.

Beyond these priority groups, estuarine fish are prioritised according to their level of dependence on estuarine environments, with greater emphasis placed on species heavily reliant on estuarine environments to complete life cycles. Native fish that occur in estuaries are divided into three groups:

- Freshwater species
- Estuarine species usually further divided into permanent or seasonal
- Marine stragglers – visitors to the estuary environment.

Figure 7 shows the variation in how fish groups use and rely on an estuary. This degree of variation is evident at the Curdies River estuary, where the river and estuarine environments provide important habitat for fish migration, spawning and rearing for a range of species.

The Victorian Biodiversity Atlas compiled by DELWP lists 17 fish species reported to occur in the Curdies River estuary (DELWP 2016). However, it is unlikely that these records reflect the true species diversity in the estuary, which has not been surveyed in recent years.

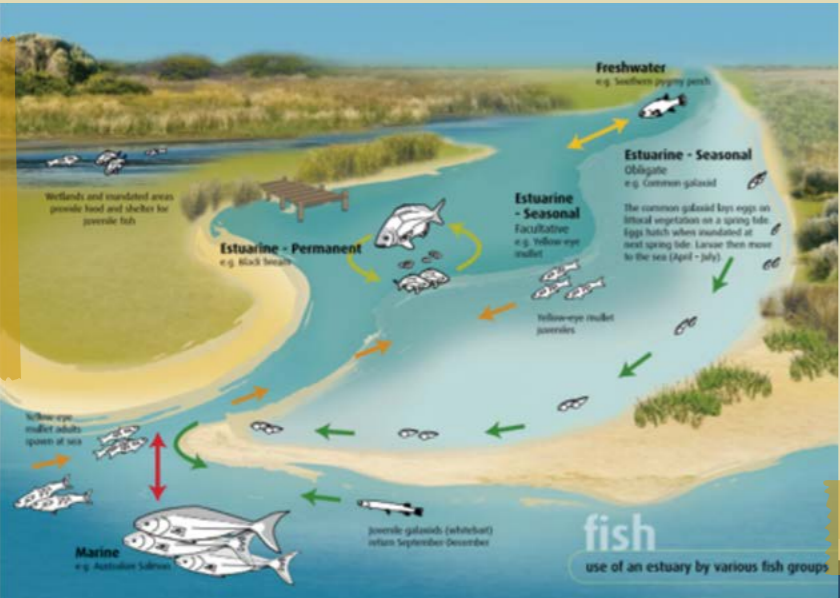
The list includes marine species such as the Australian Salmon (*Arripis trutta*) and as well as the Southern Shortfin Eel (*Anguilla australis*) and Common Galaxias (*Galaxias maculatus*) that use the estuary to migrate between freshwater and marine environments. Yellow-eye mullet (*Aldrichetta forsteri*) juveniles will utilise seagrass beds in the estuary and Estuary Perch (*Macquaria colonorum*) and Black Bream (*Acanthopagrus butcheri*) use the estuary for all life stages. The shallow water adjoining the estuary provides important foraging habitat and a refuge for juvenile fish of many species (Water Technology

2008). One listed species the Yarra Pygmy Perch (*Nanoperca obscura*) has been recorded in the estuary and is classified as vulnerable at both a state and national level (Barton & Sherwood 2004).

The estuary also provides excellent bait harvesting opportunities. Popular recreational fish species targeted include:

- Pinky Snapper, Gummy Shark, Whiting, Mullet, Trevally and Salmon in the surf, and;
- Estuary Perch, Black Bream, Mullet and Salmon in the tidal section.

Figure 7. Use of an estuary by various fish groups (Arundell 2006)



* Listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act* (1999) or *Victorian Flora and Fauna Guarantee Act* (1998).

As determined from information derived from DELWP resources and the Scientific Advisory Panel.



Estuary Perch are common in the Curdies estuary (Image: Fishes of Australia)

9.2 Birds

A diversity of bird species (130 in total) has been recorded from the Curdies River estuary.

This is a reflection of both the level of survey effort and range and size of habitats available in and around the estuary compared with many smaller estuaries in southwest Victoria. Important habitats vary with water levels and include (Barton & Sherwood 2004):

- Extensive areas of open water of varying depth
- Mudflats
- Vegetated areas
- Sandy shores.

The Victorian Biodiversity Atlas identifies almost 40 species listed as rare or threatened on the Victorian Advisory List for the area, including 8 that are listed

under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act* 1999 (DELWP 2016). A list of the bird species that are recognised at state and national level are included in Appendix 4.

Of particular note are the following listed species known to utilise the Curdies River estuary:

- Orange-bellied Parrot (*Neophema chrysogaster*) – nest and feed in saltmarsh and other coastal vegetation over winter
- Rufous Bristlebird (*Dasyornis broadbenti*) – ground dwelling birds that nest close to the ground in coastal vegetation
- Hooded plovers (*Thinornis rubricollis*) – nest directly on the beach or in dunes.

9.3 Vegetation

Estuarine vegetation plays an important role in filtering sediment, recycling nutrients and providing habitat for a range of invertebrate, fish and bird species. Ecological Vegetation Classes (EVCs) are used to describe and map plant communities across Victoria. An EVC is a component of a vegetation classification system, grouping vegetation communities based on floristic, structural, and ecological features.

A 2010 study describes 14 EVCs occurring at the Curdies River estuary. Amongst these, a stand of Estuarine Wetland (EVC 10) is noted as one of the largest in southeast Australia and is listed as depleted in the Warrnambool Plain bioregion. According to Osler & Cook (2010), the quality of Estuarine Wetland varies considerably and is influenced by different land management practices.

Swamp Scrub (EVC 53) has a bioregional conservation status of 'endangered' and it is within this vegetation community that the nationally vulnerable Swamp Greenhood orchid (*Pterostylis tenuissima*) has been recorded. Similarly, a large population of the nationally vulnerable species Curly Sedge (*Carex tasmanica*) has been recorded in the Brackish Grassland EVC (Osler & Cook 2010).

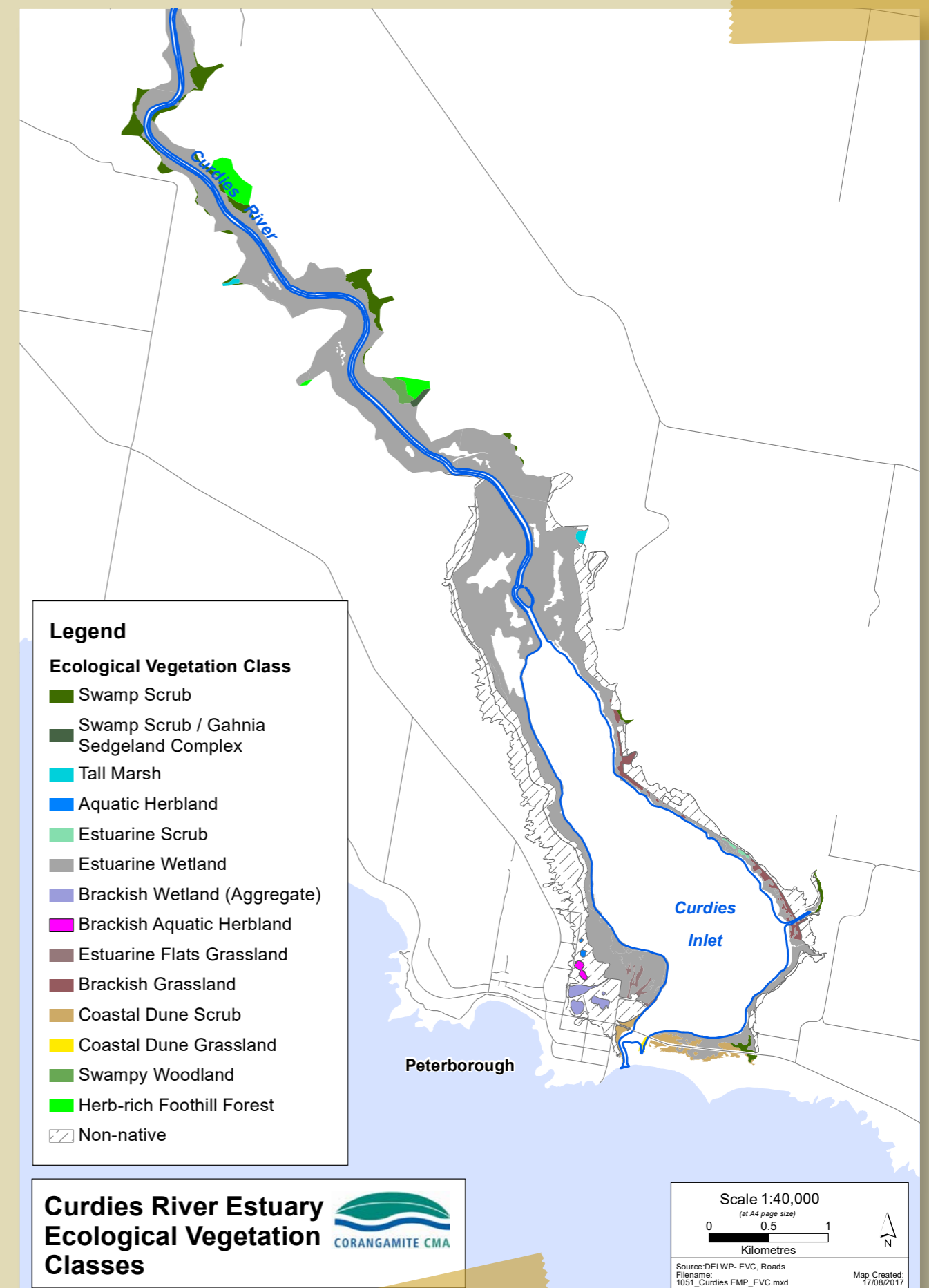
There are also significant stretches of coastal saltmarsh occurring around the estuary. This includes 1.58km² of saltmarsh vegetation, which is an important habitat component for the critically endangered Orange-bellied parrot (Water Technology 2008).

Appendix 5 provides a list of the flora species of conservation significance at the Curdies River estuary. Figure 8 shows the main EVCs that occur around the Curdies River Estuary.



Pelicans, Curdies River

Figure 8. Ecological Vegetation Classes surrounding the Curdies River Estuary



9.4 Socio-economic values

Prior to European settlement the Barath gundidj clan of the Kirrae Wurrung language group occupied the mouth of the Curdies River (DELWP 2016a) and the Ngaragurd gundidj lived in the coastal area east of the estuary. The Curdies River estuary and surrounds would have been a rich source of birds, fish and terrestrial mammals for the Baradh gundidj people of the estuary mouth and the Ngaragurd gundidj of the coastal area.

European settlers began to explore the Curdies River from as early as 1845-1855 and noted the abundant natural resources including birds, fish, timber and pasture. Early expeditions to settle and develop the land began in 1866 and the township of Peterborough was first surveyed this same year. Curdievale developed quickly in the 1920s with a bridge built across the estuary in 1927, a school opening and building of the Fisherman's Inn, a popular holiday destination.

The catchment was extensively cleared for soldier settlement after World War 2, with 165,000 ha of land cleared in the Scotts Creek and Cooriemungle catchment (DEPI 2005). The catchment is now primarily developed for dairy farming and is considered one of the state's key dairying areas.

In 2008, dairy production was expected to double in the region via increased efficiency, larger properties and enhanced production techniques and machinery.

There is one caravan park in Peterborough and the summer holidays are the peak visitation period for the area (December to January). The lagoon, river mouth and surrounding beach are popular locations for families sightseeing. Nearby attractions, including the 12 Apostles Marine National Park, Port Campbell National Park, the Arches Marine Sanctuary, the Bay of Islands Coastal Park and the Great Ocean Road also draw people to the area.

There are numerous options for cycling, walking, boating, non-motorised watercrafts, surfing, fishing and swimming in and around Peterborough, the estuary, lagoon and the beach. A 2005 study of 618 residents along the Great Ocean Road, found that the main reason they visited local estuaries included walking or bushwalking (55%), relaxing or to unwind (34%), fishing (29%), sightseeing (22%), swimming (21%), to have a picnic/BBQ (13%), a family outing (12%) or to watch birds (10%) (Nexus Research 2005).

Fishing pontoon at Curdies Inlet



10. Estuary Entrance Management Support System (EEMSS)

Parks Victoria manages all artificial estuary openings at the Curdies River. Parks Victoria and the Corangamite CMA use the Estuary Entrance Management Support System (EEMSS) at times when there is the threat of flooding due to estuary mouth closure. The EEMSS provides estuary managers with a tool for assessing the likely impacts of artificially opening, or not opening, an estuary. This includes consideration of the environmental, social and economic impacts.

The EEMSS also contains important baseline data such as records of estuary openings, water levels, water quality data and species lists. Agricultural data has been recently collected and will be incorporated into the EEMSS for the Curdies River estuary. Collection of this data involved consultation with local landholders to understand their assets and threats in relation to the estuary water level for particular times of the year.

Originally the EEMSS was developed as a database in 2006, but has since been redeveloped as a web-based tool and can be accessed at: www.victorianestuaries.com.au

Information relating to the history of artificial estuary openings at the Curdies, is provided in Appendix 6.



An excavator moves sand to open the estuary mouth



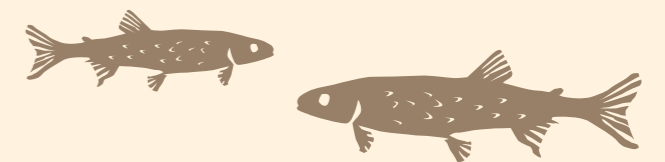
An artificial opening to the sea at the Curdies estuary

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12. Glossary

- Acid:** Water with a pH lower than 7.
- AHD:** Australian Height Datum is the standard measure for height with zero being a mean sea level.
- Alkaline:** Water with a pH higher than 7.
- Anaerobic:** Living or active in an environment where oxygen is absent.
- Anoxic:** Areas of marine or freshwater that are depleted of dissolved oxygen.
- Asset Values Identified and Risk Assessment (AVIRA):** A spatial tool for assessing the values and threats to river reaches, wetlands and estuaries.
- Bathymetry:** The terrain beneath the water's surface, which could be marine, riverine or wetland.
- Berm:** The sand accumulated at the mouth of a waterway (river or creek).
- Catchment:** An extent of land where water from precipitation drains into a waterway.
- Dissolved Oxygen:** Oxygen dissolved in water. Usually measured in milligrams per litre (mg/l or ppm) but can also be presented as percent saturation.
- Ecological Vegetation Class (EVC):** A component of a vegetation classification system, grouping vegetation communities based on floristic, structural, and ecological features.
- Electrical conductivity (EC):** A measure of how well a material accommodates the transport of electrical charge. EC is used to estimate the concentration of dissolved salts.
- Estuary:** Semi-enclosed body of water where salt from the sea mixes with freshwater flowing from the land.
- Estuary Management Support System (EEMSS):** A decision support database tool to inform artificial estuary mouth openings by considering the risks to social, environmental and economic assets or values.
- EstuaryWatch:** A community based estuarine monitoring program administered by the Corangamite CMA.
- Estuary Water Level (EWL):** Refers to the surface height of water within the estuary.
- Freshwater:** Looking at estuaries, water with a low salinity. Not necessarily potable or clear.
- Halocline:** An area of transition from lower to higher salinity with increasing depth.
- Hydraulic:** Operated by, moved by, or employing water or other liquids in motion. Studying the hydraulics of the estuary will explain where the water moves and the way it does within the estuary.
- Hydrodynamics:** The branch of science concerned with the hydraulic properties of water and in this context, how the water within the estuary moves based upon the physical boundaries within the system such as bank steepness and roughness, depth (bathymetry) and bank width.
- Index of Stream Condition (ISC):** Standard measure of river health in Victoria reported every six years.
- Index of Estuary Condition (IEC):** Still at draft stage the IEC will have a similar statewide measure of estuary health as that for wetlands (IWC) and rivers (ISC).
- Land Subject to Inundation Overlay (LSIO):** A flood related town planning control.
- Longshore sediment transport:** The general direction of sand and sediment transport along the Victorian coastline in west to east.
- Marine:** Of or pertaining to the sea; existing in or produced by the sea.
- µS/cm:** micro Siemens per cm – the unit of measurement for electrical conductivity (salinity). mS/cm gives an indication of the salt content in a solution; the more salt there is in a solution, the easier it is for an electric current to flow.
- NTU:** Nephelometric Turbidity Units – the unit of measurement for turbidity. Turbidity is normally measured by an instrument called a Nephelometer, which determines the scattering of light and is measured in standard NTUs.
- Parameters:** The different types of qualities that estuary water is tested for can be termed parameters.
- pH:** A measure of how many H⁺ and OH⁻ ions are in solution giving a measure of acidity or alkalinity on a scale of 1-14, where less than 7 is acid, 7 is neutral, and greater than 7 is alkaline.
- Terrestrial:** Belonging to the land rather than the sea or air living or growing on land.
- Saline:** Water containing significant content of salt.
- Salt wedge:** The physical separation of marine and riverine water within an estuary with the denser salty marine water sitting beneath the riverine water and forming a wedge.
- Stratification:** Water stratification occurs when water masses with different properties such as salinity (halocline), oxygen (chemocline), density (pycnocline) temperature (thermocline) form layers that act as barriers to water mixing.
- Threats:** Something which may do harm to a value or asset.
- Turbidity:** Visible cloudiness due to suspended material in water causing a reduction in the transmission of light.
- Tributary:** A stream that flows to a larger stream or other body of water.
- Values:** Things important to the community and stakeholders.



Appendix 1: Working Group

A Working Group was established to guide the development of the Curdies River Estuary Management Plan. The following organisations were represented (or invited to participate) on the Working Group:

- Corangamite Catchment Management Authority
- Corangamite Shire
- Moyne Shire
- Parks Victoria
- Department of Environment, Land, Water and Planning
- Department of Economic Development, Jobs, Transport and Resources
- Victorian Recreational Fishing
- Eastern Maar Aboriginal Corporation
- Kuuyang Maar Aboriginal Corporation
- State Emergency Services
- Game Management Authority
- Great Ocean Road Tourism Committee
- Western Coastal Board
- Heytesbury District Landcare Network
- EstuaryWatch
- Peterborough Residents Group
- Friends of the Bay of Islands
- Private industry
- Local business operators.



A relaxing vantage point overlooking Curdies Inlet

Appendix 2: Adapting to climate change

The Corangamite CMA has prepared the *Corangamite Natural Resource Management Plan for Climate Change*, which provides the background, current information and detailed processes required to enable the impact of climate change to be considered in managing the region’s natural assets.

The plan:

- Provides regional information on the projected changes in climate and its likely impact on the region’s natural assets
- Provides guidance to the Corangamite CMA and other regional NRM agencies in developing adaptation and mitigation actions to address the impact of climate change on the region’s natural ecosystems
- Identifies priority landscapes for carbon plantings and other carbon sequestration methods, as well as strategies to build landscape integrity
- Provides guidance for regional decision-making, community engagement and research methods to improve understanding of the impact of climate change, and how those impacts can be managed.

The plan also includes a web portal with relevant climate change data and information, with the ability to include new data as it becomes available. The portal can be accessed at: www.swclimatechange.com.au

What will the climate in Corangamite look like in the future?

RAINFALL	<ul style="list-style-type: none">• Less rainfall in the cool season – up to less than 25% in winter and 45% in spring by 2090, under high emissions.• Changes to summer and autumn rainfall are possible, but less clear.• Increased intensity of extreme rainfall events is projected.• Time spent in drought is predicted to increase over the century.
TEMPERATURE	<ul style="list-style-type: none">• Average temperature will continue to increase in all seasons, with more hot days and warm spells and fewer frosts.• By 2030, average annual warming is expected to be around 0.4 - 1.1°C.• By 2090, under high emissions warming is expected to be 2.4 - 3.8°C and under an intermediate emissions scenario 1.1 - 1.9°C.
MARINE & COAST	<ul style="list-style-type: none">• By 2030, sea level is projected to rise by 0.08 - 0.18m.• By 2090, sea level is projected to rise by 0.29 - 0.64m under an intermediate emissions scenario and by 0.39 - 0.84m under high emissions.• Sea surface temperature is expected to increase in the range of 1.6 - 3.4°C by 2090 under high emissions.• An increase in the frequency and height of extreme sea level events.• The oceans are predicted to become more acidic.
OTHER	<ul style="list-style-type: none">• There is likely to be a harsher fire-weather climate in the future.• Potential evapotranspiration is projected to increase in all seasons.• An increase in solar radiation and a decrease in relative humidity are projected in the cool season.

Appendix 2: Climate change impacts to estuaries

Estuaries are exposed to climate change impacts arising in both the catchment and the coast. The predicted reduction in rainfall, and subsequent freshwater inflows, coupled with coastal and marine influences such as sea level rise and storm surge events will have a major impact on estuaries. It is important that future management of the Curdies River estuary considers the impacts of climate change on the system, that new information is incorporated as it becomes available and adaptation responses are prepared.

Flooding at Peterborough



Inundation of built assets upstream at Boggy Creek



Inundation of the floodplain near Peterborough

References:

Climate Change and Victoria, DELWP: www.climatechange.vic.gov.au/understand

Corangamite CMA: www.ccma.vic.gov.au/What-we-do/Climate.aspx

Appendix 3: Blue Carbon

Saltmarsh, mangroves and seagrass meadows are collectively known Blue Carbon habitats. They have recently been identified as one of the most effective carbon sinks on the planet, burying carbon at a rate 35-57 times faster than tropical rainforests and storing it for thousands of years. These features make vegetation coastal habitats ideal candidates for carbon offset programs and nature-based climate mitigation initiatives.

The main benefits of blue carbon habitats include:

- They sequester nearly equivalent quantities of organic carbon as terrestrial vegetation, despite comparatively limited biomass (0.05% of terrestrial plant biomass).
- The ability to store carbon at around 40 times the rate of terrestrial systems. The anaerobic soils prevent organic carbon remineralisation, helping to achieve long-term sequestration.
- Carbon in these habitats can be stored for centuries to millennia.
- The ability to produce and store their own carbon, but also trap carbon produced from other locations.
- Their ability to trap particles and suspended sediments means they may appropriate large quantities of carbon that originates from adjacent habitats, both terrestrial and marine. This is of particular importance in the Corangamite region where a majority of waterways filter through coastal saltmarsh before entering the sea.
- The provision of a range of other ecosystem services including nursery habitat for fish species and shoreline stabilisation.

While blue carbon habitats are excellent at accumulating carbon, degradation and loss of vegetated coastal habitats could shift them from carbon sinks to carbon sources, releasing atmospheric CO₂. Impacts include land clearing, changes to tidal influences and stock grazing.

The Corangamite CMA has identified the protection, and improvement of blue carbon habitats as a priority for the region. During 2014, the CMA commissioned Deakin University to conduct a blue carbon stock assessment across the region.

The study found that the majority of the region's blue carbon stock comprises mostly saltmarsh (62%) and seagrass (37%), and mangroves contributing <1%. Estuaries in particular were found to have higher carbon stocks than other coastal environments.

The Curdies River estuary has been identified as an area with potential blue carbon habitat areas worthy of further research for carbon sequestration purposes. The CMA, in conjunction with Deakin University, has sponsored a PhD research into the effectiveness of blue carbon habitats in Corangamite and potential carbon sequestration opportunities. Knowledge and opportunities in this area will continue to evolve and should be considered in the overall management of the Curdies River estuary.

Reference:

Corangamite CMA (2016) *Corangamite Natural Resource Management Plan for Climate Change*. Corangamite Catchment Management Authority, Colac, Victoria.

Extensive areas of saltmarsh habitat exist at the Curdies estuary



Appendix 4:

Bird species of conservation significance

The following table identifies bird species occurring at the Curdies River estuary that have conservation significance under either, or both, of the *Victorian Flora and Fauna Guarantee Act 1988* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.

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Table 4. Bird species of conservation significance at state (*FFG Act 1988*) and/or federal (*EPBC Act 1999*) level (DELWP 2016)

Scientific name	Common name	FFG	EPBC
Passerine Birds			
<i>Dasyornis broadbenti</i>	Rufous Bristlebird	L	
<i>Dasyornis broadbenti caryochrous</i>	Rufous Bristlebird (Otway)	L	
Wader Birds			
<i>Limosa lapponica</i>	Bar-tailed Godwit		VU
<i>Thinornis rubricollis rubricollis</i>	Hooded Plover	L	VU
<i>Charadrius leschenaultii</i>	Greater Sand Plover		VU
<i>Sternula albifrons sinensis</i>	Little Tern	L	
<i>Sternula nereis nereis</i>	Fairy Tern	L	VU
<i>Hydroprogne caspia</i>	Caspian Tern	L	
<i>Calidris ferruginea</i>	Curlew Sandpiper		CR
<i>Tringa brevipes</i>	Grey-tailed Tattler	L	
<i>Numenius madagascariensis</i>	Eastern Curlew		CR
<i>Calidris tenuirostris</i>	Great Knot	L	CR

L = Listed
VU = Vulnerable
EN = Endangered
CR = Critically Endangered
EX = Extinct

Table 4. Bird species of conservation significance at state (*FFG Act 1988*) and/or federal (*EPBC Act 1999*) level (DELWP 2016) (continued)

Scientific name	Common name	FFG	EPBC
Non-Passerine Birds			
<i>Egretta garzetta nigripes</i>	Little Egret	L	
<i>Ardea modesta</i>	Eastern Great Egret	L	
<i>Ardea intermedia</i>	Intermediate Egret	L	
<i>Botaurus poiciloptilus</i>	Australasian Bittern	L	EN
<i>Grus rubicunda</i>	Brolga	L	
<i>Haliaeetus leucogaster</i>	White-bellied Sea-Eagle	L	
<i>Neophema chrysogaster</i>	Orange-bellied Parrot	L	CR
<i>Anseranas semipalmata</i>	Maggie Goose	L	
<i>Lewinia pectoralis pectoralis</i>	Lewin's Rail	L	
<i>Accipiter novaehollandiae novaehollandiae</i>	Grey Goshawk	L	
<i>Stictonetta naevosa</i>	Freckled Duck	L	
Marine Birds			
<i>Thalassarche melanophris melanophris</i>	Black-browed Albatross		VU
<i>Thalassarche cauta</i>	Shy Albatross	L	VU
<i>Halobaena caerulea</i>	Blue Petrel		VU

L = Listed
VU = Vulnerable
EN = Endangered
CR = Critically Endangered
EX = Extinct



Appendix 5: Flora species of conservation significance

The following table provides a list of the threatened flora species occurring at the Curdies River estuary, including those have conservation significance under the *Victorian Flora and Fauna Guarantee Act 1988* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.

This information has been extracted from the Victorian Biodiversity Atlas (DELWP 2016). It is possible that the data may omit some species, such as the Curly Sedge (*Carex tasmanica*) that was identified at the Curdies River estuary by Osler & Cook (2010).

Table 5. Threatened flora species at the Curdies River estuary (DELWP 2016)

Scientific name	Common name	Victorian Advisory List	FFG	EPBC
<i>Lachnagrostis rudis subsp. rudis</i>	Rough Blown-grass	Rare		
<i>Baumea laxa</i>	Lax Twig-sedge	Rare		
<i>Cladium procerum</i>	Leafy Twig-sedge	Rare		
<i>Exocarpos syrticola</i>	Coast Ballart	Rare		
<i>Haloragis exalata var. exalata</i>	Square Raspwort	Vulnerable		VU
<i>Lawrencia spicata</i>	Salt Lawrencia	Rare		
<i>Lobelia beaugleholei</i>	Showy Lobelia	Rare		
<i>Monotoca glauca</i>	Currant-wood	Rare		
<i>Pterostylis tenuissima</i>	Swamp Greenhood	Vulnerable		VU
<i>Pterostylis lustra</i>	Small Sickie Greenhood	Endangered	L	
<i>Eucalyptus ovata subsp. grandiflora</i>	West-coast Swamp-gum	Rare		

L = Listed
VU = Vulnerable
EN = Endangered
CR = Critically Endangered
EX = Extinct

Appendix 6: History of artificial openings

The Curdies River naturally opens and closes in response to prevailing conditions such as freshwater inflows, weather changes or tidal movements. Periodically a sand bar forms at the mouth of the Curdies River causing water to be trapped. When the estuary mouth is closed and water levels rise, there is a threat of flooding and potential damage to infrastructure such as roads and agricultural land.

For generations, local landholders would manually open the estuary mouth to prevent estuarine water inundating agricultural land and impacting built infrastructure.

In 2001 the responsibility for authorising works on waterways at the Curdies River estuary was vested with the Corangamite CMA. A permit to manage the opening of the Curdies River mouth has since been issued to Parks Victoria, who use an excavator to open the estuary at certain times of the year.

The built infrastructure at Peterborough is the main determinant in managing artificial estuary openings and the current trigger for an opening is 1.3mAHD on a gauge board at the Great Ocean Road bridge.

In 2013 the release of the Victorian Waterway Management Strategy required waterway managers to develop a Memorandum of Understanding (MoU) to identify the roles and responsibilities and the process for artificial estuary openings. Work is currently underway to prepare a MoU for the Curdies River estuary.

Sea water mixes with estuarine waters following an artificial opening at the Curdies estuary





Cover: Great Ocean Road
bridge, Curdies River Estuary