Curdies Estuary Management Plan

September 2008

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

in association with

DEAKIN UNIVERSITY

LA TROBE UNIVERSITY

Curdies Estuary Management Plan

Moyne Shire
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It is the responsibility of the reader to verify the currency of revision of this report.

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Abbreviations used in this Plan

CCMA	Corangamite Catchment Management Authority
CSC	Corangamite Shire Council
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EEMSS	Estuary Entrance Management Support System
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation Act
ESO	Environmental Significance Overlay
EVC	Ecological Vegetation Classes
FFG	Flora and Fauna Guarantee Act
GHCMA	Glenelg Hopkins Catchment Management Authority
LSO	Landscape Significance Overlay
MSC	Moyne Shire Council
NHT	National Heritage Trust
SEPP	State Environment Protection Policy
TVF	Threatened Vertebrate Fauna
VROT	Vulnerable, Rare or Threatened (species)

1 BACKGROUND TO THE MANAGEMENT PLAN

The Curdies River Estuary Management Plan was developed for Moyne Shire by Water Technology, Deakin University (Warrnambool) and Latrobe University in conjunction with consultation with the community and support from a wide range of government agencies (Parks Victoria, DSE, Fisheries, DPI, and Corangamite CMA).

Guiding principles for estuary management in this region are defined by the South West Estuaries Coastal Action Plan. It is proposed that these principles be adopted (with minor revision) to underpin this management plan:

- The present generations have a basic duty of care to ensure that the health and diversity of the environment is maintained or enhanced for the benefit of future generations.
- Ecosystems, and the individual life forms and natural processes that underpin them, have by their very nature value in their own right.
- The precautionary principle applies wherein *if* there are threats of serious environmental damage *then* lack of scientific certainty should not be used as a reason to postpone measures to prevent environmental degradation.
- Estuaries are owned by all, including the plants, animals and other organisms that live there.

1.1 Scope of the Plan

The Curdies River estuary is defined as extending from the entrance at Peterborough to the confluence of the Curdies River with A'Becketts Creek, which is the physical extent of the estuarine reach. The scope of the management plan encompasses the catchment area that drains directly into the Curdies River along this reach, or into the tributaries that join the Curdies River below the A'Becketts Creek confluence. A map showing the catchment of the Curdies River estuary is shown in Figure 1.

1.2 Significance

The environmental significance of the Curdies River estuary, and the township of Peterborough at its coastal extent, is described by the Moyne Planning Scheme[1] as follows:

Peterborough is located on the banks of the Curdies River estuary and the start of the spectacular limestone cliffs of the Bay of Islands Coastal Park. The coast around the township contains a range of geomorphological features including cliffs, coastal stacks, headlands and beaches. The Curdies River estuary located to the east of the town is a significant ecosystem and nursery for a range of fish species that provides an important habitat for a variety of birdlife.

A number of geomorphologically and ecologically significant limestone depression wetlands or 'sinkholes' occur within the catchment of the Curdies River estuary. They vary in size and typically can have a diameter in excess of 40 metres with many containing water all year round. Because some of these limestone depressions are located within Peterborough they are

[1] Moyne Planning Scheme: Schedule 2 to the Environmental Significance Overlay (ESO2).

sensitive to the impacts of urban development including pollution from stormwater runoff and disturbance from development activity.

It is important that development does not detrimentally affect these drainage features or further reduce water quality of the Curdies River estuary or impact on the environmental values of the coastal area.

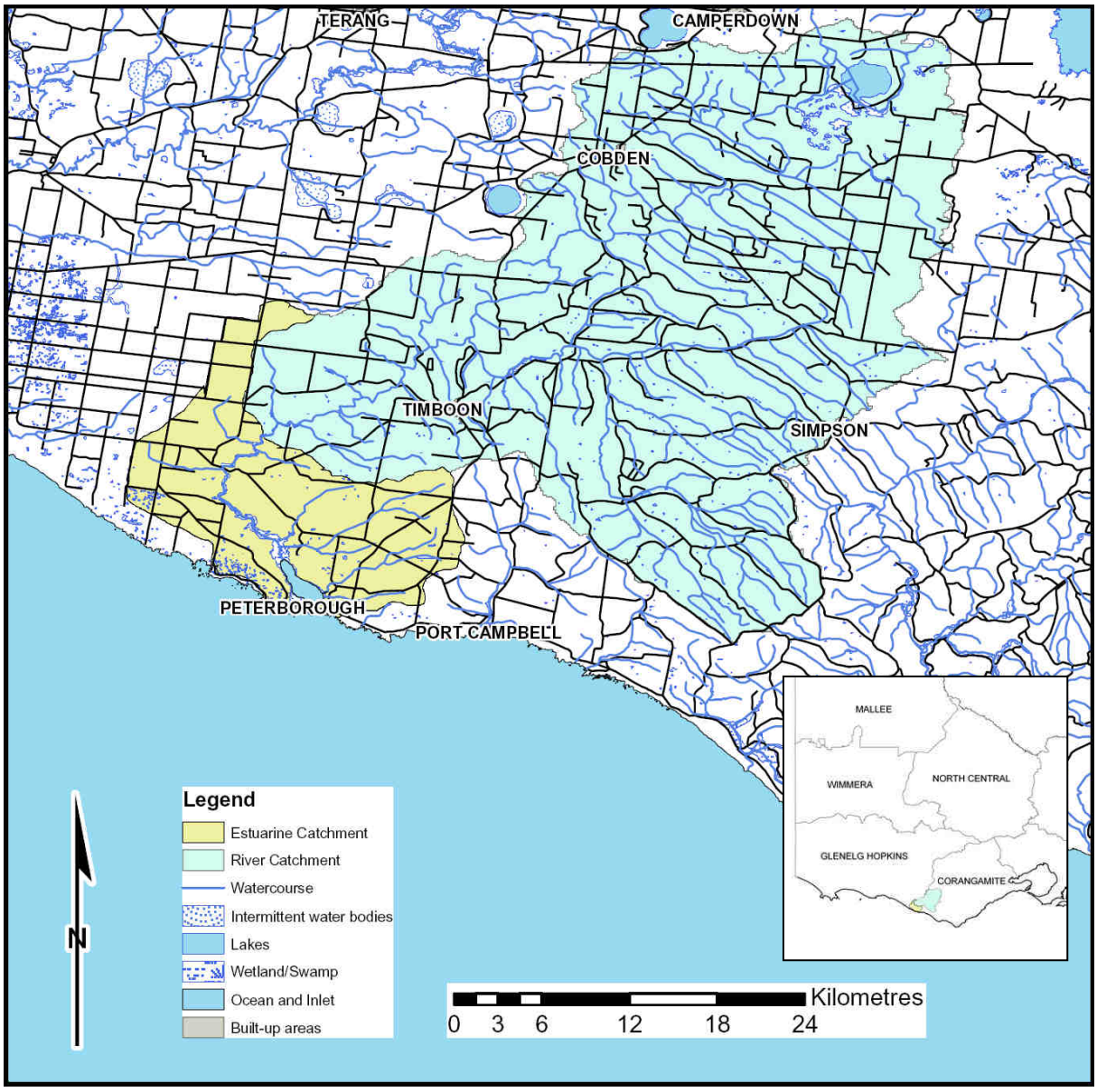

Figure 1. Catchment of the Curdies River estuary. The upstream limit of the estuary is at the boundary of the estuarine and river catchments. Inset shows location of the catchment in relation to CMA areas.

1.3 Purpose

The purpose of this management plan is to describe a vision for the Curdies River estuary and to define the detailed strategies that should be undertaken over the next 5 years so as to move toward achieving that vision. It is anticipated that a mid-term progress review will be

undertaken in 2010 by a panel of representatives from each of the agencies responsible for completing works (as specified by the plan). The plan will be due for revision in 2012.

The scope of the plan includes identifying key assets of the Curdies estuary and specific actions required to protect and enhance those assets. The actions provide general rather than detailed direction for implementation. However, clear targets are set so implementation of each action can be evaluated.

1.4 Development of the Plan

The Curdies River Estuary Management Plan was developed following consultation with members of the steering committee, representatives of relevant government agencies and community groups or individuals with an interest in the Curdies River estuary.

The Project Steering committee comprised[2]:

Kath Gosden	Moyne Shire Council (Chairperson)
Russell Guest	Moyne Shire Council
Lyall Bond	Corangamite Shire Council
Steve Blackley	Western Coastal Board
Andrew Standish	Department of Primary Industry
Gene Gardiner	Corangamite CMA
Steve McDougall	Department of Sustainability and Environment
Ross Martin	Department of Sustainability and Environment
Alex Green	Parks Victoria

The management plan was developed in three stages:

1. Development of an Estuary Overview Report.
2. Community consultation via a workshop.
3. Management Plan Preparation and Review.

[2] **Note:** At the time this project was undertaken Moyne Shire were in the process of taking applications from the three registered local indigenous groups. Consequently there was no indigenous community member available for active consultation (although all members of the Curdies community were invited to attend the community consultation workshop). Hence, Moyne Shire undertook to ensure that appropriate consultation with the indigenous community takes place prior to the implementation of the Final Curdies River Estuary Management Plan (K. Gosden pers. comm., 26 June 2007).

1.4.1 Estuary Overview Report

The Estuary Overview Report collated existing information to provide a comprehensive but focussed description of estuarine values and the potential threats to those values. In recent years, agency staff and members of the Curdies River community have provided input into the Estuary Entrance Management Support System (EEMSS, 2006) and a risk assessment process investigating nutrient enrichment in the Curdies River catchment (DPI, 2005). The values of the Curdies River estuary established therein were used as a basis for developing objectives for the estuary. The Steering Committee provided initial guidance to existing documents relevant to the management plan.

1.4.2 Community consultation

Following production of the overview report a community workshop was held at the Schomberg Hotel, Peterborough on August 23, 2007. A wide range of community representatives, members of the steering committee and the project team attended the workshop (as listed in Table A).

Table A. Workshop Attendees

Community / Agency Attendees		Affiliation
Ron	Irvine	Lower Curdies River Landcare Group
Annie	Fraser	Wildlife shelter owner & resident
Steve	Fogarty	Minerva Gas Plant
Richard	Stevens	SW Bird Observers Club
Jenny	Stevens	SW Bird Observers Club
Rebecka	McCann	Heytesbury District Landcare Network
Dean	Drayton	Curdies Landcare
Steve	Cumming	Councillor CSC
Bruce	Couch	Councillor MSC
Lorna	Couch	Peterborough resident
Steve	McDougall	DSE
Heath	Cameron	DPI
Jim	Giblin	Curdies Angling Club
Gene	Gardiner	CCMA
Project Team		
Adam	Pope	Deakin University
Helen	Arundel	Deakin University
Brett	Anderson	Water Technology
Geoff	Brown	Tangent Consulting (Facilitator)

1.4.3 Workshop structure

The following steps were undertaken during the workshop to identify and prioritise management actions:

1. *Review Estuary Overview Report*
   The report was presented and any gaps in the values and/or threats included in the report identified.
2. *Create Action List*
   Existing strategies and documents were reviewed prior to the workshop to identify actions relevant to achieving the stated objectives. Workshop participants reviewed the action lists and added any other relevant actions.
3. *Prioritise Actions*
   Five criteria were used to score each action (Table B). Priorities were assigned according to the total scores (Table C).
4. *Develop Targets*
   For each action that scored **high** or **very high** on the prioritisation scale, a target was included. These targets addressed the question:'How do we measure success'. Targets were designed to specify an appropriate way to measure successful completion of each action and a timeline for doing so.

1.4.4 Method for prioritising actions

Actions were prioritised following an approach developed and commonly employed by Melbourne Water (2004). The approach requires scores to be assigned to 5 independent factors: the level of public concern/support (for a given action); opportunity to implement the action (i.e. is it possible); whether the action provides multiple benefits; what the return on investment is likely to be; and how strongly the action supports the overall objective. The generic scoring strategy is described in Table B. The level of priority given to different total scores for the Curdies Estuary is presented in Table C.

1.4.5 Input from the Steering Committee

Following the community consultation workshop the project team reviewed the action lists and targets established in the workshop. These were compiled into a master list and actions with similar goals were combined to condense the final list of recommendations. The project team also identified the lead agencies and partner organisations that will be responsible for implementing each action.

This prioritised list of actions forms the basis of the management plan recommended for the Curdies River. It was submitted in draft form for review by the project steering committee prior to final acceptance by Moyne Shire. Subsequent to this the stakeholders responsible for implementing the actions will need to ratify the plan. Note that ratification and implementation will be a separate process to the development of the plan itself.

Table B. Scoring criteria for prioritisation of actions.
(Source: modified from Melbourne Water (2004))

Score	Criteria
1. Public concern/support	
3	Public/political outrage if action not a high priority and/or public highly supportive of action
2	Public/political concern if action not a high priority and/or some public support
1	No major outrage or concern if action not a high priority and/or no public support
2. Opportunity	
3	Little difficultly to implement action e.g. technology available, feasible etc
2	Moderately difficult to implement action, but not impossible
1	Difficult to implement action or almost impossible to implement action
3. Multiple benefits	
3	Action improves multiple values or addresses multiple threats
1	Action does not improve multiple values or address multiple threats
4. Return on investment	
1	Low return on investment (IOB)
2	Medium return on investment (IOB)
3	High return on investment (IOB)
5. Link to Objective	
15	Direct link to criteria for significance of sub-management unit, i.e. social, economic or environmental
10	Indirect link to criteria for significance of sub-management unit, i.e. social, economic and environmental
1	No link to criteria for significance of sub management unit, i.e. social, economic and environmental

Table C. Priority level associated with total scores
for the Curdies River Estuary.

Level of priority	Total Score
Very high priority	>25
High priority	25
Moderate	21-24
Low	<21

1.5 Implementation

The formal adoption of this management plan will occur following submission of the final Curdies River Estuary Management Plan by Moyne Shire to council for sign off. Implementation of the plan will then require each of the various responsible government agencies to formally adopt the plan. Indeed, the first recommendation of the management plan relates to establishing a formal adoption process. The recommendation is as follows:

Objective: To pursue formal adoption of the Curdies River Management Plan by all stakeholders to ensure effective, accountable and timely implementation of the plan.

Code	Recommended Action	Priority
I1.1	Establish an Implementation Committee to co-ordinate works across multiple agencies and groups	VH

2 RECOMMENDED OBJECTIVES AND ACTIONS

The proposed Management Plan for the Curdies River Estuary was developed around achieving objectives that address key issues associated with managing the estuary. These issues and objectives are listed in Table 1.

Each of the issues is described in detail in subsequent sections of this report. A series of possible actions have been proposed in order to achieve each objective. These actions were prioritised at the community workshop and are presented in this section as the recommended plan for managing the estuary.

The recommended actions are presented as follows:

- Section 2.1 Highest Priority Actions
- Section 2.2 High Priority Actions
- Section 2.3 All Management Actions – Grouped by Objective

Table 1
Key list of issues and objectives for the Curdies River Estuary

Issue	ID	Objective
Implementation	I	Ensure effective, accountable and timely implementation of this management plan
Hydrology	H	Maintain and enhance estuarine condition through management of flow. Ensure there is an environmental flow down the river
Estuary Mouth	EM	Maintain an entrance regime which considers the environmental and socioeconomic values of the estuary.
Climate Change	CC	Increase understanding, awareness of and preparedness for potential impacts of climate change
Water Quality	WQ	1) Develop appropriate management targets
		2) Understand how Curdies estuary works and how to improve its condition
		3) Reduce nutrient inputs, improve water quality and reduce risks of algal blooms
Vegetation	V	Protect and enhance the extent and condition of EVCs associated with the estuary
Fauna	F	Protect and enhance the biodiversity of native fauna
Pest Plants & Animals	PPA	Reduce the extent and/or number and prevent the introduction of pest plant and animal species
Recreation	R	1) Protect and enhance recreational opportunities of the Curdies Estuary without diminishing environmental values
		2) Provide opportunities for water-based activities such as fishing and swimming

2.1 Highest Priority Actions

HIGHEST (VH) PRIORITY ACTIONS				
Objective	**Actions**	**Agency**	**Success measure**	**Comment**
I1.1	Establish an Implementation Committee to co-ordinate works across multiple agencies and groups	CCMA	Establish Implementation Committee by early 2008	Widespread support for this action at the workshop
H1.1	Determine the environmental flow needs of the estuary	CCMA (DSE)	Process for assessing the level of flow study required for catchment or estuary completed by end 2008. If required, commissioned in 2009.	High cost but a necessary prerequisite to determining an appropriate flow allocation.
H1.2	Ensure flow needs of the estuary are explicitly addressed in allocation of surface and ground water resources. Ensure environmental flows are implemented.	DSE (CCMA)	Have a bulk water entitlement for the environment by 2012	Low cost but difficult. Key factors to monitor may include lake exposure, winter water levels and salinity.
EM1.2	Use EEMSS to revise the entrance management protocols for the Curdies estuary	Parks Vic (CCMA, GHCMA)	EEMSS entrance management protocols developed and formally adopted for Curdies Estuary	
CC1.1	Develop fine scale bathymetric and topographic maps of the estuary and surrounds	CCMA (DSE)	Maps are available by July 2009 and regular repeat survey planned.	Required for H1.1 to be completed.
CC1.8	Provide updates to describe likely climate change impacts and the implications for the Curdies. This could be in the form of an information leaflet or community seminar.	CCMA (DSE)	Leaflet produced and distributed.	

HIGHEST (VH) PRIORITY ACTIONS

Objective	Actions	Agency	Success measure	Comment
WQ2.2	Conduct baseline monitoring of the condition of the estuary particularly aquatic and riparian vegetation and sediment quality. Report baseline results.	CCMA	Baseline report delivered by mid 2009	Strong support. Could investigate possibility to include Curdies monitoring in a course at Deakin University
WQ2.4	Investigate the effects of changes in sediment load and flow on levels of estuarine sedimentation and depth	CCMA	Knowledge available for use in flow and estuary management by 2011	Deep core being analysed at Adelaide University (P. Gell)
WQ3.1	Implement a nutrient reduction program and quantify sources of nutrients, causes and effects of algal blooms	CCMA (DPI)	Reduced frequency of toxic algal blooms and decrease in nutrient loads (as per DPI 2005) Decrease in nutrient loads	Relates also to WQ2.1
WQ3.3	Implement Corangamite and Moyne Stormwater Management Plans	MSC, CSC	Implemented by recommended times	
V1.9	Provide ongoing information and education opportunities to land managers and land owners on vegetation communities, threats, rare & threatened species and their management options	CCMA (Landcare DSE, DPI)	Community engagement plan developed by 2009	A variety of methods should be employed e.g. information and education events, field days, Factsheets, posters, workshops etc. Evaluation of effectiveness of consultation method should be included in all programs.
PPA1.2	Provide ongoing information and education opportunities to land managers and land owners on pest plant and animal control measures	DPI	Education programs established by mid 2008	Evaluation of programs essential

HIGHEST (VH) PRIORITY ACTIONS				
Objective	**Actions**	**Agency**	**Success measure**	**Comment**
R2.1	Undertake regular water quality monitoring and report against the standards for primary contact. This should include development of a risk management plan for blue-green algal blooms as per DSE Blue/green Algae Circular 2007/08	CCMA	Water quality monitoring program in place by 2008	

2.2 High Priority Actions

HIGH PRIORITY ACTIONS				
Objective	**Actions**	**Agency**	**Success measure**	**Comment**
EM1.1	Establish a program such as Estuary Watch to monitor water level and entrance status	CCMA (PV)	Visual monitoring done consistently Program commenced in 2008.	
CC1.7	Prepare a mitigation and adaptation strategy to identify and address the following potential impacts specific to Curdies estuary: • Decreased rainfall but increased evaporation. • More frequent extreme rainfall events. • Sea level rise increasing berm height at entrance. • Increased storm wind strength, incident wave energy and coastal erosion potential.	DSE, CCMA (MSC, CSC)	Strategy written and document available to the public.	Results of DSE coastal mapping program are required prior to development of strategy.
WQ2.3	Investigate the effects of changes in water quality and flow (special circumstances/ events based) on flora and fauna.	CCMA	Information available for review of management plan in 2012	In part information required for this action would be provide by an Environmental Flow study (Obj. H1.1)
WQ2.5	Install logging nutrient and sediment/turbidity meters upstream of the estuary in combination with broader monitoring program	CCMA	Meters operational and reliable by 2008	

HIGH PRIORITY ACTIONS

Objective	Actions	Agency	Success measure	Comment
WQ3.2	Develop integrated and flexible management of flow, mouth openings and eutrophic conditions	CCMA, PV, DSE	Flow allocation and entrance management which includes consideration of nutrient effects	Linked to Hydrological and Entrance Management objectives
V1.1	Map the extent of EVCs (instream, emergent and terrestrial) at a scale of not less than 1:10 000	CCMA (DSE)	Map & GIS layer developed.	Monitor change over time (ground truthing required)
V1.2	Assess the condition of each EVC	CCMA (DSE)	Condition assessment undertaken by 2009.	Investigate use of 'Rapid site assessment' method (Tim D'ombrain)
V1.4	Implement management strategies to protect rare and threatened species identified in mapping	CCMA (MSC, CSC DSE, PV)	Actions ongoing.	Specific actions will depend on species and location but could include: photo points, km/ha protect or enhanced, km fencing, trees planted.
V1.6	Implement management strategies to protect EVCs. Ensure management strategies are appropriate for the EVC and location on estuary (see also F1.8)	CCMA (MSC, CSC, PV)	Actions ongoing.	Specific actions will depend on species and location but could include: photo points, km/ha protect or enhanced, km fencing, trees planted
V1.10	Implement Environmental Significance Overlay for Moyne planning scheme to protect the values of the Curdies Estuary/ Inlet	MSC	Overlays in planning schemes by 2012	see also F1.11
F1.5	Encourage participation of community groups such as bird observers and local conservation groups in wildlife surveys	CCMA (Landcare)	Program developed by 2010 and ongoing	Program could be component of F1.1.&F1.4. Also see F11 Friends of the Curdies

HIGH PRIORITY ACTIONS				
Objective	**Actions**	**Agency**	**Success measure**	**Comment**
F1.10	Undertake an ongoing pest animal and weed control program (See PPA 1.3 (note different score for each objective)).	CCMA (DPI, Parks Vic)	implementation/ weed survey by 2010 co-ordinate between DPI CCMA & Landcare	
F1.11	Implement Environmental Significance Overlay for Moyne planning scheme to protect the values of the Curdies Estuary/ Inlet	MSC	Overlays in planning schemes by 2012	see also V1.10
F1.12 V1.8 PPA 1.4	Establish a 'Friends Group' of the Curdies Inlet and Lower Curdies Landcare group	CCMA	Establishment of group by 2010. Reference group meetings held. Links to existing groups made.	Also applies to pest plants & animals 'Friends of Bay of Islands' already exists
PPA1.1	Map and monitor occurrence of noxious and environmental weeds and pest animals within the area using methods that are not detrimental to the environment	CCMA (DPI, Parks Vic)	Monitoring program established by mid 2008. Should include mapping weeds	Monitoring and on ground programs. The following species need attention: rabbits, coastal wattle and foxes.

HIGH PRIORITY ACTIONS				
Objective	**Actions**	**Agency**	**Success measure**	**Comment**
R1.1	Develop a master plan for the area on the west bank south of the Great Ocean Road bridge. The plan should indicate how to enhance coastal dependent recreational opportunities while also protecting and enhancing environmental values.	MSC	Master Plan to be completed in 2008.	Plan should include: • protection of ephemeral water bodies; • weed removal; • delineating and protecting native vegetation; • identifying recreational needs and siting of any infrastructure identified as required. Plan should also include how this area links to walking trails and/or boardwalk if this is still considered to be necessary once recreational needs are identified.
R2.2	Maintain boat ramp facilities to ensure safe and efficient access to estuary	MSC	Boat ramp monitoring and maintenance program in place by 2008	

2.3 All Management Actions - grouped by objective

Objective	Actions	Agency	Priority	Success measure	Comment
I1.1	Establish an Implementation Committee to co-ordinate works across multiple agencies and groups	CCMA	VH	Establish Implementation Committee by early 2008	Widespread support for this action at the workshop
H1.1	Determine the environmental flow needs of the estuary	CCMA (DSE)	VH	Process for assessing the level of flow study required for catchment or estuary completed by end 2008. If required, commissioned in 2009.	High cost but a necessary prerequisite to get flow allocation
H1.2	Ensure flow needs of the estuary are explicitly addressed in allocation of surface and ground water resources. Ensure environmental flows are implemented.	DSE (CCMA)	VH	Have a bulk water entitlement for the environment by 2012.	Low cost but difficult. Key factors to monitor may include lake exposure, winter water levels and salinity.
H1.3	Investigate increasing importance of irrigation dams and development in water budgets	CCMA (DSE)	L	Study report available	This could be efficiently achieved in conjunction with REALM study required as part of environmental flow assessment (see H1.1) as a small extension to the standard modelling required.
EM1.1	Establish a program (such as EstuaryWatch) to monitor water level and entrance status	CCMA (PV)	H	Visual monitoring done consistently Program commenced in 2008.	

Objective	Actions	Agency	Priority	Success measure	Comment
EM1.2	Use EEMSS to revise the entrance management protocols for the Curdies estuary	Parks Vic (CCMA, GHCMA)	VH	EEMSS entrance management protocols developed and formally adopted for Curdies Estuary	
EM1.3	Investigate the cost and feasibility of installing a continuous water level recorder	Parks Vic	M	Business case developed for installing water level recorder.	
EM1.4	Investigate the potential benefits of and means to reinstate the original entrance configuration as a result of building new GOR bridge (especially losses to the blue hole and direct flush	CCMA	M	Study commissioned	
CC1.1	Develop fine scale bathymetric and topographic maps of the estuary and surrounds	CCMA (DSE)	VH	Maps are available and regular repeat survey planned.	Required for H1.1 to be completed.
CC1.2	Monitor berm elevation with respect to a local benchmark surveyed to the Australian Height Datum	CCMA	L	Monitoring occurring. Gauge board installed by mid-2008.	
CC1.3	Monitor rate of retreat of rocky headlands and diminution of protective islands by setting up photopoints	CCMA	M	Photopoint established by mid-2008.	Program should include collection of historical pictures and storage and management of photos. new and recent photos.

Objective	Actions	Agency	Priority	Success measure	Comment
CC1.4	Monitor the lateral extent of the beach and condition of the coastal barrier dunes with particular focus on the geometry of the spit to Schomberg rock	CCMA	L	Protocol in place to make continuing measures from 2012.	
CC1.5	Monitor fencing (on inland side of dunes) and revegetation works to ensure continued stability of coastal barrier dunes	CCMA	L	Fencing in good condition. Vegetation cover healthy and of a similar extent.	
CC1.6	Planning policy to identify buffer area around the estuary which allows for migration of plant species and protection of infrastructure	MSC, CSC (DSE)	M	Current planning policy reviewed. Buffer zones declared.	
CC1.7	Prepare a mitigation and adaptation strategy to identify and address the following potential impacts specific to Curdies estuary:- • Decreased rainfall but increased evaporation • More frequent extreme rainfall events • Sea level rise increasing berm height at entrance. • Increased storm wind stength, incident wave energy and coastal erosion potential.	DSE, CCMA (MSC, CSC)	H	Strategy written and document available to the public.	Monitoring of the estuary would be required prior to development of the strategy.

Objective	Actions	Agency	Priority	Success measure	Comment
CC1.8	Provide updates to describe likely climate change impacts and the implications for the Curdies. This could be in the form of an information leaflet or community seminar.	CCMA (DSE)	VH	Leaflet produced and distributed.	
WQ1.1	Endorse/review management targets specified in River Health Strategy and nutrient risk assessment, recognising that high levels of nutrients will remain in sediments for years to come	CCMA	M	Targets for nutrient management in Curdies estuary reviewed and endorsed by end 2008	
WQ2.1	Develop water quality monitoring program to measure the effectiveness of management actions and identify any new threats and report monitoring results.	CCMA	M	Program in place by end 2008	
WQ2.2	Conduct baseline monitoring of the condition of the estuary particularly aquatic and riparian vegetation and sediment quality. Report monitoring results	CCMA	VH	Documented by mid 2009	Strong support. Could investigate possibilities of inclusion of Curdies monitoring in course at Deakin
WQ2.3	Investigate the effects of changes in water quality and flow (special circumstances/ events based) on flora and fauna.	CCMA	H	Information available for review of management plan in 2012	
WQ2.4	Investigate the effects of changes in sediment load and flow on levels of estuarine sedimentation and depth	CCMA	VH	Knowledge available for use in flow and estuary management by 2011	Linked to climate change and hydrology objectives

Objective	Actions	Agency	Priority	Success measure	Comment
WQ2.5	Install logging nutrient and sediment/turbidity meters upstream of the estuary in combination with broader monitoring program	CCMA	H	Meters operational and reliable by end 2008	
WQ3.1	Implement a nutrient reduction program and quantify sources of nutrients, causes and effects of algal blooms	CCMA (DPI)	VH	Frequency of toxic algal blooms (as per DPI 2005) Decrease in nutrient loads (as per DPI, 2005)	Also relates to WQ2.1
WQ3.2	Develop integrated and flexible management of flow, mouth openings and eutrophic conditions	CCMA, DSE	H	Flow allocation and entrance management which includes consideration of nutrient effects	Linked to Hydrological and Entrance Management objectives
WQ3.3	Implement Corangamite and Moyne Stormwater Management Plans	MSC, CSC	VH	Implemented by recommended times	
WQ3.4	Investigate options for active remediation of sediments including dredging and containment	CCMA	L	Cost-benefit assessment completed	May follow from WQ 3.1
V1.1	Map the extent of EVCs (instream, emergent and terrestrial) at a scale of not less than 1:10,000	CCMA (DSE)	H	Map & GIS layer developed.	Monitor change over time (ground truthing required)
V1.2	Assess the condition of each EVC	CCMA (DSE)	H	Condition assessment undertaken by 2009.	Investigate use of 'Rapid site assessment' method (Tim D'ombrain)
V1.3	Identify and map any rare or threatened species of flora	DSE (CCMA)	M	Sites identified & mapped by 2009.	Size & condition of populations should be noted in mapping.

Objective	Actions	Agency	Priority	Success measure	Comment
V1.4	Implement management strategies to protect rare and threatened species identified in mapping	CCMA (MSC, CSC DSE, PV)	H	Actions ongoing. Specific actions will depend on species and location but could include: photo points, km/ha protect or enhanced, km fencing, trees planted.	Depends on how land managers approach! Depends on species and info available and how good mapping is. High return on investment only if implemented properly (criterion 4). Same applies for multiple benefits
V1.5	Investigate opportunities to protect extent and condition of EVCs ensuring ongoing maintenance.	CCMA (MSC, CSC, DSE, PV, Landholders)	M	Programs investigated and appropriate programs selected and underway by 2009.	Projects could include fencing and stewardship programs such as bush tender
V1.6	Implement management strategies to protect EVCs. Ensure management strategies are appropriate for the EVC and location on estuary (see also F1.8)	CCMA (MSC, CSC, PV, Landholders)	H	Actions ongoing. Specific actions will depend on species and location but could include: photo points, km/ha protect or enhanced, km fencing, trees planted	
V1.7	Encourage research into environmental requirements and management of EVCs	CCMA	L	Relevant research projects developed and included in RCIP (or other funding programs) by 2010	Potential subjects include: impact of inundation regimes, die back of estuarine wetland.
V1.8	See F1.12	CCMA	H	Establishment of 'Friends Group by 2010,	'Friends of Bay of Islands' already exists

Objective	Actions	Agency	Priority	Success measure	Comment
V1.9	Provide ongoing information and education opportunities to land managers and land owners on vegetation communities, threats, rare & threatened species and their management options	CCMA (Landcare DSE, DPI)	VH	Community engagement plan developed by 2009	A variety of methods should be employed e.g. information and education events, field days, Factsheets, posters, workshops etc. Evaluation of effectiveness of consultation method should be included in all programs.
V1.10	Implement Environmental Significance Overlay for Moyne planning scheme to protect the values of the Curdies Estuary/ Inlet	MSC	H	Overlays in planning schemes by 2012	see also F1.11
V1.11	Revegetation of waterways and catchment with indigenous plant species	CCMA, Landcare, DSE (Landholders)	M	Revegetation program developed in 2008	Advice available at Landcare and CCMA(CCMA)
F1.1	Establish terrestrial and aquatic fauna monitoring program for the study area	CCMA (DSE)	M	Program developed and implemented by 2010	Survey of species other than fish and birds, which are included in separate actions
F1.2	Establish monitoring programs to assess the condition (diversity and health) of native fish populations in the Curdies estuary	DPI (CCMA)	L	Fish survey by 2012 and report submitted	
F1.3	Establish monitoring programs to assess the condition of native fish targeted for recreation (e.g. black bream & estuary perch)	DPI (CCMA)	L	As for F1.2 plus tagging survey	Tagging program currently underway (Victag) Also refer to relevant actions in Draft Corangamite Fishery Management Plan.

Objective	Actions	Agency	Priority	Success measure	Comment
F1.4	Liase with Birds Australia to develop a bird monitoring program	CCMA	M	Program developed and implemented by 2010.	Program could include: diversity of bird species; number of each species time of year; and habitat type utilised (e.g. water depth & veg type). DSE contour depth survey could inform action.
F1.5	Encourage participation of community groups such as bird observers and local conservation groups in wildlife surveys	CCMA (Landcare)	H	Program developed by 2010 and ongoing	Program could be component of F1.1.&F1.4. Also see F11 Friends of the Curdies
F1.6	Support recommended actions in the 'Orange-bellied parrot Action Statement'	DSE CCMA	M	Actions ongoing	
F1.7	Implement Birds Australia guidelines for monitoring and managing beach nesting birds	Parks Vic (DSE)	M	Guidelines implemented as developed and on going	
F1.8	Review needs of habitat management incorporating habitat requirements of threatened species and including an assessment of the need for a burning regime.	DSE (CCMA)	M	Report strategy by 2009	
F1.9	Re-establish, protect and revegetate indigenous habitat species in waterways and catchment	CCMA	M	Area replanted/ ha, Area protected/ ha. Ongoing - yearly target	SEE V1.11
F1.10	Undertake an ongoing pest animal and weed control program (See PPA 1.3 (note different score for each objective)).	CCMA (DPI, Parks Vic)	H	Implementation/ weed survey by 2010 co-ordinate between DPI CCMA & Landcare	

Objective	Actions	Agency	Priority	Success measure	Comment
F1.11	Implement Environmental Significance Overlay for Moyne planning scheme to protect the values of the Curdies Estuary/ Inlet	MSC	H	Overlays in planning schemes by 2012	see also V1.10
F1.12	Establish a friends group of the Curdies Inlet and Lower Curdies Landcare group	CCMA	H	Establishment of group by 2010, reference group - meetings. Links made and maintained	Also an Action for V1 and PPA 1 'Friends of Bay of Islands' already exists
PPA1.1	Map and monitor occurrence of noxious and environmental weeds and pest animals within the area using methods that are not detrimental to the environment	CCMA (DPI, Parks Vic)	H	Monitoring program established by mid 2008. Should include mapping weeds	Monitoring and on ground programs. The following species need attention: rabbits, coastal wattle, foxes.
PPA1.2	Provide ongoing information and education opportunities to land managers and land owners on pest plant and animal control measures	DPI	VH	Education programs established by mid 2008	Evaluation of programs essential
PPA1.3	Implement pest plant and animal control programs, ensure ongoing maintenance and continuation of existing programs and adapt approach and/ or effort as required using methods that are not detrimental to the environment	CCMA (DPI, Parks Vic)	M	Control Program established by 2009	Ongoing evaluation of effectiveness of program essential
PPA1.4	See F1.12	CCMA	H	Establishment of 'Friends Group' by 2010,	'Friends of Bay of Islands' already exists

Objective	Actions	Agency	Priority	Success measure	Comment
R1.1	Develop a master plan for the area on the west bank south of the Great Ocean Road bridge. The plan should indicate how to enhance coastal dependent recreational opportunities while also protecting and enhancing environmental values.	MSC	H	Master Plan to be completed in 2008.	Plan should include: protection of ephemeral water bodies; weed removal; delineating and protecting native vegetation; identifying recreational needs and siting of any infrastructure identified as required. Plan should also include how this area links to walking trails and/or boardwalk if this is still considered to be necessary once recreational needs are identified.
R1.2	License commercial tour operators and use licence fees to maintain reserves and provide interpretation and directional signage.	MSC, CSC	L	No commercial tour operators currently use the Curdies and there are limited opportunities on or around estuary at this stage	
R1.3	Construction of areas along roadsides to allow tourist vehicles and sightseers to pull vehicles off The Great Ocean Road to photograph wetland biota.	VicRoads	L	Area redesigned and constructed by 2010.	Existing pull off area could include platform and improved interpretative signage relevant to the estuary. This action could be included in Masterplan (R1.1) so area integrates with other facilities
R2.1	Undertake regular water quality monitoring and report against the standards for primary contact. This should include development of a risk management plan for blue-green algal blooms as per DSE Blue/green Algae Circular 2007/08	CCMA	VH	Water quality monitoring program in place by 2008	

Objective	Actions	Agency	Priority	Success measure	Comment
R2.2	Maintain boat ramp facilities to ensure safe and efficient access to estuary	MSC	H	Boat ramp monitoring & maintenance program in place by 2008	
R2.3	Monitor recreational use of estuary to allow for adequate provision of services, safety and environmental protection	MSC, CSC	L	Program monitoring recreational use in place by summer 2008/09	
R2.4	Investigate impact of boat use on river banks	CCMA	L	Carry out periodic assessment of bank erosion starting 2008	
R2.5	Liaise with Marine Safety Victoria to review water craft use on the estuary	MSC, CSC, PV	L	Review watercraft use and appropriateness of current zoning and signage on estuary with Marine Safety Vic by end of 2008	

3 MANAGEMENT OF CURDIES RIVER ESTUARY

3.1 Legislative Framework and Policy Setting

Direction for objectives and actions in the Curdies River estuary management plan is provided by a range of state and regional strategies and plans developed under a variety of legislation (see Figure 2). For simplicity only arrows which show the major direction of influence are included in the diagram. However links exist between all state strategies and regional NRM documents.

To ensure alignment of the EMP with other strategic documents, relevant regional strategies and plans were examined and information and actions relevant to the Curdies River estuary identified and incorporated into the Curdies EMP

Two documents are of particular relevance to the Curdies EMP. The South West Estuaries Coastal Action Plan, which provides direction for the content of individual estuary management plans; and the Corangamite River Health Strategy, which identifies both the assets associated with the Curdies River estuary and the threats to those assets.

Relevant legislation and state and regional strategic documents:

Victorian Coastal Strategy (Victorian Coastal Council, 2002) was developed under the Coastal Management Act 1995, and establishes an overall framework for planning and management of the Victorian coast. A revised version of this strategy is due for release in late 2008.

South West Regional Coastal Action Plan (Western Coastal Board, 2002b) provides guidance on implementing the principles and priorities of the VCS at a regional level (From Breamlea to the South Australian Border).

Moyne Shire Coastal Action Plan (Moyne Shire, 2002) provides direction for implementing The VCS and Regional CAP within the Moyne Shire region

South West Estuaries Coastal Action Plan (Western Coastal Board, 2002a) establishes a regional framework for the development of individual estuary management plans

Corangamite Regional Catchment Strategy (Corangamite Catchment Management Authority, 2003) provides long-term direction for management of land, water resources, biodiversity and seascapes in the region.

Corangamite River Health Strategy (CCMA, 2001) identifies the environmental, social and economic assets of rivers in the Corangamite CMA region and threats to those assets.

The Victorian River Health Strategy identifies the environmental, social and economic assets of rivers and threats to those assets. These are subsequently incorporated in each regional RHS such as the Corangamite RHS

Corangamite Native Vegetation Plan (CCMA, 2005) Provides strategic direction for the protection, enhancement and restoration of the regions native vegetation.

The Corangamite Native Vegetation Plan strategically directs future action in the protection, enhancement and restoration of the region's native vegetation.

Corangamite Wetland Strategy 2006-2011 (CCMA, 2006)

The Corangamite Wetland Strategy provides a framework for promotion, protection and enhancement of the region's wetlands.

SEPP (Waters of Victoria) Provides a framework for achieving sustainable uses of surface waters. It identifies water uses and water quality objectives required to protect them.

The risk assessement approach outlined in the SEPP was trialled on the Curdies River (Department of Primary Industries and Department of Sustainability and Environment, 2005). The study examined the risk to the estuary from high levels of nutrient in both surface water and sediment and identified actions required to protect the values of the estuary.

Additional legislation that is of relevance to the Curdies EMP but not included in Figure 2 are:

The Aboriginal Heritage Act (2006) protects cultural heritage sites and objects.

The Environment Protection and Biodiversity Act (1999) is federal legislation that protects wetlands, species and cultural places of national significance; and

The Marine Act (1988) regulates activities on Victorian waterways. It establishes regulations that affect safety such as standards for vessels and operators and speed limits for operation.

The Planning and Environment Act (1987) provides a template (Victorian Planning Provisions) for the construction of consistent planning schemes across the state.

The Crown Land (Reserves) Act (1978) regulates the appointment of committees of management. Committees manage, improve, maintain and control reserves on behalf of the Minister for Planning.

The National Parks Act (1975) provides for creation and management of Victoria's National, State and Marine parks and sanctuaries.

The Wildlife Act (1975) aims to protect and conserve wildlife.

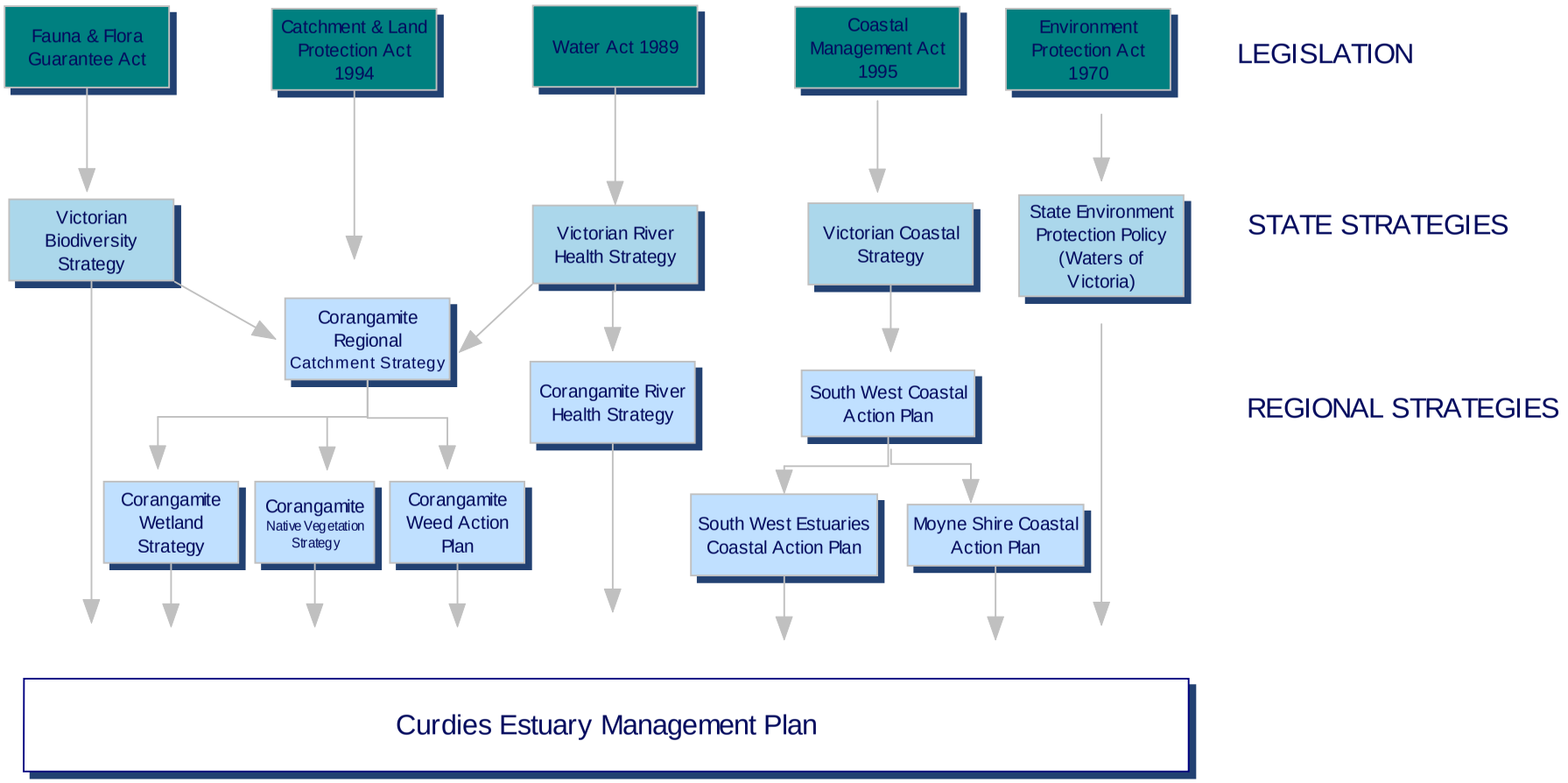

Figure 2. Key legislation and strategies informing the Curdies Estuary Management Plan

3.2 Land Tenure

3.2.1 Roles and responsibilities

The diversity of habitats and land tenure surrounding estuaries typically results in the involvement of many stakeholders undertaking different management roles. This is particularly the case on the Curdies River estuary where effective management of the estuary requires coordination and cooperation of a range of agencies and groups. Details of their roles in estuary management at a state and local level are provided in Table 2.

Table 2.
State and local agency responsibilities. Modified from the South West Estuaries Coastal Action Plan (Western Coastal Board, 2002a)

State Agency	Statewide Responsibility	Local Agency	Local Responsibility
DSE	Strategic direction for park and reserve management; management of all public land except parks and reserves; management of flora and fauna; catchment management and agricultural services	South West	Policy advice for management of forests, Crown Land and public land water frontages. Ensure activities comply with Planning & Environment, Catchment & Land Protection, FFG and EPBC Acts. Referral authority under planning schemes for development on coastal land
DPI	Strategic direction for use and management of fisheries and agricultural land. Issue of fisheries licences	South West	Provides advice to landholders Enforcement of fisheries regulations
Parks Victoria	Service delivery– park and reserve management	Victoria West	Manage 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 licences for activities associated with parks and reserves managed by Parks Victoria (excluding water-based activities).
Victorian Catchment Management Council	Advisory body only – regional catchment management, strategic direction for land and water resource management.	Corangamite and Glenelg-Hopkins Catchment Management Authorities	Development of Regional Catchment Strategies; advice in catchment management; funding for catchment management works to protect restore or rehabilitate catchment (including waterways) condition Assessment of Public Land Water Frontage licences. Development of Streamflow Management Plans. License offstream diversions (stock and domestic), Issues 'works on waterway' permits for erosion and stabilisation works on bed and banks and artificially opening estuary. Referral Authority for developments on floodplain.

Table1. (cont.)
State and local agency responsibilities. Modified from the South West Estuaries Coastal Action Plan (Western Coastal Board, 2002a)

State Agency	Statewide Responsibility	Local Agency	Local Responsibility
Environment Protection Authority	Statutory body, protection, restoration and enhancement of air land and water quality and control of unwanted noise EPA licence sewage and other discharges, water quality monitoring, recommend State Environment Protection Policies for specified segments of the environment (SEPP - Waters of Victoria).		Monitors water quality of the Curdies River estuary.
Regional Water Authority	Service delivery - provide water and sewerage service to urban communities, management of specific water supply catchments	Wannon Water	Referral Authority under Planning Schemes. Manages Peterborough STP (under construction)
Rural Water	Service delivery – provide irrigation, drainage, salinity control, water supply, management of specific water supply catchments	Southern Rural Water	Issues licences for extraction of groundwater
Victorian Coastal Council	Overall strategic planning advice for state coastal planning and management matters. Administers the Victorian Coastal Strategy.	Western Coastal Board.	Provides strategic regional coastal planning and management advice and co-ordinates the preparation of Coastal Action Plans
Local Government	Service delivery - regulate local development through planning schemes, on ground works, manage urban and rural drainage	Corangamite and Moyne, Shire councils	Administers planning schemes and regulates land use and development activities. Corangamite SC is responsible for land use on the East bank and Moyne SC the west bank of the Curdies River estuary.
Committees of Management	CoM have no state wide responsibilities. Members are elected or skills based and appointed by DSE to manage Crown Land under the Crown Land (Reserves) Act 1978.	Curdies River and Recreation Reserve Committee	Manages activities on the estuary and adjacent Crown land reserve
Marine Safety Victoria	Coordinates management of waterway activities. Develops standards for vessels and operators. Funds improvement and development of associated infrastructure.		Enforces regulations re Marine Safety. The Marine Act (1988) establishes boat speeds for inland waters.

3.2.2 Planning framework

Planning maps showing planning zones and relevant overlays can be accessed online via the planning schemes online interface[3]. The western shore of Curdies River marks the boundary between the Corangamite and Moyne Shires as shown by Figure 3. Consequently, the east and western lands that flank the estuary are zoned differently and subject to different overlays.

Land on the eastern (Corangamite) shore is designated a rural conservation zone (RCZ1) inland from the Great Ocean Road bridge to the Narrows (see Figure 3). There are no specific requirements that pertain to the Curdies River listed in the schedule, thus the general rural conservation zone objectives apply. These provide for agricultural land use consistent with the conservation of environmental and landscape values of the area. However, the area designated RCZ1 is also subject to an Environmental Significance Overlay schedule 1 (ESO1 - not visible on Figure 3). The overlay runs the length of the western shore of the Curdies River from the estuary entrance to beyond Curdievale, encompassing the RCZ1 area and extending inland about 100-200 metres. This ESO is designed to protect significant water bodies within Corangamite Shire with environmental objectives including:

- To maintain the biological, physical and chemical quality and quantity of water within the watercourse, water body or wetland.
- To conserve existing wildlife habitats close to natural watercourses and encourage regeneration of riparian and fringing vegetation.
- To minimise the environmental impact on estuarine environments by controls over water releases and sand bar management in line with Southern Rural Water's established protocol (refer to Section 4.3.3).
- To protect and ensure the long term future of fauna and flora habitats in wetland and estuarine areas.

Land further inland from the Narrows on the eastern side, and all the land (excluding Peterborough) on the Moyne side, is designated farming zone (FZ or FZ1). The coastal corridor to the south of the Great Ocean Road is a public conservation and resource zone (PCRZ) managed by Parks Victoria, with the exception of the foreshore region in the immediate vicinity of Peterborough which is a public park and recreational zone (PPRZ) which is the responsibility of Moyne Shire.

Current land tenure maps were produced by DSE. These tenure maps are included as Appendix 4 to this report. The maps indicate that the majority of river frontage along both sides of the estuary are grazing tenures on Crown river frontage. There are six stretches of Crown frontage not currently under licence above the Narrows, and around the 'Lake' only the eastern shore south of lot 97 (or about 1 km north of the Great Ocean Road) is not licenced. The large number water frontage licence holders are key stakeholders in the development and implementation of this management plan.

[3] http://services.land.vic.gov.au/maps/pmo.jsp (last accessed: 7 August 2007)

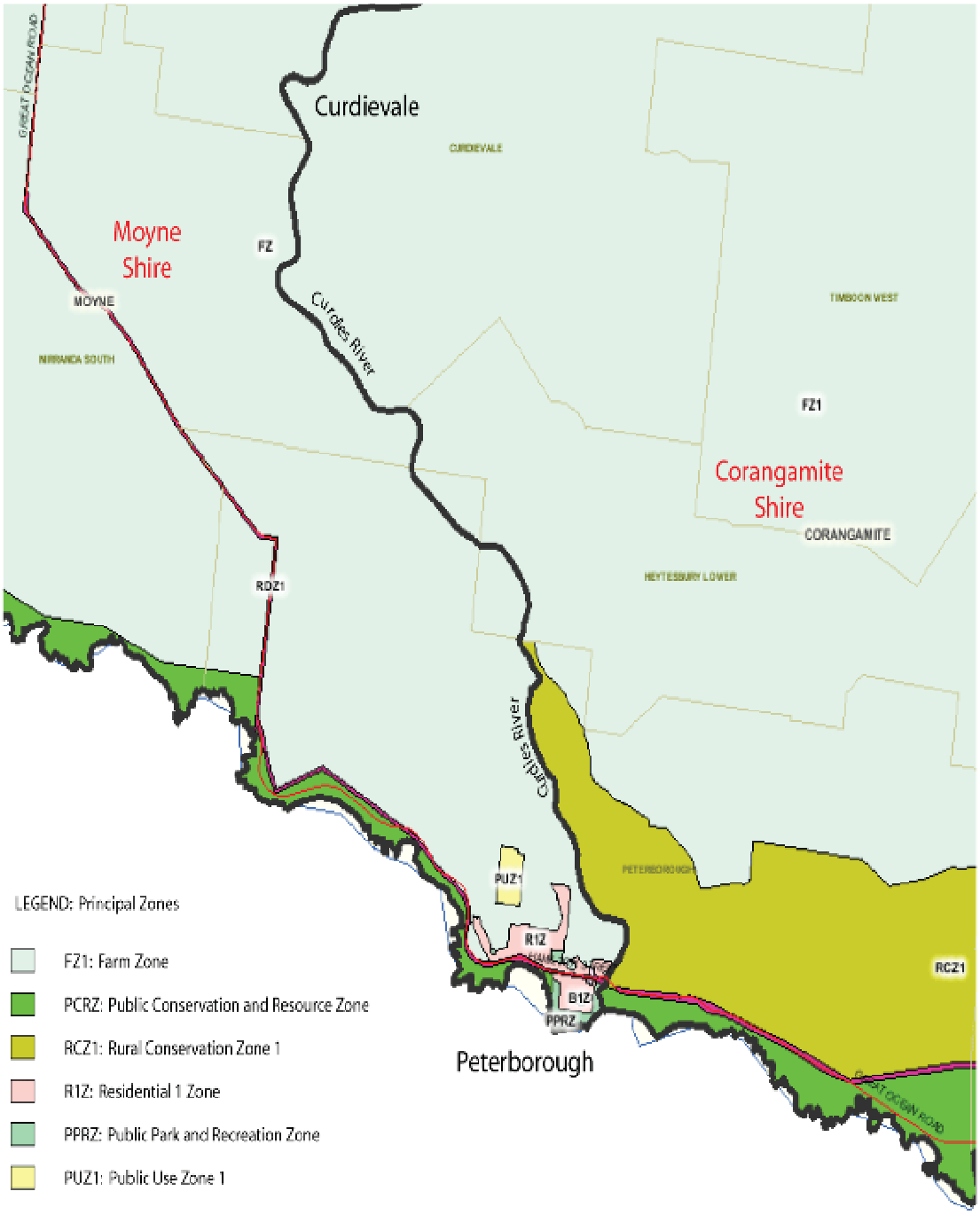

Figure 3. Overview of planning zones in the Curdies River estuary region (basemap produced using Planning Maps Online[3])

Townships

Peterborough is an important and growing coastal township located on the estuary of the Curdies River between Port Campbell National Park and the Bay of Islands Coastal Park. Development is guided by the Peterborough Urban Design Framework which identifies the landscape character and its vulnerability to development due to the open and highly exposed landscape and limited, low coastal vegetation and few trees. The framework is supported by two key planning overlays: environmental significance schedule 2 (ESO2) and significant land schedule 2 (SLO2). These define a series of environmental objectives (Table 3) and landscape

character objectives (Table 4) that guide development and management within Peterborough. A number of the objectives describe values that relate directly to the Curdies River estuary (water quality, estuarine ecology and revegetation with native species). The present Estuary Management Plan should explicitly include and reinforce these objectives.

Outside of the town boundary a public use zone for service and utility provision (PUZ1) is designated to the west of MacGillvray Road. Also, the area between the northeast boundary of Peterborough and the estuary lagoon is designated either land subject to inundation (LSIO) or is a designated floodway (FO). The LSIO identifies land affected by the 1 in 100 year flood that is either flood storage or a flood fringe area. The designation of the LSIO is to ensure development does not compromise the free passage and temporary storage of flood waters, minimises flood damage and protects water quality (amongst other things).

Table 3. Environmental Objectives for the Peterborough Area defined by ESO schedule 2

1. To conserve and enhance the environmental qualities of the coast, estuarine ecology of the Curdies River and structural and water quality of the limestone depressions and in particular to ensure that: • the water quality of the limestone depressions and the estuary of the Curdies River is maintained and enhanced; • sand dunes and coastal cliffs in the coastal area remain in a stable condition; and • valuable ecological systems are protected.
2. To require the proper management of stormwater discharges to the Curdies River estuary and limestone depressions from development.
3. To encourage development to implement stormwater and grey water recycling systems.
4. To encourage revegetation using native coastal species local to the Peterborough area.

Table 4. Landscape character objectives for the Peterborough Area defined by LSO schedule 2

1.	To maintain the small scale seaside village character of Peterborough.
2.	To encourage the development of buildings that fit within the landscape and do not dominate the streetscape and long distance views from the coast, estuary, the rural hinterland and along the Great Ocean Road.
3.	To minimise the impact of buildings that project above the vegetation canopy.
4.	To encourage development to continue the use of light colours and tones, rather than bright or garish colours.
5.	To provide space around buildings for the retention and planting of vegetation, particularly native coastal species common to the area.
6.	To maximise opportunities for view sharing, particularly where views are available to the ocean, Curdies River, the rural hinterland and along the Great Ocean Road from private dwellings.
7.	To protect vistas of the ocean and the Curdies River available from public viewing points in the town, Bay of Islands Coastal Park and other areas of high visual amenity.

Curdie Vale comprises 28 allotments and is located near the upper estuary. The eastern shore of the estuary lies within the town boundary and is managed either by the shire (delegated authority) or is Crown land. There are no planning overlays associated with Curdie Vale.

Two actions are proposed that recommend a re-examination of aspects of the planning framework, these are: V1.10 (see Section 4.6.2) and F1.11 (see Section 4.7.5).

4 NATURAL HERITAGE

4.1 Geology and Geomorphology

Curdies Inlet is the estuarine lagoon of the Curdies River at Peterborough in south western Victoria. Curdies River catchment and its major tributaries, Scotts Creek and Coorriemungle Creek, enclose an area cited as 1245 km^2 by Saenger and Bucher (1989) although Barton and Sherwood (2004) refer to the area as 1015 km^2. For this project, an area of 1042 km^2 was measured using MapInfo V7.5 on the State database stream network and ten metre contours. Using this figure and assuming tidal penetration to A'Becketts Creek five kilometers upstream from Curdie Vale (Barton and Sherwood, 2004), approximately 183 km^2 or 17.5% of the catchment has slopes and tributaries that flow directly into the estuarine sector.

The catchment encloses an area of distinctive landform, and the origin and age of the catchment topography has been the subject of much speculation (Bock and Glenie, 1965; Jenkin, 1981; Jenkin, 1984; Sandiford, 2003; Wallace et al., 2005). The catchment has developed at the boundary of four distinctive geomorphic regions - the southern edge of the Western District Volcanic Plains, the Hanson Plain, the western flank of the Otway Ranges and the Port Campbell Coastal Plain (Figure 1, Figure 2). Elements of all these regions are present in the catchment, including the volcanic crater that holds Lake Purrumbete (the source of the trunk stream of Curdies River), the flat surface of the Hanson Plain, the steep ridge and valley slopes of Scotts Creek and Cooriemungle Creek, and the lower, undulating surface of the coastal plain bordering the western side of Curdies inlet.

The Curdies River is a distinctive catchment and along with the estuarine sector comprises a region of major geoscience significance. The geoscience values are based on:

- the distinctive geomorphology of the catchment including the rectilinear drainage pattern;
- the degree of incision of the Curdies River and its major tributaries;
- the interaction of tectonics, river incision and volcanicity in the upper reaches of the catchment;
- the inference that rapid, recent substantial uplift has occurred based on interpretation of the former strandlines;
- the unusually long and deep river estuarine section;
- the clearly defined components of the estuary including a drowned and infilled valley sector, a broad lagoon with active river and tidal deltas and an intermittent connection to the ocean that provide the opportunity for comprehensive studies of estuarine evolution;
- the amount of sedimentation that has occurred to infill much of the estuarine sector;
- the potential for palaeoecological studies of the estuary and floodplain sediment to determine the late Pleistocene and Holocene submergence history of the estuary;
- the wide, largely infilled entrance complex cut through the Cainozoic rocks; and
- the unusual asymmetry of the drainage basin with the main channel occupying the western margin.

4.1.1 Geology

The catchment is part of the Port Campbell Embayment, a structural sub-unit of the Otway Basin. There are no very old rocks in the catchment. Although the 70 million to 80 million year old rocks (that form the Otway Ranges) underlie the catchment at depth, they are buried by younger sedimentary and volcanic rocks generally less than 25 million years old. As much of the surficial geology is comprised of poorly consolidated sedimentary beds, there is little outcrop even on steep slopes, and detailed mapping relies on inspection of road cuttings, dams, quarries and aerial photograph interpretation (Tickell et al., 1992). There are four broad groups of geological materials and they occupy distinct topographical positions across the catchment. They represent changing geological conditions dating back to 50 million years. These conditions led to deposition of thick layers of sediment, initially in rivers and lakes and progressively becoming marine as global sea levels rose beginning 25 million years ago. These higher sea levels deposited the distinctive fossiliferous lime-rich sediments of the rocks exposed in the coastal cliffs at Peterborough and Port Campbell. The youngest geological materials are a result of falling global sea levels beginning 5 million years ago as the planet entered a glacial climatic phase and coastal waters became shallower. The sediments deposited were coarser-grained and show evidence of beach and shoreline conditions. Faulting and broad tectonic movements have uplifted these sediments so they are now 100 to 200 metres above sea level (Sandiford, 2003; Tickell et al., 1992). Volcanic activity in western Victoria began about 4 million years ago and continued until the last few thousand years, resulting in clearly recognizable volcanic features such as lake-filled craters and hills. The catchment geology is described according to age and broad mode of origin.

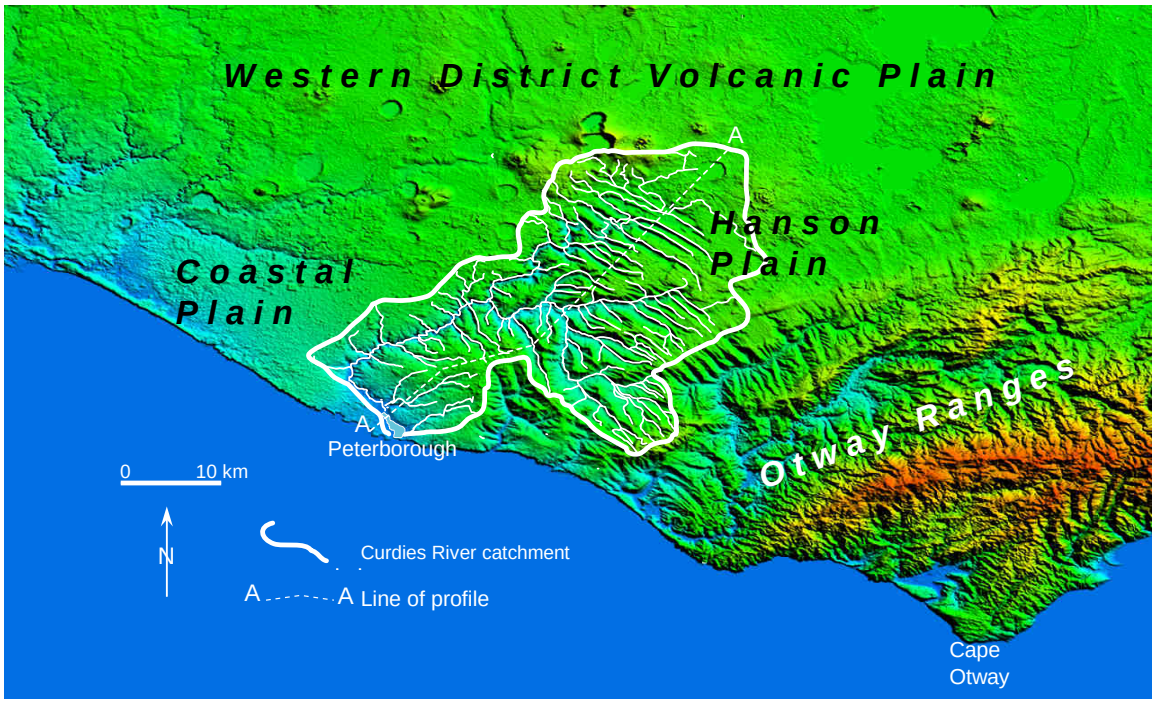

Figure 4. Geomorphology of the Curdies River region. The catchment overlaps four geomorphic units on the western flank of the Otway Ranges. (Source: Shuttle Radar Topographic Mission – Prepared in Global Mapper).

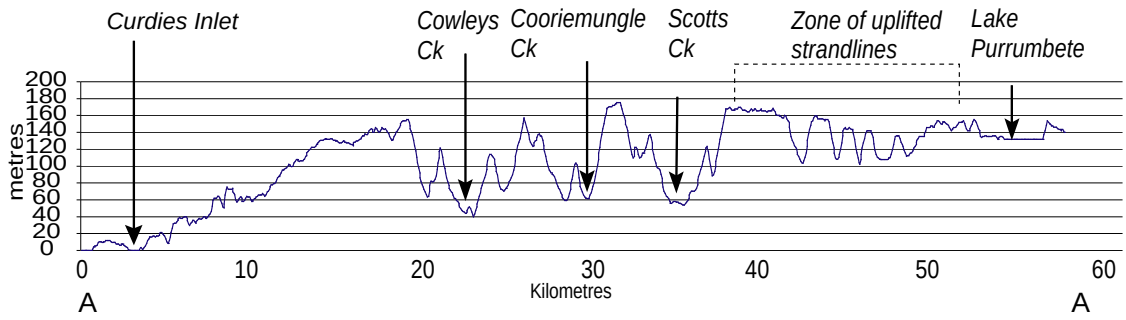

Figure 5. Profile A – A from Figure 1 across the major geomorphic elements of the Curdies River catchment. (Source: 3D Path Profile Tool – Global mapper)

- *50 million to 10 million years ago*: transition from river and lake conditions to an environment of coastal lagoons, deltas, estuaries gradually becoming submerged and replaced by deepening waters depositing marine to open marine and continental shelf sediments. The oldest of these deposits, the Dilwyn Formation, is the first stage of the marine transgression that produced thick-bedded carbonaceous sandy clay and silt interbedded with sand and gravel layers. In the Curdies River catchment, this formation is now restricted to the ridge at Ferguson Hill in the core of the Ferguson Hill Anticline. Overlying the Dilwyn Formation and also restricted to the Ferguson Hill area is the richly fossiliferous Narrawaturk Marl, a pale to dark brown marl and calcareous mudstone with thin interbedded limestone. The most widespread marine units in the Curdies River catchment are the Gellibrand Marl and Port Campbell Limestone, the uppermost calcareous sedimentary units of the Heytesbury Group. These beds form the spectacular high cliffs, gorges and rock stacks along the coast from Princetown west to Childers Cove. The Gellibrand Marl is grey calcareous clay to silty clay while the Port Campbell Limestone contains less mud and is predominantly a bedded calcarenite. Both units are rich in marine fossils, dominantly bryozoans and molluscs, with echinoids and brachiopods also common. As the units dip gently to the west, the Gellibrand Marl becomes lower in the landscape and the Port Campbell Limestone becomes the dominant surface unit. Gellibrand Marl outcrops only to the east of the Curdies River valley and is the dominant surface material in the ridge and valley landscape of the Cooriemungle Creek and Scotts Creek.

- *10 million to 5 million years ago*: shallowing and withdrawal of the sea and widespread deposition of a coarse to medium-grained sand, clayey sand and minor gravel unit. The unit has a maximum thickness of 10 metres and was named Hanson Plain Sand by Tickell *et al.* (1992). It occurs in the highest parts of the landscape either as a capping on the elongate ridges between incised valleys and forms the surface of the Hanson Plain in the centre and east of the catchment. Tickell *et al.* (1992) regarded the Hanson Plain Sand as non-marine (fluvial) with only a minor marine component, but Dickinson *et al.* (2001) and Sandiford (2003) interpreted the formation as nearshore and beach deposits. These latter authors argue that the composition and distribution of the Hanson Plain Sand, and the configuration of the landscapes they occur in, provide important clues to the evolution of the geomorphology of the Curdies River and Gellibrand River catchments.

- *5 million years ago to present time:* basalt volcanism including scoria and maar eruptions and lava flows. The Curdies River catchment is developed along the southern margin of the Western District Volcanic Plain and eruption points and lava flows have greatly influenced the geomorphic development of the northern part of the catchment.

There are a number of eruption points in an arc around Cobden with Lake Purrumbete and Birmingham Hill the most prominent volcanoes inside the catchment. A cluster of five small vents was identified around McCormacs Hill between Tandarook and Tandarook South by Tickell *et al.* (1992). The Curdies River valley is lateral to a lava flow southwest of Cobden, and while tongues of dissected lava occur mainly as ridge cappings between incised meanders, a separate younger lava flow occupies the floor of the Curdies River valley and extends for 14 kilometres downstream from McCormacs Hill.

- *last 10 thousand years*: colluvial and alluvial (fluvial, shallow marine, estuarine and lagoonal) sediments and peat, beach and dune sands. Lower valley sides across the catchment have a mantle of weathered clay-rich sedimentary rock forming alluvial and colluvial fans, in places with active slope failures. The channels of the incised valleys are flanked by well-defined alluvial terraces and floodplains. Along the margin of Curdies Inlet is a narrow zone of marshland intermittently submerged by tidal inflow when the entrance is open and the river is in flood. Since sea level rose to its current elevation ~6000 years ago the estuary has gradually become less marine with deposition of sediments. The inlet connection to Bass Strait is now encumbered and frequently closed by a wide barrier and beach and a narrow zone of calcareous-rich sand dunes.

Tectonics has played a major role in shaping the Port Campbell embayment and several structures extend across the Curdies River catchment. The most prominent is the Ferguson Hill anticline with the hinge forming the high ridge trending ENE from Ferguson Hill. Tickell et al. (1992) mapped a series of parallel NW to NNW trending folds across the central part of the catchment including the Cooriejong Monocline that influences the direction of the Coorriemungle Creek and Cowleys Creek. Based on his evaluation of the origin of landforms and surface materials, Sandiford (2003) argued that rapid uplift of between 175 and 200 metres had occurred in the Curdies River catchment in the last 2 million years.

4.1.2 Geomorphology

The catchment is of modest altitude. The highest elevations are around 220 metres at Ferguson Hill and 240 metres on the southern rim of Mt Leura. The Curdies River is incised along the western margin of the catchment while the major tributaries flow either south to north (Coorriemungle Creek) or east to west (Scotts Creek). The upper reaches of Curdies River are deeply incised and entrenched with 70 metres to 100 metres of relief. The drainage pattern is strongly rectilinear with the tributary streams showing consistent northwest alignment, similar to those of the Tomahawk Creek in the adjacent Gellibrand River system, suggesting a structural control on valley and channel direction (Tickell et al., 1992). The catchment terrain comprises six broad systems based on elevation and dissection.

- *Hanson Plain*: The easternmost part of the catchment is a gently undulating plateau around 150 to 170 metres elevation. The margins of the plateau are incised by numerous tributary streams.
- *Incised tributary plateau*: The most extensive terrain in the catchment is a deeply incised network of parallel valleys and ridges comprising the upper tributaries of the Curdies River and the catchments of Scotts Creek, Cooriemungle Creek and Cowleys Creek. This strongly NNW oriented drainage network was originally interpreted by Jenkin (1981) as controlled by a series of higher sea level strandlines that had been later uplifted. Sprigg (1986) and Tickell *et al.* (1992) provided alternative views (a combination of slumping, jointing and minor faulting, although Dickinson *et al.* (2001),

Sandiford (2003) and Wallace *et al.* (2005) on the basis of new evidence from digital terrain models and airborne radiometrics and magnetics strongly support the strandplain origin.

- *Curdies River incised valley*: The Curdies River occupies a well-defined, steep-sided valley along the western margin of the catchment, incised 60 to 80 metres below the level of the plateau.
- *Coastal plateau*: Bordering the middle and lower sections of the Curdies River is a limestone-capped plateau sloping from 80 metres elevation towards the south and terminating in the coastal cliffs flanking the Curdies Inlet entrance. On the western side of the river there are few streams and the surface has numerous enclosed subsidence and solution depressions. There is a distinct "step" in the topography at 10 to 15 metres elevation along the peninsula that defines the lower western margin of Curdies Inlet.
- *Estuary and marginal tidal and river floodplain*: This terrain with relief of one to five metres occurs along the middle and lower reaches of the catchment bordering the lagoon and channel. Curdies Inlet is a compound estuary with a long, deep drowned river channel opening into a broad, shallow estuarine lagoon. This accords to a WDE (wave dominated estuary) under the national conceptual estuary model of Ryan *et al.* (2003). Barton and Sherwood (2004, citing CLS 1981) reported that "Curdies River follows a slight synclinal depression in the Port Campbell limestone to form a shallow coastal lagoon..." This is based on Baker (1944) who followed Wilkinson (1865) and his own coastal mapping. More recent published mapping (Tickell *et al.* 1992) and other literature (e.g. Bird, 1993) make no reference to this structure and the coastal outcrops show no clear evidence of dip reversal on either side of the estuary. Curdies Inlet is an elongate, shallow lagoon approximately 3.8 km long and up to 1.25 km wide although these dimensions are dependent on the amount of submergence. Saenger and Bucher (1989) measured the open water area of Curdies Inlet as 2.94 km^2, with 0.35 km^2 of seagrass mapped, 0.24 km^2 of intertidal flats, and 1.58 km^2 of "saltmarsh/salt flats". Estuarine water is reported to penetrate between 16 km inland (Tunbridge and Rogan, 1981) and 17 km (Barton and Sherwood, 2004). In the lower reaches of Curdies Inlet is a broad, shallow sandy tidal delta formed during storm and high tide overwash into the lagoon. This becomes progressively muddier upstream with salt marsh vegetation giving way to brackish water reed-fringed shorelines. The head of the lagoon is well-defined with the deep, narrow river channel opening via a reed-fringed delta. This delta is progressively reclaiming the estuary effectively converting the bordering lowland into a riverine floodplain. The lower (coastal) reaches of the lagoon are shallow and also infilling with sand washed in by flood tides and storm surge forming a tidal delta.
- *Estuary entrance*: Curdies Inlet is linked to the Southern Ocean by an intermittently open tidal channel effectively one kilometre long including the subaqueous sector inside the lagoon. The maximum west-east extent of the entrance is approximately 1.5 kilometres and defined by coastal outcrops of Port Cambell Limestone and Bridgewater Group calcarenite and cut by river outflow during Pleistocene lower sea levels. As the Holocene rise in sea level flooded into the Curdies River valley, sand was deposited as a coastal barrier anchored between these entrance points and crossed by tidal channels. A tidal palaeochannel is evident on the eastern side of the entrance underneath the Great Ocean Road bridge. The barrier is now capped by calcareous dunes with varying degrees of mobility. The tidal entrance frequently closes by accumulation of wave and wind-blown sand. The estuary infrequently naturally opens when flows and water

levels are high but more often is artificially opened with an excavator with the aim of lowering water levels.

4.2 Erosion and Sedimentation

As indicated by the degree of incision of the Curdies River system, and the probability of rapid recent tectonic uplift, a large volume of sediment has been moved from the upper catchment. Catchment erosion continues with active slope failure and mass movement evident on many steep slopes. As much of this sediment is sourced from fine-grained rocks (carbonaceous clay, marl and limestone) there has been rapid movement through the steeper channel systems to the low gradient estuarine sector leading to development of an alluvial floodplain. This has reclaimed much of the valley base in the narrow estuarine sector of the river and advanced the opening of the channel via a prograding delta into the broader estuarine lagoon. Sedimentation in the lagoon is derived from multiple sources. River delta growth continues with sedimentation assisted by fringing reedswamp. The middle and lower (seaward) reach of Curdies Inlet is dominated by coastal sand derived from tidal inflow and augmented by wind-blown sand from the barrier dunes. Sediment is also cycled inside the lagoon by erosion of the fringing alluvial lowland during high and falling water levels. Artificial opening of the entrance contributes to both sedimentation and erosion. Initially, sediment is flushed out the newly opened entrance but is replaced with tidal inflow adding to the tidal delta. Rapid lowering of water levels exposes sand and mud banks and contributes to bank slumping and sapping around the lagoon margin as ground water levels are lowered and injection of salt water reduces the vigour of reedswamp regeneration. Given the dimensions and dynamics of Curdies Inlet, it is likely that it is an effective sediment trap for both fluvial and marine sediments. This is in accordance with the "key functional characteristics of Australian estuaries and coastal waterways" proposed by Ryan et al. (2003) in that estuaries of this type are "...an efficient 'trap' for terrigenous sediment and will rapidly change over time due to infilling, resulting in shallowing of the central basin, and expansion of the fluvial delta". While there are anecdotal reports of rapid shallowing of the lagoon since European settlement little evidence is available. Preliminary results from a sediment core taken from the lagoon indicate that the rate of sedimentation since European introduction of pines has been approximately 10 times the average rate of the last 5300 years (P. Gell, pers. comm.). Annual modelled inputs of fine sediment to the estuary have been estimated at 9600 tonnes; nearly 50 times greater than the estimated pre-European input of 200 tonnes (SEDNET modelling results: available at www.ozcoasts.org.au). In more recent years (1977-1998) there has been no upward or downward trend in turbidity at a freshwater monitoring site at Curdie (Smith and Nathan, no date: 2000?).

4.3 Hydrology and Climate

Knowledge of the hydrology and climate of the Curdies River estuary is based principally on the works of Arundel (2003) and Barton and Sherwood (2002). Their words and analyses have been reproduced in the following section with limited additional attribution.

The region's climate is classified as temperate humid with a winter rainfall maximum (*i.e.* 'Mediterranean': Skinner and Porter, 1995). Annual rainfall in the Curdies catchment is 700 mm along the coastal fringe and decreases inland.

River discharge reflects the rainfall pattern having high discharge in winter and spring, and low discharge in summer and autumn. Mean monthly winter discharges are over 20 times those of the dry autumn months (Sherwood, 1988). A gauging station is located at Curdievale (site code 235203). Variations in the annual flow, expressed as coefficients of variation, were

calculated using mean monthly flows for data commencing in November 1955 and concluding in May 2001(Arundel, 2003). Annual variation in flow of the Curdies River is similar to the Australian average (CV=0.7: Eyre, 1998).

The monthly variation in mean daily discharge between 1997 and 2001 is shown in Figure 6. Discharge patterns vary considerably from year to year and from day to day, in particularly in the wetter months in response to the passage of frontal and low pressure systems over the region.

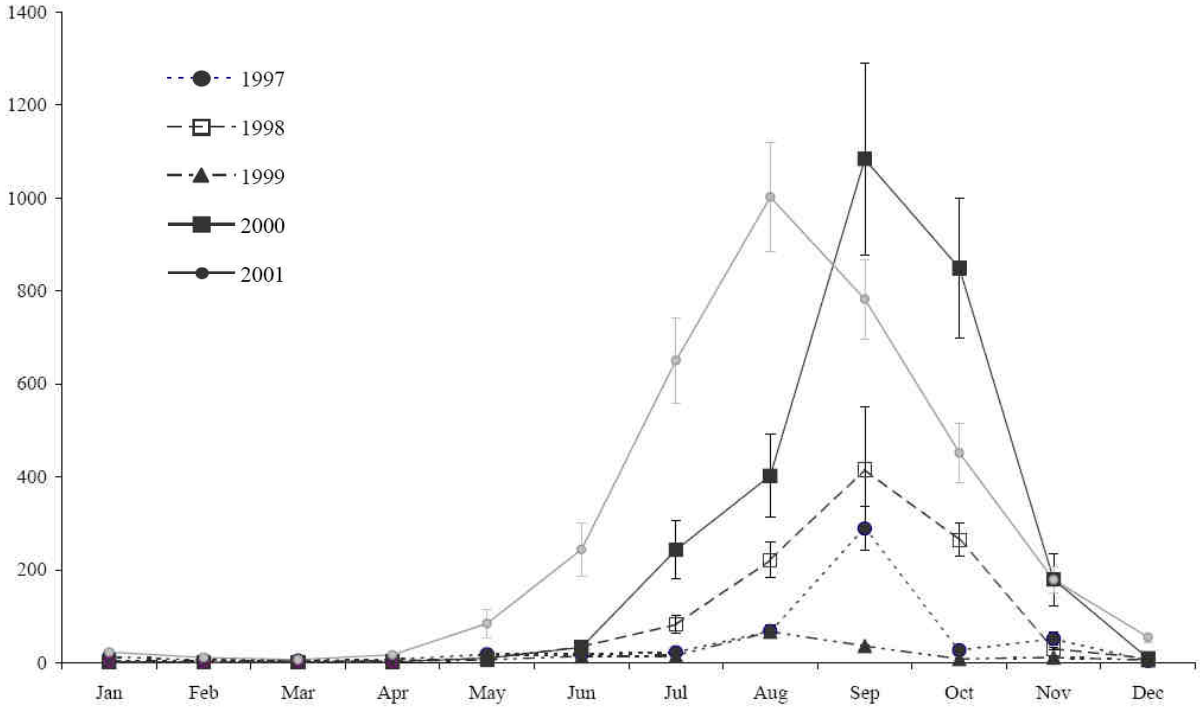

Figure 6. Mean daily discharge (ML/day - recorded at gauging station 235203) for each month in the period 1997 – 2001. Faint grey line indicates mean discharge (Nov 1955-May 2001). after Arundel, 2003, Fig. 2.3. Note that 2001 data is for the first quarter of that year only.

The large difference in seasonal flows has a marked impact on the turbulent energy regime of the estuary (see Section 4.5). Winter floods may flush salt water from the estuary completely With lower flows in summer and autumn the sandbar can constrict the mouth and tidal exchange is reduced.

There are no major dams in the river catchment. The River downstream of Curdievale scored 9 out of 10 in the ISC assessment of hydrology, as the observed 1999 flows were not significantly different from modelled natural flows (Barton and Sherwood, 2002, Figure 24). However the flows were over 60% less in summer and autumn than modelled natural flows (Barton and Sherwood, 2002, Figure 25), and this may have implications for mouth closure frequency.

4.3.1 Tides and other factors causing sea level variations

The tides along the coast are semi-diurnal with a tidal range of approximately 0.8 m during spring tides and 0.6 m during neap tides. During the summer spring tides, the greater tidal difference occurs during the night. However, the reverse is the case in winter with the greater difference during the day. The sill/sand barrier at the mouth of the estuary further attenuates the tidal influence in the estuary.

Atmospheric pressure leads to sea-level variations, by what is known as the inverse barometer effect (Beer 1983). Based on measurements made by Hamon (1966), Barton and Sherwood (2002) calculate that sea levels may vary by up to 50 cm as a result of the passage of pressure systems.

In western Victoria, on-shore winds from the west and southwest are common in all months and may reach speeds up to 30 knots. Such strong winds are often associated with low pressure and cold fronts and therefore can enhance pressure-based sea level super-elevation.

The coastline into which the Curdies River enters has very high wave energy from the prevailing southwesterly ocean swell and storm waves arriving through deep water over a narrow section of the Australian continental shelf (Bird, 1993). Large waves generated by Southern Ocean storms may arrive at the coast any time and do not necessarily synchronise with the local weather system. However, such waves have been known to overtop sand bars at the entrance to west Victorian estuaries and add significant volumes of sea water. For example, In April 1994 the Hopkins estuary level rose 10 cm in 6 hours due to this effect (Rouse, 1998).

4.3.2 Objectives and Recommended Management Actions for Hydrology

Objective H1: ***Maintain and enhance estuarine condition through management of flow. Ensure there is an environmental flow down the river***

Code	Recommended Action	Priority
H1.1	To determine the environmental flow needs of the estuary	VH
H1.2	Ensure flow needs of the estuary are explicitly addressed in allocation of surface and ground water resources. Ensure environmental flows are implemented.	VH
H1.3	Investigate increasing importance of irrigation dams and development in water budgets	L
H1.4	Investigate cost and feasibility of monitoring water quality at Curdievale	M

4.3.3 Flooding and Estuary Entrance Dynamics

Like many estuaries in Victoria, the Curdies estuary intermittently closes following the formation of a sandbar at the estuary entrance. Several factors interact to determine when an estuary closes and the length of time it remains closed (Figure 7). While water movement, from freshwater discharge and ebb-tide flow, removes sand from the entrance and acts to keep the estuary open, currents and swell resuspend and deposit sand at the estuary mouth which will eventually cause the estuary to close.

The rocky headland to the west of the Curdies entrance interrupts the movement of sand suspended in currents. If the currents are easterly – which prevail over the summer months – the headland promotes sand deposition at the estuary entrance. Water movement from freshwater discharge and tides, which are less than 2 m, are at times not adequate to keep the estuary open.

No long-term, systematic records of mouth condition that is, when the mouth is open and closed were located. Daily records from March to October 2002 show the mouth was open for 50% of the time (Mondon *et al*., 2003). Although incomplete, some oter records were available and are presented in Table 5

Table 5.
Estuary entrance condition

Year	Date open	Natural or artificial opening	Estuary height AHD (m)	Date closed	Source
1996	6/6/96	artificial	1.32	-	Barton & Sherwood (2002)
1998	3/8/98	artificial		8/12/98	Arundel (2003)
1999	16/09/99	artificial		25/9/99	Arundel (2003)
2000	25/7/00	artificial		25/12/00	Arundel (2003)
2001	9/8/01	natural	1.7		Barton & Sherwood (2002)
2002	June	artificial	1.3		D. Fuller Parks Victoria
2003	July	artificial			D. Fuller Parks Victoria
2004	June	artificial			D. Fuller Parks Victoria
2005	July October	artificial	1.46 1.3		D. Fuller Parks Victoria
2006	August	artificial	1.3		D. Fuller Parks Victoria
2007	16/7/07	artificial	1.3		H.Arundel (pers observation)

Once the estuary closes, the water level in the estuary rises and causes flooding of infrastructure, such as the boat ramps and jetties at Curdievale, and some septic tanks in the Peterborough township.

The estuary is usually artificially opened at least once a year when the water level in the estuary reaches 1.3 m AHD on a gauge board on the western side of the Great Ocean Road bridge. A contractor is engaged by Parks Victoria to open the estuary with an excavator. This occurs in the same place on each occasion (Barton and Sherwood, 2002).

Two authorisations are required before estuary mouths are artificially opened.

1. A ‘works on waterways’ permit which is issued by the Catchment Management Authority (CMA) as an authority under the Water Act 1989 (section 67). A condition of this permit is that water quality tests be conducted pre and post artificial openings.; and

2. A consent to ‘use’ or ‘develop’ coastal Crown land, issued under the Coastal Management Act 1995 (section 37). The consent is issued by either the Department of Sustainability and Environment or in the case of the Curdies estuary, Parks Victoria as the land at the entrance is reserved under the National Parks Act 1975 (section 27)

There are a range of potential environmental impacts associated with opening an estuary. These include 'fish kills', loss of fish eggs and larvae and loss of fish and bird habitat (EEMSS, 2006). There have been no records of fish kills associated with artificial estuary openings of the Curdies estuary. Water quality monitoring conducted by Deakin University, prior to artificially opening the estuary on September 1999, July 2000 and August 2001, indicated the water column was well oxygenated (i.e. dissolved oxygen levels > 5 mg/L). The risk of a 'Fish Kill' was therefore considered to be low (Barton and Sherwood, 2002). Other potential impacts of artificially opening the Curdies estuary identified in EEMSS (2006) have not been assessed for the Curdies estuary.

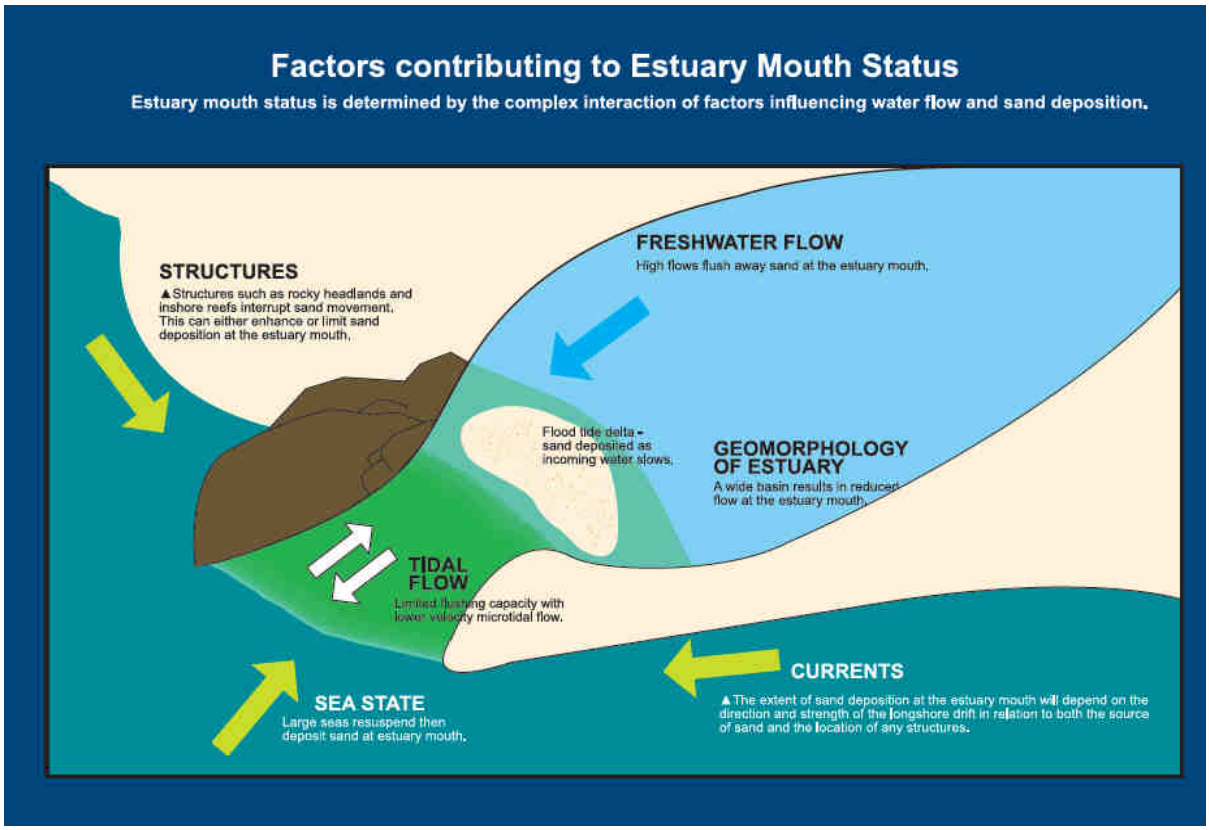

Figure 7. Factors contributing to estuary mouth status. Source: with permission EEMSS (2006)

4.3.4 Objectives and Recommended Management Actions for Entrance Management

Objective EM1: ***Maintain an entrance regime which considers the environmental and socioeconomic values of the estuary***

Code	Recommended Action	Priority
EM1.1	Establish a program (such as EstuaryWatch) to monitor water level and entrance status	H
EM1.2	Use EEMSS to revise the entrance management protocols for the Curdies estuary	VH
EM1.3	Investigate the cost and feasibility of installing a continuous water level recorder and WQ	M

EM1.4	Investigate the potential benefits of and means to reinstate the original entrance configuration as a result of building new GOR bridge (especially losses to the blue hole and direct flush	M

4.4 Climate Change

> *"Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas." (IPCC, 2007b, p.6)*

It is now widely accepted that global climate is changing and that these changes are likely to impact significantly on Victoria's environment. Climate change science remains a hotly debated and increasingly a political topic. Therefore, the information presented in this section has been carefully compiled from the most current sources to provide sufficient context to enable informed planning. The first two sections present the current data on climate change, both internationally and locally. The final section describes the possible ramifications for the Curdies River estuary.

4.4.1 Global Data: The IPCC

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations' Environment Program and the World Meteorological Organisation. It is responsible for providing the international community with authoritative advice on scientific, technical and economic issues relating to climate change. The IPCC's Third Assessment Report (released in 2001) concluded that global warming had accelerated in recent decades. The recently released Fourth Assessment Report (4AR), Climate Change 2007 (IPCC, 2007a; IPCC, 2007b), increased the level of scientific certainty upon which climate change and projections are made. It provides stronger evidence that the majority of global surface warming is attributable to increases in greenhouse gas emissions associated with human activities.

Table 6 presents a summary of conclusions from the IPCC Fourth Assessment Report (IPCC, 2007a). Of particular relevance to the preparation of this EMP are the projected increase in sea level (which has a direct bearing on the dynamics of the estuary entrance), changes to extreme weather patterns, and changes to precipitation and average surface temperatures. In the case of the latter, predictions for southern Australia suggest decreased precipitation accompanied by increased evaporation (IPCC, 2007b, p.9).

Table 6. Summary of Conclusions from the Fourth IPCC Assessment Report (IPCC, 2007a)

There is unequivocal observational evidence of; • global warming (11 of the last 12 years were among the warmest years on record), • increased ocean temperatures, • widespread melting of snow & retreating of sea-ice and glaciers, • widespread changes in precipitation amounts, • changes in wind patterns, • changes in extreme weather, including droughts, and • rising global sea levels over the 20th century of ~ 0.17m.
Global average surface temperatures are projected to increase by between 1.1°C and 6.4°C by the end of the 21st century.
Global average sea levels are projected to increase relative to present levels by 2095 (Nicholls et al., 2007, Table 6.3) by • 0.19m to 0.37m (Low emission scenario[4] – B1) • 0.28m to 0.58m (High emission scenario – A1F1)
Climate change will adversely affect water resources, agriculture, forestry, fisheries, ecological systems, human settlements and human health in many parts of the world.
Global warming and sea level rise will continue for centuries due to timescale lags associated with climate processes, even if greenhouse gas emissions were stabilised.

The IPCC reports have a global focus, describing the expected nature and magnitude of climate changes at large scales. In Victoria, the Department of Sustainability and Environment (DSE) maintain a Greenhouse Strategy[5] that has funded a range of investigations that help to understand, and prepare for, likely climate change impacts on this state.

4.4.2 Local Data: DSE and CSIRO

The most current, region-specific information for the Curdies area can be found in climate change booklets prepared in 2004 for the Glenelg-Hopkins and Corangamite regions (DSE, 2004a; DSE, 2004b). A summary of the climate change projections is presented as Figure 8.

[4] The IPCC Third Assessment Report defined an agreed set of emissions scenarios based on the primary factors that drive greenhouse gas emissions. They define in particular future trends in global population growth and storylines for economic development and energy consumption. These storylines consider the rate at which new and more efficient technologies emerge and whether mitigation efforts are pursued globally or locally.

[5] http://www.greenhouse.vic.gov.au/index.html (last accessed: 6 August, 2007)

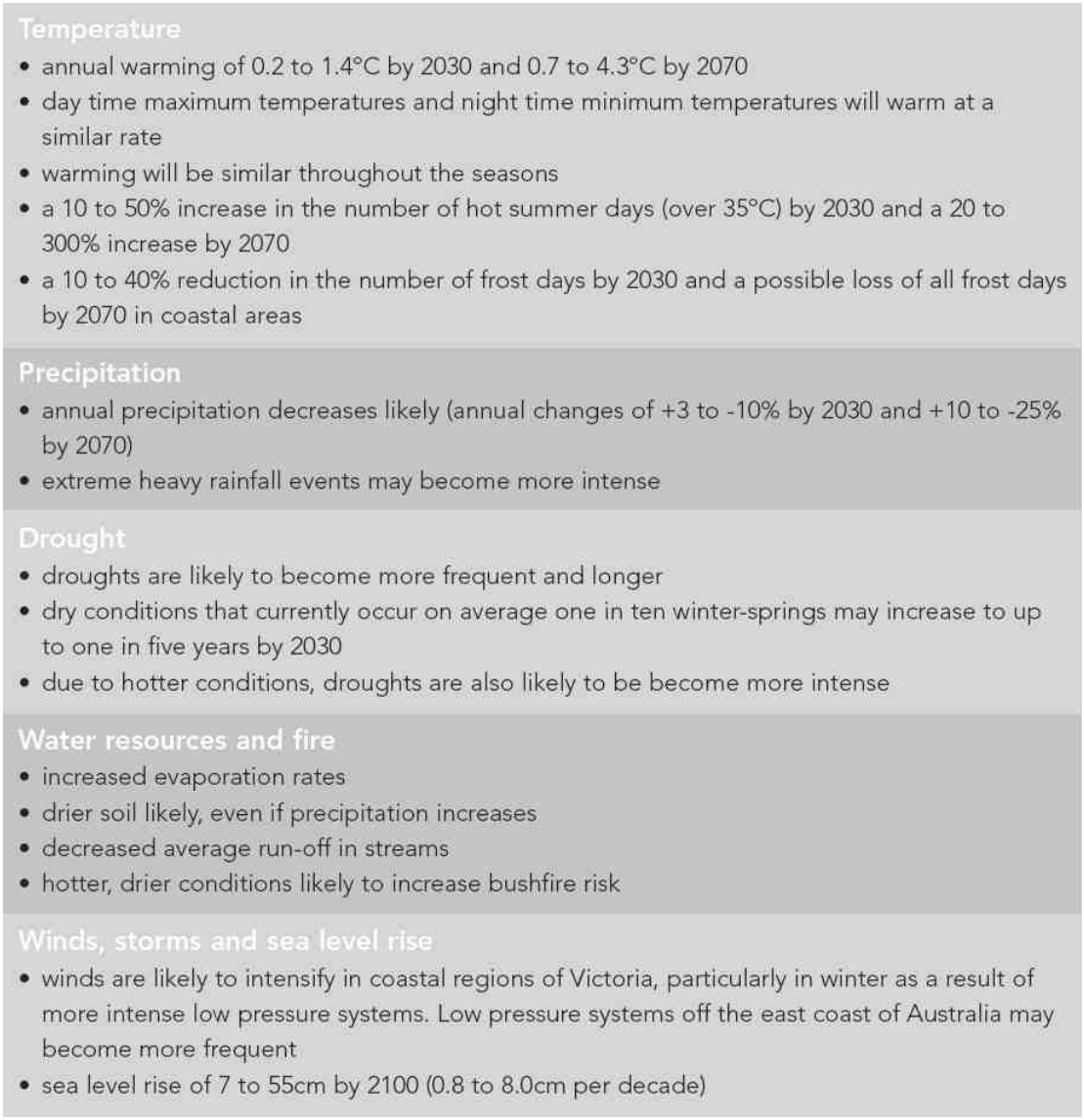

Figure 8. Summary of projected climate changes for the Glenelg-Hopkins region (after DSE, 2004b, p.5)

The projections in Figure 8 broadly concur with more recent IPCC data, with the notable exception that larger sea level rise is now expected (minimum 0.19 m rather than 0.07 m). This local information is based on a study completed in 2004 by the CSIRO (Suppiah et al., 2004). It is anticipated that new climate change projections for Victoria will be available in late 2007or early 2008 (DSE, 2007). Dr Kathleen McInnes of the CSIRO Division of Marine and Atmospheric Research is currently undertaking an analysis that will provide predictions of sea level rise and storm surge for the southwest coast including the Peterborough region (K. McInnes, 2007, pers. comm., 6 August).

4.4.3 Impacts on the Curdies River Estuary

Climate changes are likely to cause a range of gradual, but persistent, changes to the Curdies estuary some of which are discussed in Sherwood (1988).

As sea levels rise, the height of the sand berm at the entrance will also rise (so a half metre rise in sea levels will tend to produce a berm that is half a metre higher). The elevation of the berm is a key physical feature of the estuary as it is the primary control of the water surface level that can be held in the lagoon of the estuary. Increased berm height will cause the estuary to be

deeper and cover a greater area when full. This will particularly impact on low-lying areas in Peterborough and also fringing farm land. Deeper water in the estuary may increase the frequency and persistence of stratification, heightening the risk of eutrophication (algal blooms) and will also modify interactions with the groundwater system.

Sea level rise is also associated with coastal retreat where sandy beaches are present. Retreat magnitudes vary according to the local beach profile which is typically in the range 1:50 to 1:100 (Silvester and Hsu, 1997). Consequently, a retreat of between 25 - 50 m would be expected were sea levels to rise by 0.5 m. Such a retreat at the Curdies River entrance would modify the downcoast (easterly) dune systems, threatening the coastal reserve and frontages on the south side of the Great Ocean Road.

Changes to the wind climate are also predicted for the region. Wind strengths are projected to increase by between 10-15% in Bass Strait which translates to a 20-25% increase in significant wave height (McInnes et al., 2005) and hence greater storm energy. The increase in energy will lift coastal erosion rates, increasing both longshore and cross-shore sediment transport. If the increase in up-coast erosion (i.e. from the Bay of Islands and further west) is insufficient to match the increase in longshore transport rates, then the beach at Peterborough may be starved of sand reinforcing the rate of shoreline retreat. However, the reverse may also occur where changes in sediment supply outstrip increased transport rates. Uncertainty surrounding the process balance here illustrates the difficulty associated with making definite predictions of climate change impacts.

Other climate change variables likely to impact on estuary condition include more frequent extreme rainfall events but reduced overall totals. Such changes may increase flood risk along the lower estuary. The increased frequency of high rainfall events, coupled with the likelihood of an elevated entrance berm, indicate that the present overlays indicating land subject to inundation and floodways will most likely need to be revised.

Finally, climate change is also predicted to increase net evaporation (rainfall – evaporation), implying a decrease in freshwater baseflow entering the estuary. The salinity regime is likely to change in response to lower flows, higher evapo-concentration in the lagoon and modified estuary entrance dynamics. Elevated salinity would be likely to influence the character of fringing vegetation (salt tolerant species will spread further inland) and potentially degrade the productive capacity of fringing farmland (in particular for water frontage licence holders).

4.4.4 Adaptation and Mitigation

There are an array of possible strategies that human societies may pursue to adapt to climate change, or at least to ameliorate the effects. These range from purely technological actions, such as the construction of sea defences, to behavioural shifts or changes in planning policies. These are available to the Curdies River communities, however the IPCC panel recommends that "adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long run as most impacts continue to increase in magnitude" (IPCC, 2007b, p.17). The IPCC recommends a mix of strategies be employed, including:

- mitigation by considering climate change impacts in future land-use planning and infrastructure designs; and
- develop disaster risk reduction strategies to reduce vulnerability to extreme events that are likely to occur at increasing frequencies.

4.4.5 Objectives and Recommended Management Actions for Climate Change

Objective CC1: ***Increase understanding, awareness of and preparedness for potential impacts of climate change***

Code	Recommended Action	Priority
CC1.1	Develop fine scale bathymetric and topographic maps of the estuary and surrounds	VH
CC1.2	Monitor berm elevation with respect to a local benchmark surveyed to the Australian Height Datum	L
CC1.3	Monitor rate of retreat of rocky headlands and diminution of protective islands by setting up photopoints	M
CC1.4	Monitor the lateral extent of the beach and condition of the coastal barrier dunes with particular focus on the geometry of the spit to Schomberg rock	L
CC1.5	Monitor fencing (on inland side of dunes) and revegetation works to ensure continued stability of coastal barrier dunes	L
CC1.6	Planning policy to identify buffer area around the estuary which allows for migration of plant species and protection of infrastructure	M
CC1.7	Prepare a mitigation and adaptation strategy to identify and address the following potential impacts specific to Curdies estuary:- • Decreased rainfall but increased evaporation; • More frequent extreme rainfall events; • Sea level rise increasing berm height at the entrance; and • Increased storm wind strength, incident wave energy and coastal erosion potential.	H
CC1.8	Provide updates to describe likely climate change impacts and the implications for the Curdies. This could be in the form of an information leaflet or community seminar.	VH

4.5 Water Quality and Estuary Processes

The mixing of fresh and salt waters is a defining feature of estuaries. The way that these two sources of waters mix within an estuary defines not only where the upstream limit of an estuary is, but also the types of plant and animal that are able to live in different parts of that estuary. Other aspects of water quality are also important for biota – the availability of essential requirements such as oxygen, carbon and nutrients varies within and between estuaries across both space and time. The presence of pollutants at different times and places

can also have large effects on plants and animals. Processes associated with the movement and transformation of these substances is a major determinant of the distribution and composition of ecological communities in estuaries.

In a nationwide audit of estuaries in 2001, the condition of Curdies estuary was rated as modified on the basis of elevated sedimentation (see Section 4.2) and nutrient inputs (National Land and Water Resources Audit, 2002). High nutrient inputs from the catchment were considered to be a cause of algal blooms in the estuary in 1991, 1998, 2001 and 2003. Concern about nutrient levels and algal blooms led to a targeted ecological risk assessment in 2005 (Department of Primary Industries and Department of Sustainability and Environment, 2005). A range of studies have measured water quality in the Curdies estuary (Table 7). Data from these studies provides the basis for the following sections.

Table 7.
Water quality sampling details from previous studies: sal: salinity; temp: temperature; DO: dissolved oxygen; redox: redox potential; Secchi: Secchi depth; turb: turbidity; TSS: total suspended solids. Brackets indicate parameters sampled for a subset of sites or times.

Study	Sampling Period & Frequency	Locations	Parameters
Lucas, 1990	Mar-Sept 1989 monthly	2 along estuary (1 depth profile)	sal, temp, DO, pH, Secchi, TSS, nutr
Pearce, 1994	11 April 1994 one-off	8 along estuary (5 depth profiles)	sal, temp, DO, nutr
EPA, unpub. data	Sept 1999 – Apr 2003 6 monthly	1 depth profile at Boggy Creek	sal, temp, DO, pH, redox, turb, nutr
Maher, 2001	Mar-August 2001 monthly	9 along estuary (9 depth profiles)	sal, temp, DO, (pH), Secchi, TSS, nutr
Mondon *et al.*, 2003	March & August 2002 two-off	3 along estuary (surface and bottom))	sal, temp, DO, nutr
Arundel, 2003	Oct 1998 – April 2001 monthly	2 near mouth (3 depth profiles)	sal, temp, DO
Barton, 2006	December 2002 one-off	3 along estuary (3 depth profiles)	sal, temp, DO, pH, redox, Secchi

4.5.1 Salinity Structure

The salinity structure of western Victorian estuaries is highly dynamic due to their intermittently-open entrances and variable freshwater inflows, (Arundel, 2003; EEMSS, 2006; Pope, 2006). At different times, waters of an estuary may be relatively homogenous (at any salinity from fresh to marine or greater) or stratified, with the difference in salinity between top and bottom waters ranging from a few salinity units up to the full difference between fresh

and sea water. The depth of the boundary between fresher surface waters and saltier bottom waters also varies through time.

Changes in freshwater flow and the amount of connectivity with the sea through the entrance are the major influences on the salinity structure of intermittent estuaries (Figure 9). The salinity of the Curdies estuary can range from totally fresh during high flows (e.g. salinity throughout estuary <1 on 23/8/2001, Maher, 2001) to slightly greater than seawater in the lower estuary when there is low flow and the entrance is closed (e.g. 36.6 in December 2000, Arundel, 2003). In the upper part of the Curdies estuary stratification is typical, the degree of which increases from low to moderate flows and/or when the entrance is open and marine waters move upstream along the bottom of the estuary channel. As flow further increases, the extent of marine waters moves downstream and upper parts of the estuary become essentially fresh, while during floods the entire estuary can become fresh.

In the lower estuary greater mixing has typically resulted in a more even vertical distribution of salinity than in the upper part of the estuary, where stratification is usual. This is most likely related to limited wind mixing due to the narrow, riverine morphology and greater depths of this part of the estuary.

Compared to other estuaries of the region, the lower part of the Curdies estuary tends to be less stratified (Arundel, 2003). For example, between October 1998 and April 2001 stratification at sites near the mouth of the estuary was observed on only two of 20 sampling occasions. This is most likely a reflection of the influence of two physical factors; first, the more open and shallow nature of the lower estuary compared to the equivalent section of other regional estuaries leading to greater potential for wind mixing; second, the greater frequency of mouth closure leading to longer periods in which residual marine water can mix with fresher overlying waters.

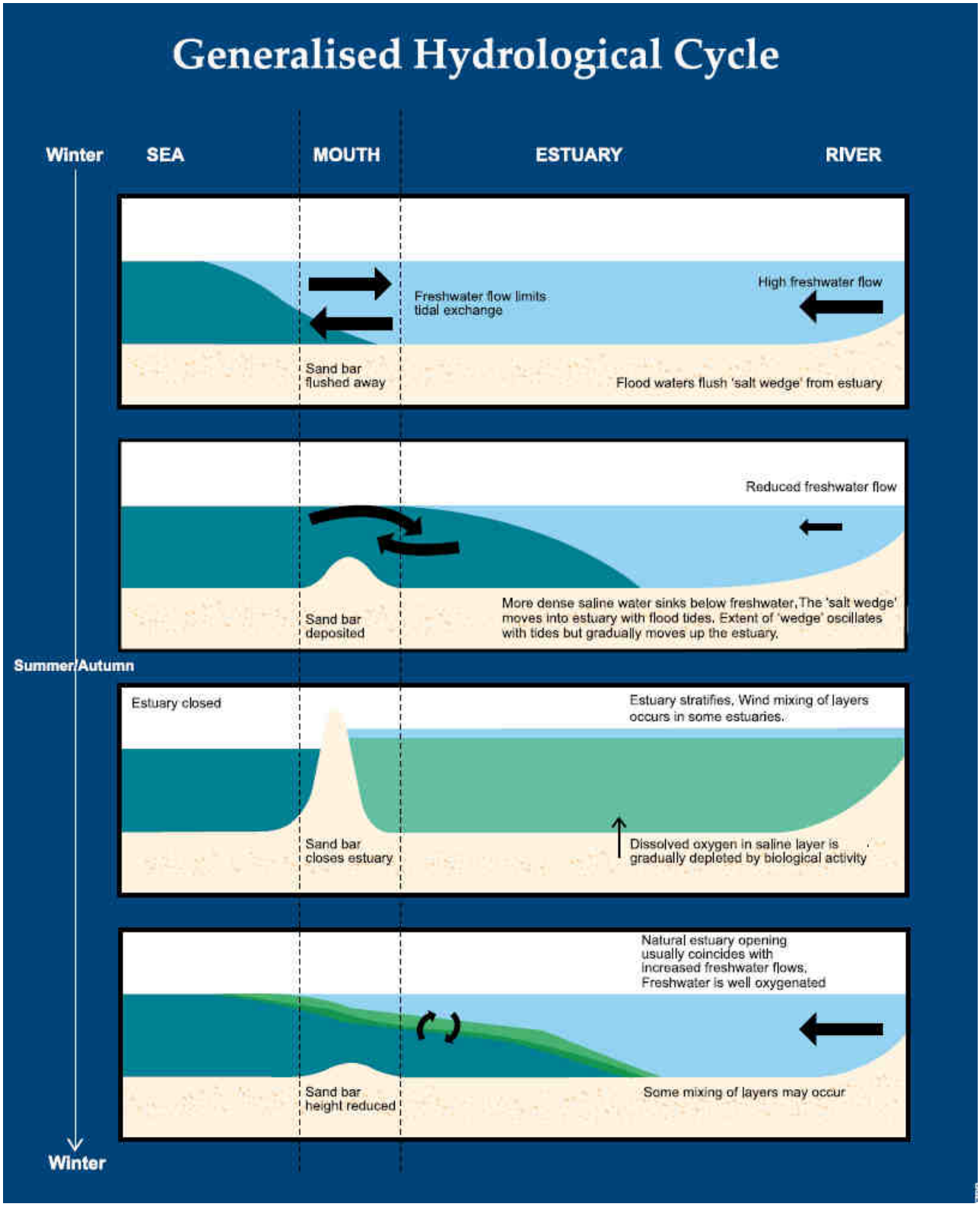

Figure 9. Generalised hydrology of intermittently-open estuaries in Victoria (modified from EEMSS, 2006).

4.5.2 Dissolved Oxygen

Oxygen is a primary requirement of estuarine animals. The atmosphere is the main net source of dissolved oxygen in estuaries (ANZECC and ARMCANZ, 2000). While oxygen is also generated *in situ* by photosynthesis during daylight, much of this is consumed by plant and algal respiration during the night. It is also consumed by animal and microbial respiration, particularly when there is a large amount of decaying organic matter present, as well as by abiotic oxidative chemical reactions. All measurements reported in this section were taken in the daytime and do not reflect potential overnight oxygen minima.

When estuaries are stratified and have little salt-water exchange, depletion of dissolved oxygen is a relatively common phenomenon in bottom waters that are effectively isolated from the atmosphere (Rochford, 1951; Roy et al., 2001). Low dissolved oxygen levels have potential to affect animals directly and via trophic interactions (e.g. Breitburg et al., 1997; Carter, 1994; Eby and Crowder, 2004). Oxygen concentrations can also influence exchange of nutrients, metals and other pollutants between sediments, organisms and the water column (e.g. Carter, 1994; Griscom and Fisher, 2004; Kristiansen et al., 2002). Two main factors influence deoxygenation of bottom waters: time of isolation of bottom waters and oxygen demand within those waters (Rochford, 1974).

In the Curdies estuary, measured oxygen concentrations can vary from almost zero in bottom waters of stratified reaches, to highly supersaturated (>300%) in association with high primary production in warmer months. Both high and low concentrations of dissolved oxygen can have negative ecological effects.

Extremely low concentrations of oxygen (<10% saturation) have been recorded in the riverine section of the estuary and substantial differences in dissolved oxygen between surface and bottom waters have existed with relatively small salinity gradients (Figure 10). The highest concentrations of dissolved oxygen at the Curdievale bridge have been in association with high flows, when all salt water has been flushed from this part of the estuary. The low dissolved oxygen concentrations regularly recorded in his part of the estuary are consistent with elevated organic matter input and decomposition that is potentially exacerbated by high nutrient inputs (see Section 4.5.3).

In the studies examined, maximum concentrations of dissolved oxygen in the bottom waters of the upper estuary never rose to the minimum concentration (80% saturation) specified as a trigger level for southeastern Australian estuaries in national guidelines (ANZECC and ARMCANZ, 2000). Oxygen concentrations in the surface waters of the upper and lower estuary have exceeded both the minimum and maximum guidelines but not to the same degree as bottom waters in the lagoon, where extremely elevated concentrations have been measured (Figure 11).

More extreme values of dissolved oxygen have been measured in the inlet during warmer months of the year, indicating the presence of algal blooms (see Section 4.5.3). Given the extremely high daytime concentration measured in this part of the estuary, there is also a strong likelihood of unrecorded low dissolved oxygen concentrations occurring at night-time. There is also some evidence of bloom conditions in the upper estuary, particularly in early 2001, but to a much lesser degree than in the lagoon. The ANZECC guidelines are conservative for Victorian estuaries, and even estuaries with the least modified catchments regularly exceed guidelines (Barton, 2006). Concentrations in the Curdies however, are indicative of degraded water quality.

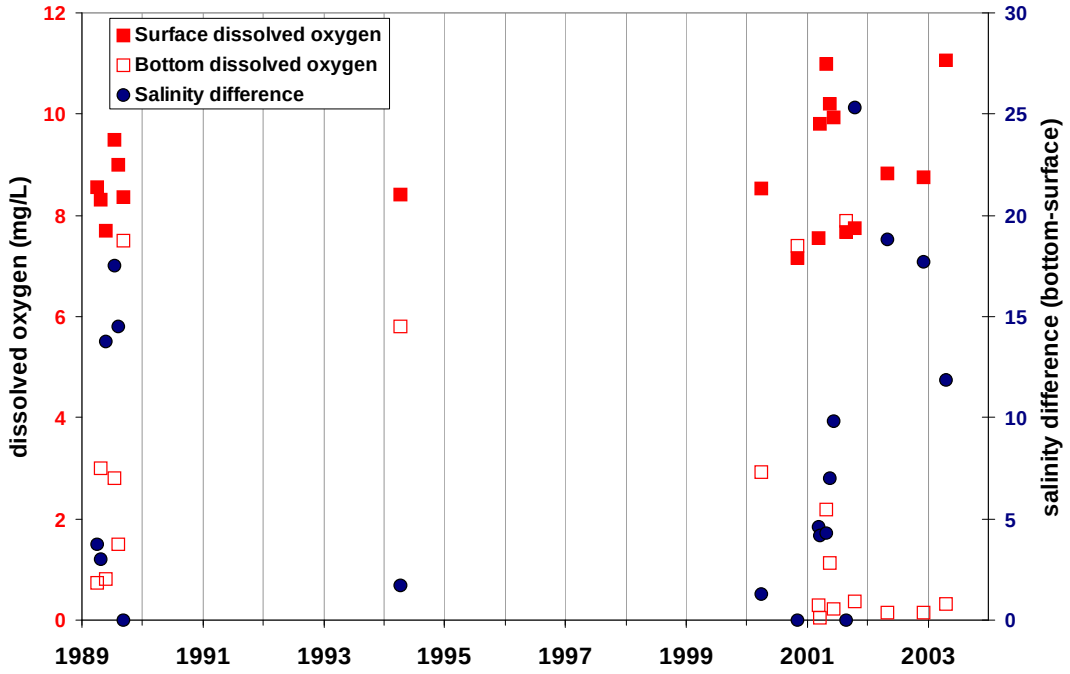

Figure 10. Vertical differences in dissolved oxygen and salinity in the upper section of the Curdies estuary. (Data from Barton, 2006, EPA unpub. data; Lucas, 1990; Maher, 2001; Pearce, 1994)

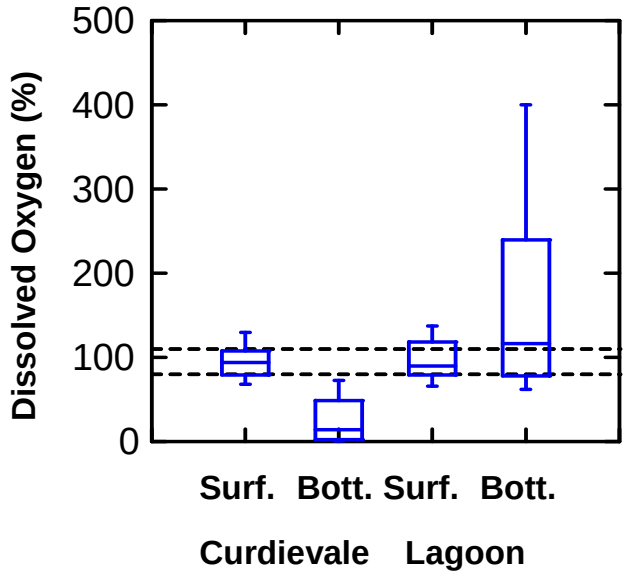

Figure 11. Dissolved oxygen in the Curdies estuary for surface (surf.) and bottom (bott.) waters at Curdievale and in the lagoon. Dashed lines indicate the range recommended as guidelines for southeastern Australian estuaries (ANZECC and ARMCANZ, 2000). (Data from Barton, 2006, EPA unpub. data; Lucas, 1990; Maher, 2001; Pearce, 1994).

4.5.3 Nutrients and Algal Blooms

Algal blooms are a frequent occurrence in the Curdies estuary, with toxic blooms recorded on four occasions (Table 8) and blooms of other species indicated by high dissolved oxygen concentrations in 1994 and 2002. While a range of factors influence these blooms, the high historic and current levels of nutrients entering the estuary were identified as the driving factor in a recent assessment of the Curdies system (Department of Primary Industries and Department of Sustainability and Environment, 2005).

Table 8.
Toxic algal blooms reported in the Curdies estuary. Sources: Maher, 2001, J. Sherwood Deakin University, pers. comm., Warrnambool Standard.

Dates Reported	Species
March 1991	*Anabaena sp.*
April-at least June 1998	*Microcystis sp.*
March-April 2001	*Nodularia spumigena*
July-August 2003	*Nodularia spumigena*

Total nitrogen and phosphorus concentrations upstream of the estuary have consistently exceeded State objectives (Environment Protection Authority, 2001). Sources of nutrients to the estuary identified in the DPI assessment include runoff from farms, dairy effluent, stock access to waterways, erosion, and sewage systems in Cobden, Timboon and Peterborough. Stormwater from towns is another potential source of nutrients to the estuary. For Peterborough, septic sources, building sites, land development and upstream flows were rated as high to very high threats to Curdies Inlet (Kellogg Brown & Root Pty Ltd, 2003b). Since that assessment, construction of a sewage system at Peterborough has begun. For Timboon and Cobden, septic and sewage inputs were not considered a high threat, but runoff from industrial areas was listed as a high threat to instream habitat in both locations (Kellogg Brown & Root Pty Ltd, 2003a). A recent assessment of upstream nutrient and sediment since the cessation of sewage inputs from Cobden in 2000 has identified the Scotts Creek/Cooriemungle subcatchment as the source of around 80% of the nutrient and sediment load to the river at Curdievale (Andrew Smith, University of Melbourne, pers. comm.).

High nutrient levels in the estuary provide a basis for algal blooms but weather, entrance, flow, sediment, salinity, oxygen and biological conditions all affect when a bloom occurs and the nature of that bloom. A conceptual model of these factors was produced by DPI and DSE (2005). A factor that should be added to that model is the effect of grazers, a potentially important but often overlooked aspect in the dynamics of algal blooms (Heck and Valentine, 2007). Values that are likely to be affected by algal blooms and excessive growth include declines in bird, fish and macrophyte communities through both direct effects of toxic blooms and indirect effects of deoxygenation and shading (Department of Primary Industries and Department of Sustainability and Environment, 2005). The models of causes and effects of algal blooms and excessive growth in Curdies Inlet provide a framework for understanding eutrophication in the estuary, but do not provide quantitative information that can be used to set targets and to assess the relative effectiveness of control measures.

4.5.4 Objectives and Recommended Management Actions for Water Quality

Objective WQ1: ***Develop appropriate management targets***

Code	Recommended Action	Priority
WQ1.1	Endorse/review management targets specified in River Health Strategy and nutrient risk assessment, recognising that high levels of nutrients will remain in sediments for years to come	M

Objective WQ2: ***Understand how Curdies estuary works and how to improve its condition***

Code	Recommended Action	Priority
WQ2.1	Develop water quality monitoring program to measure the effectiveness of management actions and identify any new threats and report monitoring results.	M
WQ2.2	Conduct baseline monitoring of the condition of the estuary particularly aquatic and riparian vegetation including sediment quality. Report monitoring results	VH
WQ2.3	Investigate the effects of changes in water quality with flow (special circumstances/ events based) on flora and fauna.	H
WQ2.4	Investigate the effects of changes in sediment load and flow on levels of estuarine sedimentation and depth	VH
WQ2.5	Install logging nutrient and sediment/turbidity meters upstream of the estuary in combination with broader monitoring program	H

Objective WQ3: ***Reduce nutrient inputs, improve water quality and reduce the risk of algal blooms***

Code	Recommended Action	Priority
WQ3.1	Implement a nutrient reduction program and quantify sources of nutrients, causes and effects of algal blooms	VH
WQ3.2	Develop integrated and flexible management of flow, mouth openings and eutrophic conditions	H
WQ3.3	Implement Corangamite and Moyne Stormwater Management Plans	VH
WQ3.4	Investigate options for active remediation of sediments such as dredging and containment	L

4.6 Vegetation

Plant communities are described and mapped in Victoria as Ecological Vegetation Classes (EVCs). EVCs within estuaries have an important function as sediment filters, nutrient recyclers, and habitat for a range of invertebrate, fish and bird species.

EVCs both in and surrounding the estuary will be affected by changed water levels and salinity associated with entrance condition and freshwater discharge and in the longer term, sea level rise. EVCs occur at different heights in the estuary, which generally reflects the hydrological requirements, or tolerances of the plant species in terms of periods of inundation and salinity levels. Because these conditions change over time, it is essential that EVCs are able to establish at levels that satisfy these requirements.

The EVCs mapped adjacent to the Curdies estuary include estuarine wetland, reed swamp and riparian forest (Figure 12). The stand of estuarine wetland at the Curdies Inlet is noted as one of the largest in south-east Australia (J. Yugovic pers. comm. in Centre for Environmental Management University of Ballarat (2005)). Small stands of Estuarine Flats Coastal Tussock Grassland were also noted to occur in the Curdies inlet but the extent is below the mapping threshold (Ibid.).

Extensive Seagrass meadows (EVC 845) and non-vegetated e.g. intertidal mudflats (EVC 990) were identified and estimated to be 0.35 km^2 and 0.24 km^2 respectively. The area of both was estimated from aerial photos and/or satellite images as part of the National Land and Water Resources Audit but no ground truthing was undertaken (Saenger and Bucher, 1989). The Audit also noted 1.58 km^2 of saltmarsh (EVC 009). The occurrence of this EVC is not noted on the Biodiversity Interactive database or in the Corangamite Native Vegetation Plan (CCMA, 2005). Saltmarsh has been identified as an important habitat for Orange-bellied parrots, a critically endangered species (see Section 4.7)

The EVC descriptions do not reflect current EVC typology (Yugovic, J pers comm.). Estuarine Wetland has recently been split into Estuarine wetland (EVC 10 *Juncus*); Estuarine Reedbed (EVC952 *Phragmites*) and Brackish Sedgeland (EVC 13 *Gahnia* and *Bolboschoenus*); and Coastal Tussock grassland (EVC 163) has been split into Estuarine Flats Grassland (EVC 914) and Brackish Grassland (EVC 934). See Appendix 2 for descriptions of the revised estuarine EVCs.

The bioregional conservation status of each EVC identified as occuring in the Curdies estuary or surrounds is presented in Table 9. Swamp scrub is recognised as a priority EVC for protection in the Corangamite Region because there is both less than 15% of its pre 1750 extent and less than 30% of the EVC occurs in land managed for conservation (CCMA, 2005) (Appendix 3).

Table 9.
Warrnambool Plain Bioregion. EVC conservation status. Source (CCMA, 2005)

EVC Description	EVC Bioregional Conservation Status
Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Vulnerable
Estuarine Wetland	Endangered
Lowland Forest	Vulnerable

Riparian Forest	Vulnerable
Herb-rich Foothill Forest	Vulnerable
Swamp Scrub	Endangered
Reed swamp	Endangered
Damp Heath Scrub	Vulnerable
Damp Heathland/ Damp Heathy Woodland Mosaic	Endangered
Damp Heath Scrub/ Heathy Woodland Complex	Vulnerable

While mapping provides a measure of the extent of each EVC, no studies were located which described the condition of the EVCs occurring on the Curdies estuary. The quality of vegetation is usually assessed in Victoria using a 'Habitat Hectares' approach (CCMA, 2004; Parkes et al., 2003). This method compares the vegetation to undisturbed, mature 'benchmark' communities and takes into account factors such as invasion of weed species, species composition, recruitment levels, patch size and connectivity of vegetation in the landscape.

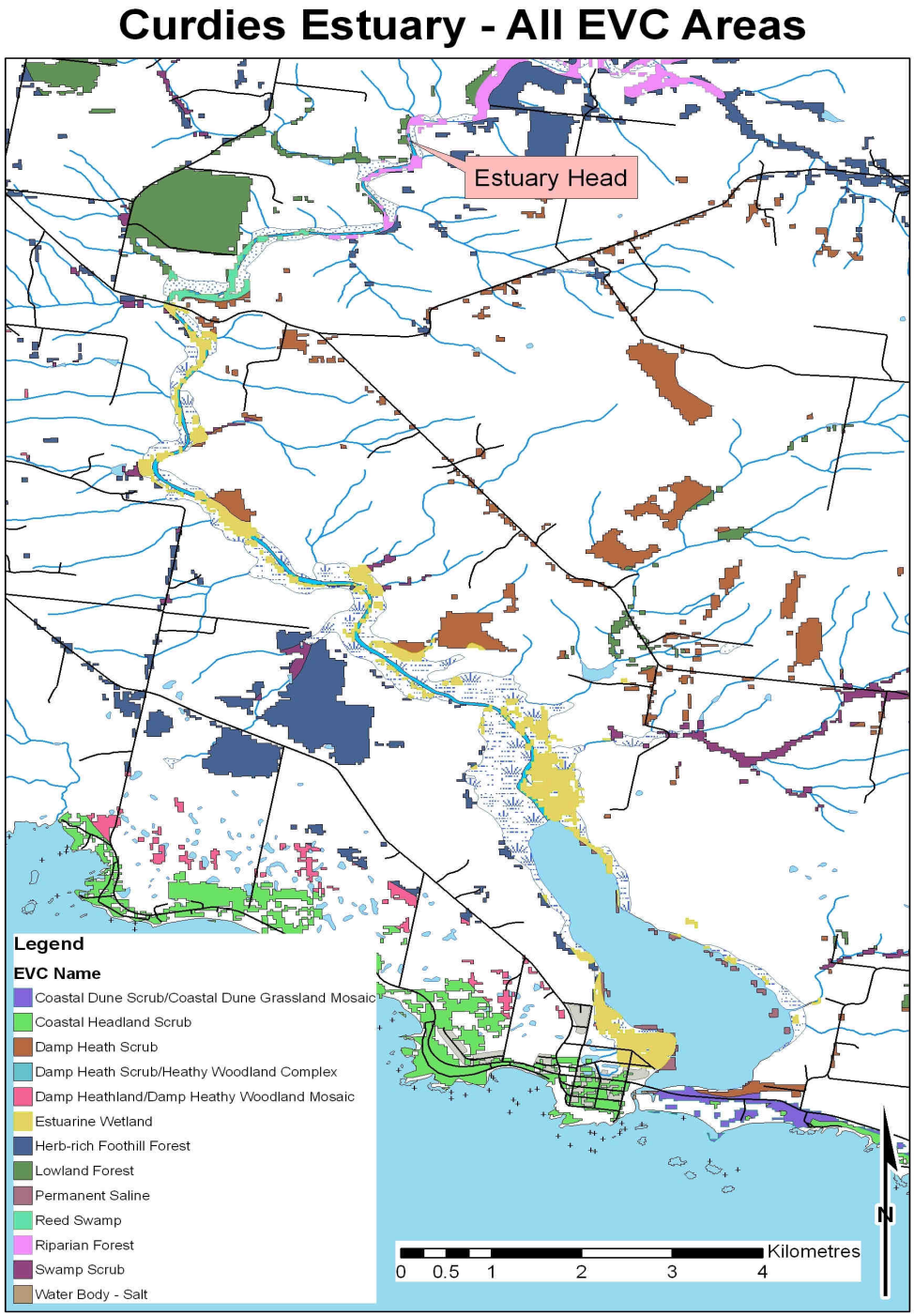

Figure 12. EVCs of Curdies estuary and surrounding area.

4.6.1 Threatened plant species

Several rare and threatened species are recorded in the vicinity of the Curdies estuary (CCMA, 2004; EEMSS, 2006)(Table 10). No information was available about the specific location or size of populations of threatened plant species. Protection of these species is generally best achieved by managing the threats to the EVCs with which each species is associated.

Table 10.
Threatened plant species and EVCs with which they are commonly associated. See Appendix 1 for key to symbols

Scientific Name	Common name	VROTS	FFG	EPBC	EVC
Atriplex paludosa subsp. paludosa	Marsh Saltbush	r			Coastal Saltmarsh
Lawrencia spicata	Salt Lawrencia	r			Coastal Saltmarsh
Limonium australe	Yellow Sea-lavender	r			Coastal Saltmarsh
Triglochin minutissima	Tiny Arrowgrass	r			Coastal Saltmarsh
Pterostylis tenuissima	Swamp Greenhood	v		VU	Swamp Scrub/ Estuarine Scrub interface
Pterostylis cucullata	Leafy greeenhood	v		VU	-
Lepidium aschersonii	Spiny Peppercress	e	L	VU	Brackish grassland; Coastal saltmarsh
Lepidium hyssopifolium	Basalt Peppercress	e	L	EN	Brackish Wetland
Monotoca glauca	Currant-wood	r			-
Haloragis exalata ssp exalata var. exalata	Square raspwort	v		VU	-

4.6.2 Objectives and Recommended Management Actions for Vegetation

Objective V1: ***Protect and enhance the extent and condition of EVCs associated with the estuary***

Code	Recommended Action	Priority
V1.1	Map the extent of EVCs (instream, emergent and terrestrial) at a scale of not less than 1:10 000	H
V1.2	Assess the condition of each EVC	H
V1.3	Identify and map any rare or threatened species of flora	M
V1.4	Implement management strategies to protect rare and threatened species identified in mapping (eg species in Table 10)	H
V1.5	Investigate opportunities to protect extent and condition of EVCs ensuring ongoing maintainence. This could include fencing and stewardship programs such as bush tender	M
V1.6	Implement management strategies to protect EVCs. Ensure management strategies are appropriate for the EVC and location on estuary (see also F1.8)	H
V1.7	Encourage research into EVCs, vegetation change and management options - eg. Die back of tussock grass, changing flower regimes, islands on the estuary	L
V1.8	Establish a friends group of the Curdies Inlet and Lower Curdies Landcare group (as also for F1.12 and PPA 1.4)	H
V1.9	Provide ongoing information and education opportunities to land managers and land owners on vegetation communities, threats, rare & threatened species and management options	VH
V1.10	Implement Environmental Significance Overlays for Moyne and Corangamite planning schemes to protect the values of the Curdies Estuary/ Inlet	H

4.7 Fauna

The species lists presented in this report are generated from a variety of sources. It should be noted that the number of species will be influenced by the survey effort and the timing of surveys. This is particularly important for migratory bird and fish species.

Information is often not provided on when the species were recorded. Some records may therefore no longer be applicable or other species may be detected if the area was surveyed now

Individual species requirements and potential threats to those species are discussed if they are recognised as threatened under the Flora and Fauna Guarantee Act 1988 or if they are a commercial fish species e.g. short-finned eels.

4.7.1 Fish

A range of fish species utilise estuaries. Species can be grouped according to their reliance on the estuary and life history stages which use the estuary (Figure 13). Some species (e.g. Australian Salmon) are mainly marine but will enter the estuary when salinity levels are suitable. Other species are considered freshwater (e.g. pygmy perch) but will move into the estuary when salinity levels are low. Several species require the estuary to migrate between freshwater and marine waters (e.g. eels and galaxiids). While yellow-eye mullet juveniles often utilise seagrass beds in estuaries, this is not a requirement of their life history. A few species (e.g. black bream and estuary perch) use the estuary for all stages in their life history i.e. spawning, juveniles and adults. The shallow water in adjoining wetlands and inundated vegetation at the edge of the estuary provides important foraging habitat and a refuge from predators for juvenile fish of many species.

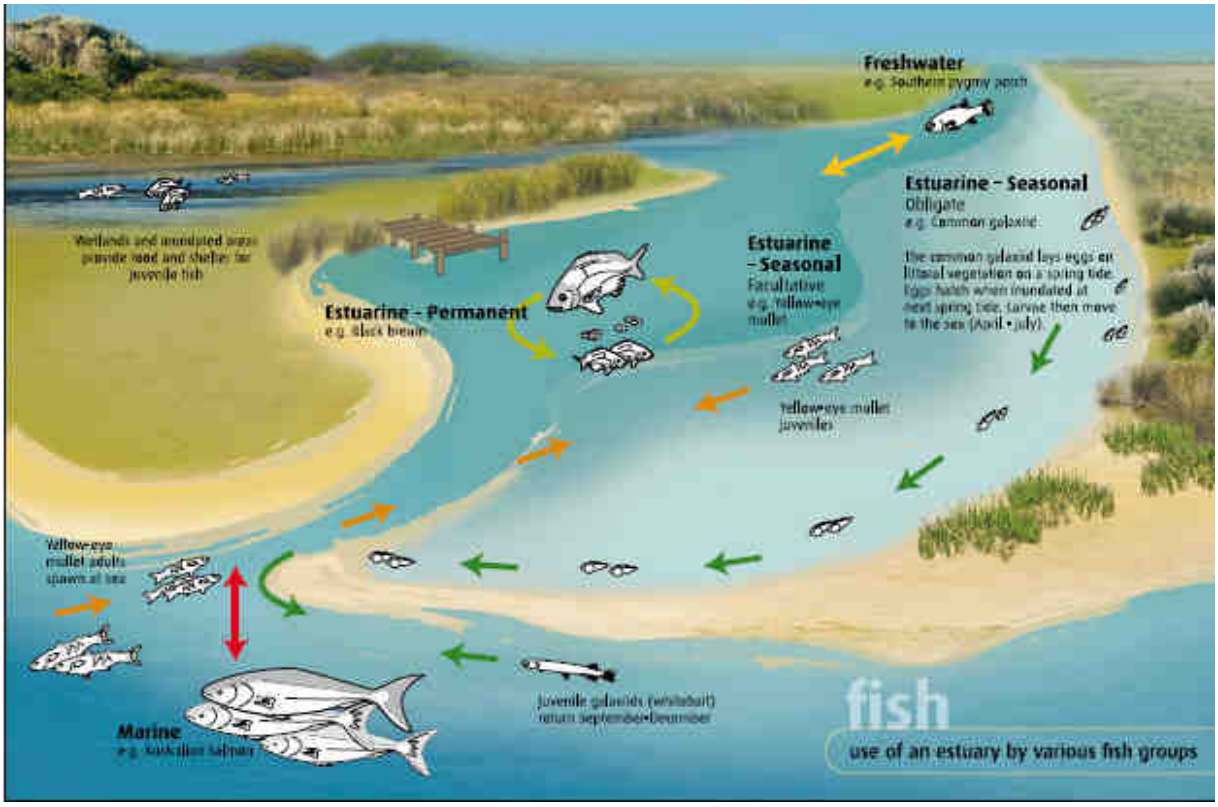

Figure 13. Estuarine Fish Groups. Source (EEMSS, 2006; McCarraher, 1986)

Eighteen fish species have been recorded from the Curdies estuary (Table 11). The list is compiled from a survey using a variety of methods conducted in 1975 (McCarraher, 1986). Yarra pygmy perch was not recorded at that time, but is recorded on the Department of Sustainability and Environment database (Barton and Sherwood, 2002). In February 2006, 2 sites in the inlet were surveyed using a 60 m fine-mesh seine haul (T. Raadick pers comm.). The results of this survey are not yet available.

Table 11.
Fish species and their conservation status (Barton and Sherwood, 2002). See Appendix 1 for key to symbols

Common Name	Scientific Name	TVF	FFG	EPBC
Tommy Ruff	*Arripis georgianus*			
Australian Salmon	*Arripis spp*			
Australian Smelt	*Retropinna semoni*			
Yarra Pygmy Perch	*Nanoperca obscura*	vu	L	VU
Short-finned Eel	*Anguilla australis*			
Long-finned Eel	*Anguilla reinhardtii*			
Common Galaxias	*Galaxias maculatus*			
Yellow-eye Mullet	*Aldrichetta forsteri*			
Long-nosed Flounder	*Ammotretis rostratus*			
Luderick	*Girella tricuspidata*			
Blue-spot Goby	*Pseudogobius olorum*			
Bridled Goby	*Arenigobius bifrenatus*			
Tamar Goby	*Afurcagobius tamarensis*			
Small-mouthed Hardyhead	*Atherinosoma microstoma*			
South Australian Cobbler	*Gymnapistes marmoratus*			
Black Bream	*Acanthopagrus butcheri*			
Estuary Perch	*Macquaria colonorum*			
Smooth Toadfish	*Tetractenos glaber*			

Yarra Pygmy Perch

The Yarra pygmy perch is recognised as vulnerable at both a state and national level. The range of the species is restricted to south west Victoria from Geelong to the South Australian Border. The species prefers small creeks or lakes with slow flowing or still water and abundant aquatic vegetation. They have been recorded from both fresh and brackish water. Spawning occurs during September to October but little is known of the species' biology (Cadwallader and Backhouse, 1983; Department of Primary Industries, 1998).

Short-finned Eels

Adult short-finned eels leave the estuary during summer and autumn to spawn near the Coral Sea. Juveniles, known as glass eels, return to estuaries around spring tides during winter and spring. Tidal movement is used to assist migration to freshwater reaches. Glass eels and brown elvers are able to climb wet vertical surfaces to reach lakes and the upper reaches of rivers. Short-finned eels can take many years to reach maturity. Males may not leave freshwater for the sea until 8-12 years of age and females until 10-20 years of age (Koehn and O'Connor, 1990).

4.7.2 Birds

One hundred and thirty species of birds have been recorded from the Curdies River estuary. Of these, 23 species have a conservation status (Table 12). The high number of species recorded reflects the survey effort to some extent but also indicates the range and size of habitats available in the Curdies compared with many smaller estuaries in south west Victoria.

Some of the species listed have a strong association with estuaries and regularly use these environments for breeding and feeding. Other species do not have a strong affiliation with estuaries and were probably recorded while transiting the area. The occurrence of waterbirds at coastal locations also depends on the extent of appropriate inland habitat.

The Curdies estuary provides a variety of habitats such as extensive areas of open water of varying depth, mudflats, vegetated areas and sandy shore at the entrance. The extent of these habitats varies during the year with water level fluctuations in the estuary. Each habitat will be utilised by different groups of birds. This is generally determined by a species preferred depth for feeding. For example, divers (e.g. cormorants and grebes) generally require deeper water than dabblers (e.g. swans and pelicans) and surface feeders (e.g. Australasian shovellers) (EEMSS, 2006). While spoonbills and sandpipers feed on mudflats, vegetation adjacent to the mudflats is also utilised as roosting sites for these species. Other species such as bitterns and ibis are more strongly associated with the vegetated margins of the estuary.

Raptors such as swamp harriers and white-bellied sea eagles prey on fish or waterbirds and prefer to nest near or over water. Ravens are also important predators often seen at estuary mouths. Species such as plovers and oystercatchers are generally associated with the sandy beach area at the estuary mouth

FFG listed species

Eleven species recorded from the Curdies are listed under the FFG Act. Although widespread throughout Australia, the intermediate, great and little egrets are more commonly found in association with larger freshwater systems such as the Murray Darling Basin and tropical wetlands. Australasian bitterns are also widespread but uncommon across south-eastern Australia. They generally favour freshwater wetlands with tall vegetation. Species recorded that may require specific local management responses around Curdies estuary are orange–bellied parrot, rufous bristlebird, white-bellied sea eagle and hooded plovers. These are discussed in more detail below

Orange-bellied Parrot

The orange-bellied parrot is considered critically endangered with only approximately 180 mature birds remaining in the wild. The birds breed in south west Tasmania and migrate to the mainland in April and return to Tasmania in September. In Victoria the species is often

associated with saltmarshes dominated by beaded glasswort (*Sarcocornia quinqueflora*) and shrubby glasswort (*Sclerostegia arbuscula*), as well as grassy or weedy pastures[6].

Both National (Orange-bellied Parrot Recovery Team, 1998) and State (Edgar and Menkhorst, 1993) plans exist to direct management actions for the recovery of the species. The DSE and GHCMA are currently undertaking a NHT project to improve protection and management of the bird's winter habitat. The project involves intensive searches of potential habitat across the state, including the Curdies Inlet. This will enable the characteristics of suitable habitat to be described . Information collected will inform future management plans for the species.

Rufous Bristlebirds

Rufous bristlebirds are ground dwelling birds that nest close to the ground in low shrubs or tussocks. They are poor fliers and their range is restricted in Victoria to a narrow coastal strip from Pt Addis to the Glenelg River with a large gap in distribution around Warrnambool (Department of Sustainability and Environment, 2003). Their specific habitat requirements are unknown but they are generally associated with patches of dense vegetation in coastal scrub or heavily vegetated gullies.

The reduction and fragmentation of suitable habitat is considered to be a threatening process in the Otway region. This includes clearing for housing, slashing heathland, removal of ground litter and controlled burning to remove undergrowth. Predators such as cats, foxes and rats may also be contributing to the decline in species numbers.

The major conservation objective is to prevent further decline in population density and further fragmentation of Rufous Bristlebird habitat and populations (Department of Sustainability and Environment, 2003). The Action Statement for this species identifies specific actions to achieve each of the following objectives.

• identify the ecological requirements of the species;

• identify gaps in suitable habitat and establishing habitat corridors between populations to allow dispersal to occur, particularly between coastal and inland populations; and

• minimise the impact of threatening processes such as introduced predators, inappropriate fire regimes and excessive removal of habitat around human habitation.

White-bellied sea eagle

No action statement has been developed for this species in Victoria. Information is sourced from the Parks and Wildlife Service Tasmania (2003)

The white-bellied sea eagle is distributed from SE Asia to Australia in coastal and near coastal areas. They feed on fish, waterbirds and carrion.

Nests are often built in large eucalypts. These are used for roosting and breeding (May to October) and as feeding platforms. Birds form permanent pairs that defend the territory around the nest tree.

A pair of sea eagles has been recorded nesting and breeding in farmland adjacent to the Curdies estuary.

Hooded Plovers

Several bird species, including hooded and red-capped plovers and sooty and pied oystercatchers, nest directly on the beach or in the dunes. The nests are simple scrapes in the

[6] Birds Australia - http://www.birdsaustralia.com.au/birds/obp.html

sand and eggs are well camouflaged. Therefore, during the breeding season (August to February), the species are extremely sensitive to the impacts of recreational beach use and predation from introduced and native predators. Hooded plovers have only a 20-24% chance of survival during the egg and chick phases[7].

Beach activities such as horse riding, fishing and walking dogs can directly impact on birds, resulting in trampling of chicks and eggs. Human disturbance can cause adult birds to temporarily abandon nests leaving chicks and eggs vulnerable to temperature variation or predation from ravens, gulls, cats and foxes. Birds can also become entangled in litter, particularly fishing line.

Port Phillip and Westernport Catchment Management Authority with Corangamite CMA and Birds Australia are coordinating a NHT funded research project to assess the effectiveness of a variety of management measures designed to protect nesting birds. Management options being investigated include community education programs, improved designation of "on and off leash" dog walking areas, temporarily fencing nesting sites, interpretive signs at beach access points, fox control programs, placement of chick shelters, and weeding (Maguire, 2007).

A manual will be developed to provide community groups and agencies responsible for managing people and birds on beaches, with guidelines for monitoring and managing beach-nesting birds. While active means of protecting nests and chicks are still being explored, it is essential that community education be carried out at sites where these birds regularly nest to complement these actions and that strict dog leashing regulations be enforced within the breeding months.

Depending on the nest location relative to the entrance, artificially opening the estuary can potentially have a positive or negative impact on beach-nesting birds. Opening can destroy nests at the entrance. However an open estuary may restrict access to the nests adjacent to the mouth. The impact needs to be assessed at the time of deciding whether or not to open an estuary.

[7] http://www.birdsaustralia.com.au/projects/beach_nesting.html

Table 12
Conservation status of bird species from the Curdies estuary and surrounds Source: Sou'west Victoria Birdlife Register 2008. See Appendix 1 for key to symbols. ** indicates introduced species.

Common name	Scientific Name	TVF	FFG	EPBC	CAMBA JAMBA
Stubble Quail	*Coturnix pectoralis*				
Musk Duck	*Biziura lobata*	VU			
Black Swan	*Cygnus atratus*				
Cape barren Goose	*Cereoptsis novaeholandiae*				
Australian Shelduck	*Tadorna tadornoides*				
Australian Wood Duck	*Chenonetta jubata*				
Pacific Black Duck	*Anas superciliosa*				
Australasian Shoveler	*Anas rhynchotis*	VU			
Grey Teal	*Anas gracilis*				
Chestnut Teal	*Anas castanea*				
Pink-eared Duck	*Malacorhynchus membranaceus*				
Hardhead	*Aytya australis*	VU			
Australasian Grebe	*Tachybaptus novaehollandiae*				
Hoary-headed Grebe	*Poliocephalus poliocephalus*				
Great-crested Grebe	*Podiceps cristatus*				
Spotless Crake	*Porzana tabuensis*				
Black-faced Shag	*Leuoccarbo fuscescens*				
Darter	*Anhinga melanogaster*				
Little Pied Cormorant	*Phalacrocorax melanoleucos*				
Pied Cormorant	*Phalacrocorax varius*	NT			
Little Black Cormorant	*Phalacrocorax sulcirostris*				
Great Cormorant	*Phalacrocorax carbo*				
Australian Pelican	*Pelecanus conspicillatus*				
White-faced Heron	*Egretta novaehollandiae*				
Little Egret	*Egretta garzetta*	CR	L		
White-necked Heron	*Egretta*				
Great Egret	*Ardea alba*	EN	L		CJ
Intermediate Egret	*Ardea intermedia*		L		
Cattle Egret	*Ardea ibis*				CJ
Nankeen Night Heron	*Nycticorax caledonicus*	VU			
Australasian Bittern	*Botaurus poiciloptilus*	EN	L		
Australian White Ibis	*Threskiornis molucca*				
Straw-necked Ibis	*Threskiornis spinicollis*				

Common name	Scientific Name	TVF	FFG	EPBC	CAMBA JAMBA
Royal Spoonbill	*Platalea regia*				
Yellow-Billed Spoonbill	*Platalea flavipes*				
Osprey	*Pandion haliaetus*				
Black-shouldered Kite	*Elanus axillaris*				
Whistling Kite	*Haliastur sphenurus*				
White Bellied Sea Eagle	*Haliaeetus leucogaster*	VU	L		C
Swamp Harrier	*Circus approximans*				
Brown Goshawk	*Accipiter fasciatus*				
White Goshawk	*Accipiter novaehollandiae*	VU	N		
Collared Sparrowhawk	*Accipiter cirrhocephalus*				
Wedge-tailed Eagle	*Aquila audax*				
Brown Falcon	*Falco berigora*				
Australian Hobby	*Falco lingipennis*				
Peregrine Falcon	*Falco peregrinus*				
Nankeen Kestrel	*Falco cenchroides*				
Brolga	*Grus rubicunda*	VU	L		
Buff-banded Rail	*Gallirallus philippensis*				
Lewin's Rail	*Rallus pectoralis*	VU	L		
Australian Spotted Crake	*Porzana fluminea*				
Magpie Goose	*Anseranas semipalmata*	EN	N		
Purple Swamphen	*Porphyrio porphyrio*				
Dusky Moorhen	*Gallinula tenebrosa*				
Black-tailed Native Hen	*Gallinula ventralis*				
Eurasian Coot	*Fulicia atra*				
Blue-billed Duck	*Oxyura australis*	VU	L		
Lathams Snipe	*Gallinago hardwickii*				J
Bar-tailed Godwit	*Limosa lapponica*				CJ
Eastern Curlew	*Numenius madagascariensis*				CJ
Common Greenshank	*Tringa nebularia*				CJ
Ruddy Turnstone	*Arenaria interpres*				CJ
Red Knot	*Calidris canutus*				CJ
Sanderling	*Calidris alba*	NT			CJ
Red-necked Stint	*Calidris ruficollis*				CJ
Sharp-tailed Sandpiper	*Calidris acuminata*				CJ
Curlew Sandpiper	*Calidris ferruginea*				CJ
Pied Oystercatcher	*Haematopus longirostris*				
Sooty Oystercatcher	*Haematopus fuliginosus*	NT			

Common name	Scientific Name	TVF	FFG	EPBC	CAMBA JAMBA
Black-winged Stilt	*Himantopus himantopus*				
Banded Stilt	*Cladorhynchus leucocephalus*				
Pacific Golden Plover	*Pluvialis fulva*				CJ
Grey Plover	*Pluvialis squatarola*				CJ
Red-capped Plover	*Charadrius ruficapillus*				
Double-banded Plover	*Charadrius bicinctus*				
Hooded Plover	*Thinornis rubricollis*	EN	L		
Red-kneed Dotterel	*Erythrogonys cinctus*				
Masked Lapwing	*Vanellus miles*				
Pacific Gull	*Larus pacificus*	NT			
Silver Gull	*Larus novaehollandiae*				
Franklins Gull	*Leucophaeus pipixcan*				
Caspian Tern	*Sterna caspia*	NT			C
Crested Tern	*Sterna bergii*	NT			J
Whiskered Tern	*Chlidonias hybridus*	NT			
Brush Bronzewing	*Phaps elegans*				
Yellow-tailed black cockatoo	*Calyptorhyncus funereus*				
Galah	*Cacatus roseicapilla*				
Long-billed Corella	*Cacatus tenuirostris*				
Crimson Rosella	*Platycerus elegans*				
Blue-winged Parrot	*Neophema chrysotoma*				
Orange-bellied Parrot	*Neophema chrysogaster*	CR	L	EN	
Shining bronze cuckoo	*Chrysococcyx lucidus*				
Barn Owl	*Tyto alba*				
Powerful Owl	*Ninox strenua*				
Fork-tailed Swift	*Apus pacificus*				
Laughing Kookaburra	*Dacelo novaeguineae*				
Superb Fairy Wren	*Malurus cyaneus*				
Southern Emu wren	*Stipiturus malachurus*				
White-browed Scrubwren	*Sericornis frontalis*				
Rufous bristle bird	*Dasyornus broadbenti*	NT	L		
Striated Fieldwren	*Sericornis fuliginosus*				
Brown Thornbill	*Acanthiza pusilla*				
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*				
Little Wattlebird	*Anthochaera chrysoptera*				

Common name	Scientific Name	TVF	FFG	EPBC	CAMBA JAMBA
Singing Honeyeater	*Lichenostomus virescens*				
White-eared honey eater	*Lichenostemus leucotis*				
New Holland Honeyeater	*Phylidonyris novaehollandiae*				
White-fronted Chat	*Epthianura albifrons*				
Flame Robin	*Petroica phoenicea*				
Grey Shrike-thrush	*Colluricincla harmonica*				
Magpie Lark	*Grallina cyanoleuca*				
Grey Fantail	*Rhipidura fuliginosa*				
Willie Wagtail	*Rhipidura leucophyrus*				
Australian Magpie	*Gymnorhina tibicen*				
Little Raven	*Corvus mellori*				
Skylark	*Alauda arvensis*				
Richards Pipit	*Anthus novaeseelandiae*				
*House Sparrow	*Passer domesticus*				
Red-browed Finch	*Neochmia temporalis*				
*European Goldfinch	*Carduelis carduelis*				
*European Greenfinch	*Carduelis chloris*				
Welcome Swallow	*Hirundo neoxena*				
White-backed Swallow	*Cheramoeca leucosternus*				
Fairy Martin	*Hirundo ariel*				
Little Grassbird	*Megalurus gramineus*				
Golden-headed Cisticola	*Cisticola exilis*				
*Silvereye	*Zosterops lateralis*				
*Common Blackbird	*Turdus merula*				
*Common Starling	*Sturnus vulgaris*				

4.7.3 Mammals

No mammal surveys of the Curdies estuary were located. Species which are recognised as threatened in Victoria and could potentially occur in the habitat types surrounding the Curdies estuary are listed in Table 13.

Table 13
Conservation status of mammal species potentially utilising the surrounds of the Curdies estuary. See Appendix 2 for key to symbols.

Common name	Scientific name	TVF	FFG	EPBC
Swamp antechinus	*Antechinus minimus* ssp *maritimus*	nt	L	
Southern brown bandicoot	*Isodon obesulus*	nt		EN
Broad-toothed rat	*Mastacomys fuscu*	nt		
White-footed Dunnart	*Sminthopsis leucopus*	vu	N	
Long-nosed potoroo	*Potorus tridactylus tridactylus*	vu	N	

Swamp antechinus *Antechinus minimus* ssp *maritimus* is listed under the FFG Act and is classified as near threatened in Victoria. This species is a soil fossicking insectivore that inhabits dense wet heath, tussock grassland or sedgelands (Menkhorst, 1995) and has been recorded from the Port Campbell National Park and Bay of Islands Coastal Park (Parks Victoria, 1998). During a site inspection for this study, a dead specimen of this species was found on the east bank of the inlet (4/08/07). Subsequent hair analysis confirmed the identification as *A. minimus* (C.Belcher pers comm.).

Southern brown bandicoot *Isodon obesulus* is listed as endangered under the EPBC Act and as near threatened in Victoria. They are omnivorous and have been captured in dense tussock and sedgelands associated with wetlands in the Bay of Islands Coastal Park (C. Belcher pers comm.).

Broad-toothed rat *Mastacomys fuscus* are listed as near threatened in Victoria. They are specialist herbivores that inhabit coastal grasslands and heath. They have been recorded from the Port Campbell National Park. Predator scat analysis indicates evidence of predation by cats, foxes and dogs (Parks Victoria, 2007a).

White-footed Dunnart *Sminthopsis leucopus* occurs in the Port Campbell National Park (Menkhorst, 1995) and are classified as vulnerable in Victoria and are nominated for inclusion on the FFG list of threatened species. The species inhabits coastal tussock grasslands and sedgelands and feed on ground- dwelling invertebrates and small reptiles (Menkhorst, 1995).

Long-nosed potoroo *Potorous tridactylus tridactylus* occur in a wide variety of wet forest and scrub habitats with a dense understory. They feed on mycorrhizal fungi associated with the roots of eucalypts (Menkhorst, 1995).

Deployment of 1080 baits in habitat suitable for native mammal species could pose a potential threat to these species. The risk to each species will depend on the presentation of the bait. Whereas carnivorous and ominverous species will consume baits prepared for fox control (McIlroy, 1986; Menkhorst, 1995), herbivores are more at risk from baits used for rabbit control. The food source of potoroos makes them unlikely to consume baits.

4.7.4 Reptiles

No reptile surveys of the Curdies estuary were located. The swamp skink *Egernia covenrtyi*, which is classified as vulnerable in Victoria and listed under the FFG Act is commonly found in wetlands and swampy habitat predominately in coastal areas (Cogger, 2000). This species was recorded from the Bay of Islands Coastal Park (Parks Victoria 1998) and could potentially occur in the surrounds of the Curdies estuary.

4.7.5 Objectives and Recommended Management Actions for Fauna

Objective F1: ***Protect and enhance the biodiversity of native fauna***

Code	Recommended Action	Priority
F1.1	Establish terrestrial and aquatic fauna monitoring program for the study area and specifically:	M
F1.2	• Establish monitoring programs to assess the condition (diversity and health) of native fish populations in the Curdies estuary;	L
F1.3	• Establish monitoring programs to assess the condition of native fish targeted for recreation (e.g. black bream & estuary perch);	L
F1.4	• Liase with Birds Australia to develop a bird monitoring program which includes: diversity of bird species; number of each species time of year; and habitat type utilised (e.g. water depth & veg type); and	M
F1.5	• Encourage participation of community groups such as bird observers and local conservation groups in wildlife surveys.	H
F1.6	Support recommended actions in the 'Orange-bellied parrot Action Statement'	M
F1.7	Implement Birds Australia guidelines for monitoring and managing beach nesting birds and educating public.	M
F1.8	Review needs of habitat management incorporating habitat requirements of threatened species and including an assessment of the need for a burning regime.	M
F1.9	Re-establish, protect and revegetate indigenous habitat species in waterways and catchment	M
F1.10	Undertake an ongoing pest animal and weed control program (Also see PPA 1.3)	H
F1.11	Implement Environmental Significance Overlays for Moyne and Corangamite planning schemes to protect the values of the Curdies Estuary/ Inlet	H
F1.12	Establish a friends group of the Curdies Inlet and Lower Curdies Landcare group (as also forV1.8 and PPA 1.4)	H

4.7.6 Objectives and Recommended Management Actions for Pest Plants and Animals

Objective PPA1: ***Reduce the extent and/or number and prevent the introduction of pest plant and animal species***

Code	Recommended Action	Priority
PPA1.1	Map and monitor occurrence of noxious and environmental weeds and pest animals.	H
PPA1.2	Provide ongoing information and education opportunities to land managers and land owners on pest plant and animal control measures	VH
PPA1.3	Implement pest plant and animal control programs, ensure ongoing maintenance and continuation of existing programs and adapt approach and/ or effort as required using methods that are not detrimental to the environment.	M
PPA1.4	Establish a friends group of the Curdies Inlet and Lower Curdies Landcare group (as also forV1.8 and F1.12)	H

5 ECONOMIC VALUE

5.1 Land value

Since the clearing of the native hardwood forests, agriculture is the principal land use for the Curdies River catchment. Dairying and cattle grazing make up the majority of the agriculture in the area, adding significant value to the local and regional economy. Indeed, the Corangamite Regional Catchment Strategy (DEH and DA, 2004)projects that dairy production is expected to double across the region by 2010 via increased production, larger properties, more mechanisation and enhanced producer/processor relationships and efficiency. Australian Bureau of Statistics data (up to an including 2006) provides the following agricultural statistics for Peterborough:

- Value of Crops $5.8 million
- Value of Livestock Slaughtered $1.2 million
- Value of Livestock $1.8 million
- Total Value of Agriculture Commodities $8.9 million

This represents approximately 3% of the total production value for southern Corangamite, with southern Corangamite contributing 12 % to commodity production for Victoria (DNRE, 2002).

The value of land adjacent to the estuary has dramatically increased in value, particularly if the land has a view of the estuary or coast.

5.2 Tourism

Peterborough is a popular tourist destination along the Great Ocean Road, particularly due to its proximity to the spectacular limestone cliffs of the Bay of Islands Coastal Park and Port Campbell National Park. The coast around the township contains a range of geomorphological features including cliffs, coastal stacks, headlands and beaches. For medium-stay visitors (1 week or more), the Curdies River estuary is a valuable attraction providing a safe swimming environment as well as opportunities for fishing and boating (see Section 6). No data was located which quantified or described activities undertaken by visitors to Peterborough or Curdievale. In particular, the importance of the estuary in attracting visitors to the area or increasing their length of stay is not known.

The Great Ocean Road attracts tourists all year round, however the summer months are the most popular. The current value of tourism to Peterborough has not been calculated specifically. Instead, the accommodation capacity and traffic count data were compiled to provide an indication of tourism potential for this study.

Peterborough has two caravan parks that provide the main source of large volume accommodation. The operators of the two parks were surveyed to determine site capacity and to indicate vacancy rates (Table 14). These data indicate the capacity to accommodate in-excess of 650 people with numbers peaking between Christmas and the end of January.

Table 14. Peterborough accommodation capacity and qualitative indication of useage.

Caravan Park	Site Capacity	Busy Times
Great Ocean Rd Tourist Park	130 sites (520 people)	December 26th to January 31st – full capacity. 4 weeks half capacity.
Peterborough Coastal Caravan Park	36 sites (144 people)	3 Weeks over Christmas – full capacity. 4 weeks – half capacity.

Traffic count data for the Great Ocean Road were sourced from VicRoads (Peter Hill, 2007, pers. comm. 17 July – see Appendix 5) and interpreted alongside the results of local traffic counts conducted by Moyne Shire in Peterborough (Kathleen Gosden, 2007, pers. comm. 6 July). Table 15 presents a summary of this data. The VicRoads data indicate that a similar volume of traffic flows to the popular eastern end of the Great Ocean Road (i.e. Lorne) as reaches the western end (i.e. Warrnambool). However, the Princes Highway (inland) carries the majority of the traffic to Warrnambool, with traffic flow past Peterborough sitting around 30% of this volume. Moyne Shire data indicates smaller local traffic volumes, with the data suggesting that Peterborough is capturing around 20% of the traffic flow as passing trade.

Table 15. Vehicle counts in Peterborough and along the Great Ocean Road

Location	Vehicle Count	Date
VicRoads Data	*AADT#*	
Great Ocean Rd (East of Lorne)	6700	2005
Great Ocean Rd (East of Warrnambool)	6800	2005
Great Ocean Rd (West of Peterborough)	1900	2005
Moyne Shire Data	*ADTM**	
Irvine St, Peterborough	382	April 2007
Irvine St, Peterborough	413	March 2000
Boggy Creek Rd, Peterborough	295	Jan 2007

AADT = Annual Average Daily Traffic Volume

* ADTM = Average Daily Traffic Volume in the Month

Because of their location on the Great Ocean Road, Peterborough and the Curdies estuary are popular tourist destinations. Tourism is an important component of the economic value associated with the Curdies estuary. The mix of visitors includes year-round passing trade as well as strong medium-stay numbers during the summer holiday period.

5.3 Commercial Fishing

Commercial fishing on the Curdies River estuary is limited to eel fishing. Statewide Short-finned Eel (*Anguilla australis*) makes up 95% of the eel fishing catch. The whole fishery has an annual average production of around 280 tonnes, with a value of between $1.4 and $4.7 million (DNRE, 2002). The eel fishing industry also directly employs around 30 full-time and up to 70 part-time people across the state. The fishery is input managed through restrictions on the types and dimensions of fishing gear, and is entry limited through control of licences.

Commercial eel fishing is conducted on the Curdies River estuary by one operator who holds Eel Fishery Access Licence No. 18 (Department of Natural Resources and Environment, 2002). Eel fishing is only allowed in the section of the estuary below 'The Narrows' (i.e. in 'the Lake' aka lagoon). The operation on the Curdies is based largely on the capture of 'sea-run' migrating eels using oversize fyke nets (under permit) to harvest eels of high export quality. This Eel Fishery is subject to the Victorian Eel Fishery Management Plan (Henry and Lyle, 2003) which is due for a major review in 2008 (Craig Murdoch, 2007, pers. comm. 12 July).

Although fishing is popular, no work has been done to quantify the value of recreational fishing on this estuary. An analysis of recreational fishing on a statewide basis has shown that estuaries are the most important recreational fishing resource in the state. Overall, recreational fishing generates in excess of $390 million per annum across Victoria (Clark, 1990).

6 SOCIAL VALUES

6.1 Recreation

Peterborough and the Curdies estuary have a large number of visitors, primarily during the summer holiday period spanning December to February. The beach at Peterborough is broad, easily accessible and safe for swimming, fishing and surfing. It is bordered by steep dunes and a rocky headland (Figure 14) with vehicular access provided at a cut in the dunes and multiple pedestrian access points. Car parking and a lookout is provided along the headland. Behind the dunes Moyne Shire maintains a toilet block, playground and grassed area.

Figure 14. Beach at Peterborough showing sand dunes and headland (left) and vehicle access point through the dunes (right) (photos: Brett Anderson)

Curdies River Estuary comprises a narrow river section that opens into a larger lagoon area prior to reaching the sea. The estuary lagoon offers safe swimming, sailboarding, boating and fishing. Boat access and fish cleaning facilities are available at Curdievale and Peterborough, where a floating dock has been recently installed (Figure 15).

Figure 15. Estuary access near Great Ocean Road bridge into Peterborough (left) and concrete boat launching ramp and floating dock (right) (photos: Brett Anderson)

6.1.1 Recreational Fishing

Surf fishing is popular around Peterborough and Newfield Bay where there are regular catches of Pinky Snapper, Gummy Shark, Whiting, Mullet, Trevally and Salmon. Within the tidal

section of the Curdies River, Estuary Perch, Black Bream, Mullet and Salmon are the main target of recreational fishing. Further up the river towards Timboon, Brown Trout and Blackfish can be caught (http://www.gatewaybbs.com.au/Fishing/).

The Curdies estuary is a significant recreational fishery both for local residents within the Corangamite and Glenelg-Hopkins regions and beyond. The estuary lagoon provides excellent bait harvesting locations along the shoreline. A recreational fishery management plan for the Corangamite CMA region is currently being developed.

6.1.2 Boating

The majority of boating activities within the estuary are related to fishing with only small craft being used. There are formal boat ramps at Curdievale and Peterborough which are capable of launching most river fishing vessels. The Marine Act (1988) establishes boat speeds for inland waters and states that speeds within 50 m of the water's edge should not exceed 5 knots. However, there is a designated ski area at Curdievale and water skiing is permitted in this area. The Curdies River Committee of Management is responsible for management of activities on the waterway.

Non-motor watercraft such as canoes, kayaks and sail boards are also used on the estuary.

6.1.3 Sightseeing

The most popular sightseeing around the Curdies River area is the wetland, river mouth and surrounding beach which is a popular location for families. The Great Ocean Road provides expansive views of the estuary inlet area.

The Bay of Islands Coastal Park is another major attraction. It extends westwards for 32 km from the Peterborough golf course to Lake Gillear, 8 km east of Warrnambool and Port Campbell National Park (1750 ha) extends east from the eastern side of Curdies Inlet at Peterborough to Point Ronald at Princetown. Both parks have extensive coastal cliffs and lookout points for viewing the coast.

6.1.4 Cycling

Cycling the Great Ocean Road is a renowned recreational activity worldwide. The road and facilities in Peterborough are the main focus for cyclists around the estuary.

6.1.5 Walking

There are limited walks around the Curdies River and within the study area. Most walking is done on the beaches and walking tracks of the Coastal and National Parks.

6.1.6 Swimming

The opportunities for swimming around Peterborough and the Curdies River are plentiful with large numbers of families visiting the area during the Christmas holiday break. Curdies Inlet is very popular along with Peterborough Beach. There is also a swimming area and diving board on the estuary at Curdievale.

6.1.7 Hunting

During the open season hunting for waterfowl the Curdies estuary is visited by many duck shooters. The duck season did not run in 2007 due to the lack of rainfall but in other years shooters must obtain a duck game license and shoot during the designated time of year and within specified areas.

6.1.8 Four wheel Driving and trail bikes

4WD and trail bike activities are generally limited within the study area because of its lack of roads. Beach access is not permitted in Victoria.

6.1.9 Bird watching

The Curdies estuary and wetlands provide excellent opportunities for bird watching. There is an active bird watching society in the Curdies area (for more detail refer to: Section 4.7.2 - Birds).

6.1.10 Dogs

Dogs are currently prohibited on the beach at Peterborough between the bridge and the monument at the car park south of Irvine Park between 9am and 6pm every year during the period 1 December to Easter Monday inclusive. Dogs must be restricted to leashes at all times in the area bounded by and including Hamilton and Irvine streets, and Schomberg and Halladale roads and in the children's playground and barbecue area in Irvine Street.

Dogs are not permitted in the Port Campbell National Park, including the beach area east of the estuary entrance. The nearby walking track from Wild Dog Cove to Bay of Islands car park in Bay of Islands Coastal Park , including the beaches, is accessible for dogs on leashes.

6.1.11 Camping

The majority of camping around the Peterborough area is in camping grounds where toilet blocks and most other facilities are provided. The two caravan parks in Peterborough are the Great Ocean Road Caravan Park and the Peterborough Coastal Caravan Park. Information about these caravan parks was given in Section 5.2. Camping is not permitted in the Coastal or National Parks.

6.1.12 Objectives and Recommended Management Actions for Recreation

Objective R1: ***Protect and enhance recreational opportunities of the Curdies Estuary without diminishing environmental values***

Code	Recommended Action	Priority
R1.1	Develop a master plan for the area on the west bank south of the Great Ocean Road bridge. The plan should indicate how to enhance coastal dependent recreational opportunities while also protecting and enhancing environmental values.	M
R1.2	License commercial tour operators and use licence fees to maintain reserves and provide interpretation and directional signage.	M
R1.3	Construct areas along roadsides to allow tourist vehicles and sightseers to pull vehicles off The Great Ocean Road to photograph wetland biota (see also: Moyne CAP).	M

Objective R2: ***Provide opportunities for water-based activities such as fishing and swimming***

Code	Recommended Action	Priority
R2.1	Undertake regular water quality monitoring and report against the standards for primary contact. This should include development of a risk management plan for blue-green algal blooms as per DSE Blue/green Algae Circular 2007/08	VH
R2.2	Maintain boat ramp facilities to ensure safe and efficient access to estuary	H
R2.3	Monitor recreational use of estuary to allow for adequate provision of services, safety and environmental protection	L
R2.4	Investigate impact of boat use on river banks	L
R2.5	Liaise with Marine Safety Victoria to review water craft use on the estuary	L

6.2 Cultural Heritage

6.2.1 Indigenous Cultural Heritage

The Curdies estuary is located in the language area of the Girai (Kirrae) Wurrung. Their area is bounded by Mt Emu Creek and the Hopkins River and extends to Mt Bolac in the North and the Gellibrand River in the east. According to Dawson, an early settler who recorded many aspects of Aboriginal society in the area, Kaawirn Kuunawarn was then the "chief" of the Girae wurrung (Clark, 1990). Twenty one Girae Wurrung clans were identified within the language area. The Baradh gundidj inhabited the land at the mouth of the estuary and the Ngaragurd gundidj, lived in the coastal area east of the estuary. Clans in the Peterborough area would have had access to a range of resources. Middens in the Port Campbell and the Bay of Island National Parks indicate that a variety of shellfish were utilised. The inlet and surrounds would have been a rich source of birds, fish and terrestrial mammals and plants would have been used for fibre, food and medicinal purposes.

A meeting, summoned by Kaawirn Kuunawarn immediately prior to occupation of the Girae wurrung country in 1838, was attended by 1000 people. By 1880 only four of those people were known to be alive (Duruz, 1972).

Consultation with Aboriginal Affairs Victoria revealed neither registered aboriginal parties nor applicants to be registered aboriginal parties for the land surrounding the Curdies estuary. The Australian Heritage Act (2006) requires that the Cultural Heritage Site Register be accessed by the land owner, or manager of public land, prior to any activities or developments that could potentially disturb cultural sites.

6.2.2 Post-Contact Cultural Heritage

The first squatters on Kirrae wurrung lands arrived in 1838 when Hamilton and Watson occupied 40,000 acres at 'Yalloak', southwest of Terang. A succession of squatters settled on the land in the following years, including Dr Daniel Curdie who established a property 'Tandarook' south of Lake Purrumbete.

Dr Curdie led a party along the east bank of the Curdies River (known then as the Cudje River) to the sea in 1845 (Duruz, 1972). In 1855, there were no white settlers in the Peterborough area but James McKain Meek, a gold prospector and his son were based on the west bank of the Curdies inlet by around 1856. Meek wrote articles and spoke at meetings describing the potential wealth of the Curdies River valley including minerals, timber, and pasture, and encouraging settlers to the area (Curdies, 1866).

In 1866, Dr Curdies led a party to find a route for a road from Camperdown to the coast, burning and clearing vegetation as they went. They arrived at the coast west of the Gellibrand River and followed the coast west across the Curdies estuary to Warrnambool. Curdies' diary of the journey notes thousands of swans on the inlet and 'great quantities of fish and wild duck' throughout the estuary. The party also caught twenty five mullet from the shallow water flowing over the sand at the entrance (Curdies, 1866).

A road from Camperdown to Glenample was formally opened at the end of 1866. In the same year the Peterborough township was first surveyed (Duruz, 1972). A monument on the headland to the west of the estuary, records that James Irvine died while crossing the estuary with the mail in 1919. However, a bridge was not built across the estuary until 1927 and replaced with current bridge in 1987.

Curdievale developed quickly in the 1920s with the establishment of the Bailey Settlement on Crown Land. The land for the development was released as a response to the depression. A

school was opened at this time and the Fisherman's Arms Inn became a popular holiday destination (Parks Victoria, 2007b).

Peterborough was a recognised tourist destination as early as 1892 with the Warrnambool Standard Almanac and Tourist guide noting 'Curdie's River… where splendid shooting and fishing are obtainable. The river is now becoming a place of resort… and when the projected railway through Nirranda district is made it will have a much greater number of frequenters'.

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8 APPENDICES

8.1 Appendix 1. Conservation Status of Flora and Fauna

An advisory list of threatened vertebrate fauna (TVF) (Department of Sustainability and Environment, 2005) classifies Victorian species according to a range of criteria as either: extinct (x), regionally extinct (rx), extinct in the wild (wx), critically endangered (cr), endangered (en), vulnerable (vu), near threatened (nt) or data deficient (dd).

An advisory list of rare and threatened plants (VROT) classifies Victorian species as presumed extinct (x), endangered (e), vulnerable (v), rare (r), poorly known (k) in Victoria

A statutory list of threatened Victorian taxa is established under the Flora and Fauna Guarantee Act 1988 (FFG Act). Taxa are classified as Listed (L), nominated (N), ineligible (I) or delisted (D)

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) lists taxa considered threatened in Australia. Species are classified as Extinct (EX), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Conservation Dependent (CD)

The China Australia Migratory Bird Agreement (CAMBA) and the Japan Australia Migratory Bird Agreement (JAMBA) provide for the protection of bird species that migrate between countries. Most migratory wader species arrive in Australia in early spring and return north to breed in early autumn (Bibby et al., 1992).

8.2 Appendix 2. Description of estuarine EVCs.

Coastal Saltmarsh (EVC 009)

Defining characteristics: Low, primarily low shrubby to herbaceous or grassy vegetation of salinised coastal soils in or adjacent to tidally influenced wetland.

Habitat: Associated with tidal wetlands of sheltered embayments and estuaries.

Floristics: Coastal Saltmarsh can include a number of zones of varying structure and floristics, reflecting tidal inundation and substrate character. Structurally prominent species variously include *Sclerostegia arbuscula, Sarcocornia quinqueflora, Suaeda australis* and *Samolus repens*, with *Frankenia pauciflora* a more localised component. *Gahnia filum, Disphyma clavellatum* and *Distichlis distichophylla* can be locally prominent in peripheral habitats.

Structure: Variable: herbland, grassland, shrubland to 1.5 metres,

Distribution: Scattered distribution in sheltered embayments and estuaries from Portland area to East Gippsland.

Vegetation Quality: Vulnerable to physical disturbance and water quality within estuary situations, but component species often with high potential for re-colonization. Few weeds in wetter zones, but *Spartina* spp. can be extremely serious in some wetter habitats. The outer margins of saltmarsh vegetation are potentially more species-rich, and are vulnerable to a wider range of weeds.

Comments: This variation is not simply classified into regional floristic communities. Coastal Saltmarsh represents an aggregate vegetation.

Estuarine Wetland (EVC 010)

Defining characteristic: Moderate height rush/sedge wetland vegetation, variously with component of small halophytic herbs, occurring on estuarine flats.

Habitat: Anaerobic peat-rich mud of estuarine flats, inundation regimes variously sustained if drainage-line outlet blocked, twice daily with tides if breached.

Floristics: Dominated by *Juncus kraussii, Bolboschoenus caldwellii* and (stunted and sub-dominant) *Phragmites australis,* with associated species including *Samolus repens, Ranunculus amphitrichus, Distichlis distichophylla, Isolepis cernua, Selliera radicans, Apium prostratum, Triglochin striata, Leptinella* spp., *Mimulus repens, Sarcocornia quinqueflora* and *Suaeda australis. Gahnia filum, Schoenoplectus pungens* and sometimes *Poa labillardierei* / *Poa poiformis* can be present on the outer verges towards the boundaries with other EVCs.

Structure: Rushland/sedgeland, typically <1 (–1.5 m) height, sometimes in mosaic with low herbland. Woody species generally absent, but scattered stunted shrubs (including *Leptospermum lanigerum, Melaleuca ericifolia* or *Myoporum insulare*) can occasionally be present.

Distribution: Scattered along the coast in estuarine situations, most extensive in association with larger estuarine floodplains, e.g. Snowy River, L. Tyers, upper reaches of Tamboon and Wingan Inlets, Gellibrand River, Aire River, Glenelg River, Gippsland Lakes, formerly Yarra River, well defined streams of Otway-Bellarine coast.

Vegetation Quality: Vulnerable to weed invasion in disturbed areas, vulnerable to local changes in hydrological regime or water quality.

Comments: Distinguished from Estuarine Reedbed by the smaller stature and reduced dominance of *Phragmites australis* (and greater diversity), from Coastal Saltmarsh by the dominance of medium-sized graminoids, and from Estuarine Scrub by the general absence of woody species. In parts of its range, Estuarine Wetland can occur adjacent to or in mosaic with these other vegetation components.

Brackish Sedgeland (EVC 013)

Defining characteristics: Sedgeland dominated by salt-tolerant sedges in association with low grassy / herbaceous ground-layer and a halophytic component.

Habitat: Mostly at least marginal wetland (including peripheral or ephemeral zones).

Floristics: Structurally prominent species include *Gahnia filum* / *Gahnia trifida* and *Baumea juncea*, with *Bolboschoenus caldwelli* and/or *Schoenoplectus pungens* in some wetter versions.

Structure: Medium to tall sedgeland to 1.5 metres,

Distribution: Scattered in near-coastal and western inland areas.

Vegetation Quality: Prone to invasion by *Juncus acutus*, drier versions prone to invasion by wider range of introduced species, notably annual grasses.

Comments: Extreme tidal events can be of high importance in maintaining the ecological zone in which this EVC occurs. Brackish Sedgeland has larger component of species shared with non-saline situations and has limited tidal input compared to Estuarine Wetland

Swamp Scrub (EVC 053)

Defining characteristic: Myrtaceous shrub species (usually) shared with Swamp Scrub occurring in association with ground-layer dominated by non-halophytic herbs.

Habitat: Essentially freshwater habitat, often on the outer verges of Estuarine Scrub and further upstream where freshwater inputs from the creek and from groundwater are sufficient to sustain non-halophytic vegetation. Soils typically have high organic content, often silty/peaty, with a thick surface layer of organic detritus.

Floristics: The usual shrub species is *Melaleuca ericifolia* in eastern Victoria and *Leptospermum lanigerum* in western Victoria. Major species of ground-layer include *Poa labillardierei*, *Gahnia clarkei*, *Carex appressa*, *Goodenia humilis*, *Villarsia reniformis*, *Acaena novae-zelandiae* and *Juncus* spp. While the vegetation is often relatively species-poor as a closed scrub, more open sites are rich in small herbs.

Structure: Shrubland to scrub to 2–4 metres.

Distribution: Widely distributed in association with lower reaches of watercourses throughout Victoria but greatly cleared for agriculture and relatively little remaining.

Vegetation Quality: Vulnerable to weed invasion, altered hydrology and clearing.

Comments: Potentially affected by estuary closure with prolonged inundation.

Seasonally Inundated Sub-saline Herbland (EVC 196)

Defining characteristic: Species-poor low herbland of seasonal saline wetland, dominated by *Wilsonia* spp.

Habitat: Seasonal wetland within relicts of former tidal lagoons. Salinity and water regimes fluctuate over wide range. Habitat is rarely inundated tidally and then only by diluted seawater, overland flows from the Barwon River are important.

Floristics: Herbland dominated by *Wilsonia* spp. (principally *W. humilis*).

Distribution: Extremely rare and occupying a very localised habitat (e.g. Salt Swamp in Barwon Estuary, Point Lonsdale).

Vegetation Quality: Damaged by past shell grit extraction, otherwise robust and stable.

Comments: Barwon Estuary is permanently open.

Brackish Herbland (EVC 538)

Defining characteristic: Low herbland dominated by species tolerant of mildly saline conditions and intermittent inundation.

Habitat: Brackish conditions associated with inland drainage-basins and lakes, and also estuarine locations. Inundation is mostly shallow and intermittent, but soils typically remain at least damp over much of the year.

Floristics: Structurally prominent species include *Lobelia irrigua*, *Sebaea* spp., *Ranunculus diminutis*, *Isolepis cernua*, *Schoenus nitens*, *Wilsonia rotundifolia*, and sometimes *Selliera radicans*, *Distichlis distichophylla* and/or *Samolus repens*.

Structure: Low herbland (sometimes with grassy/sedgy patches), mostly <0.15 m in height and often <0.05 m.

Distribution: Scattered in restricted habitat, recorded from Aire River.

Vegetation Quality: Vulnerable to invasion by aggressive environmental weeds such as Sea Wheat-grass and Spiny Rush and loss of diversity with increased salinity. Sites indicative of slight natural salinity can support a range of significant flora.

Comments: Often occurs in mosaic or complex with other wetland components.

Sea-grass Meadow (EVC 845)

Defining characteristic: A quatic meadow of sheltered shallow marine and lower estuarine habitats.

Habitat: Sheltered marine shallows, intertidal flats and estuarine inlets.

Floristics: Dominated by stands of *Zostera* and / or *Heterozostera* spp., often monospecific and sometimes in close proximity to *Avicennia marina* stands on mud flats below high-tide levels. *Zostera muelleri* extends into lower estuarine habitats, with *Heterozostera tasmanica* conspicuous on intertidal mud flats.

Structure: Herbland sward, sometimes occurring in association with Mangrove Shrubland.

Distribution: Scattered along Victorian coast, with most extensive development within Corner Inlet and Westernport Bay.

Vegetation Quality: Vulnerable to die-back from factors including altered water quality and pollution and in places potentially encroached by introduced cord-grass *Spartina* spp.

Comments: Sea-grass Meadow unambiguously represents wetland vegetation; however this context would rarely be extended into a marine context beyond the inter-tidal zone.

Estuarine Flats Grassland (EVC 914)

Defining characteristic: Tussock grassland of coastal flats, beyond zone of normal tidal inundation.

Habitat: Occurs in a range of low-lying coastal sites, typically with a shallow sand layer over a heavier soil. In at least some locations, impeded drainage can result in seasonal waterlogging -

while unusual, brief inundation can occur intermittently in some sites (e.g. the rear of saltmarshes and around drainage-line swamps behind barrier dunes).

Floristics: Major species include *Poa poiformis*, *Austrostipa stipoids*, and *Isolepis nodosa*. Comprises a mixture of salt-tolerant species such as *Disphyma crassifolium* and less tolerant species such as *Senecio pinnatifolius*.

Structure: Tussock grassland to 1 metre.

Distribution: Restricted distribution on low-lying terrain above usual inundation levels, scattered locations.

Vegetation Quality: Potentially vulnerable to high disturbance levels associated with recreational activities.

Comments: Occupies an intermediate zone between dryland / dampland and wetland vegetation. Mostly represents at least marginal wetland (including peripheral or ephemeral zones).

Brackish Grassland (EVC 934)

Defining characteristic: Grassland on sub-saline heavy soils, including dominants of Plains Grassland (and a portion of associated herbaceous species) in association with herbaceous species indicative of saline soils. Sometimes occurs as a fringing community on the verges of saline lakes.

Habitat: Generally occurs on heavy grey to black clay basaltic soils in sites which are to some extent naturally saline. Primarily occurs in dampland complex, sometimes peripheral to wetland.

Floristics: Structurally prominent species include *Poa labillardierei*, *Themeda triandra*, *Austrodanthonia* spp., *Distichlis distichophylla*, *Calocephalus lacteus*, *Selliera radicans*, *Sebaea* spp., *Wilsonia rotundifolia* and *Lobelia irrigua*. Generally consists of a limited component of tussock grasses and forbs of Plains Grassland in association with halophytic species such as *Distichlis distichophylla* and (some less water-requiring) forb species shared with Brackish Herbland (EVC 538).

Structure: Tussock Grassland to 1 metre.

Distribution: Scattered in southern lowland and plains areas, most communities critically endangered. Extremely depleted in estuarine situations, remnants few and generally highly modified.

Vegetation Quality: Generally highly modified.

Comments: Highly endangered by weed invasion, soil disturbance, urbanisation, lack of awareness by managing agencies.

Estuarine Reedbed (EVC 952)

Defining characteristic: Vegetation dominated by tall reeds in association with a sparse ground-layer of salt tolerant herbs. Distinguished from Estuarine Wetland by the vigour and total dominance of the reeds, as well as the absence of samphires in the ground layer.

Habitat: Estuarine Reedbed occurs in sub-saline situations of coastal estuaries (sometimes periodically blocked by sand bars). The habitat is subject to surface salinity as well as flushing by freshwater (including via groundwater), but is beyond direct inundation from normal tidal inputs, at elevations of approximately 1 m ASL.

Floristics: *Phragmites australis*, with associated species including *Samolus repens*, *Juncus kraussii*, *Triglochin striatum*, *Bolboschoenus caldwellii*, *Suaeda australis*, *Gahnia filum* and *Crassula helmsii*.

Structure: Reedbed, typically 2–3 m in height, with sparse herbaceous ground-layer.

Distribution: Known from scattered near coastal sites between the Otways and East Gippsland, e.g. Aire River Estuary, Jack Smith Lake, Gippsland Lakes system and Snowy River Estuary.

Vegetation Quality: While appearing reasonably resilient to weed invasion, potentially vulnerable to degradation where accessible by stock or subject to run-off of nutrients from agricultural land.

Comments: Represents an extension of EVC 821 Tall Marsh into sub-saline habitats.

Estuarine Scrub (EVC 953)

Defining characteristic: Myrtaceous shrub species (usually) shared with Swamp Scrub occuring in association with ground-layer dominated by halophytic herbs.

Habitat: Sub-saline habitat, notably on the verges of Estuarine Wetland (peripheral or further upstream), where freshwater inputs (in particular via groundwater) are sufficient to sustain shrubs but saline surface inputs maintain a halophytic groundlayer. Occurs at elevations of approximately 0.5–1.5 metres ASL. Soils typically have high organic content, often silty/peaty, with a thick surface layer of organic detritus. Estuaries and seepage zones at the rear of saltmarshes.

Floristics: The usual shrub species is *Melaleuca ericifolia* (in eastern Victoria), rarely with *M. lanceolata*, *Melaleuca gibbosa* or *Leptospermum lanigerum* in marginal sites in western Victoria. The major species of the ground-layer include *Samolus repens*, *Triglochin striatum* and *Selliera radicans*, variously with *Sarcocornia quinqueflora*, *Gahnia filum*, *Poa poiformis*, *Juncus kraussii*, *Disphyma crassifolium*, *Distichlis distichophylla* and (locally) *Juncus revolutus*. Species such as *Isolepis nodosa*, *Rhagodia candolleana*, *Tetragonia implexicoma* and *Myoporum insulare* can occur on the drier verges, but except for East Gippsland, are not characteristic of the vegetation. In East Gippsland, *Myoporum* is characteristic and *Tetragonia* waxes and wanes according to the flooding regime; it is prevalent following flooding and sustained lower water levels as occurs when estuaries open. While the vegetation is frequently relatively species-poor, some sites can be rich in small herbs.

Structure: Shrubland to scrub to 2–3 metres.

Distribution: Scattered in suitable habitat along the coast, but rare and of restricted total extent, e.g. Aire-Calder River estuary, Jack Smith Lake, Nooramunga Islands, Duck Point on Corner Inlet.

Vegetation Quality: Vulnerable to weed invasion and clearing, at least in minor estuaries where more accessible to on-going agriculture.

Comments: Can grade into Coastal Dune Scrub, Moonah Woodland and Damp Melaleuca Scrub, but occupies wetter and more saline habitats in comparison. Occurs in habitats ranging from wetland to dampland, but most examples would be considered to comprise at least marginal wetland or an associated fringing zone.

Mud flats [part of Non Vegetation (EVC 990)]

Defining characteristics: Low lying areas which are unvegetated (or nearly so).

Habitat: Including intertidal mud flats.

Floristics: Lacking vascular plant species.

Structure: Unvegetated.

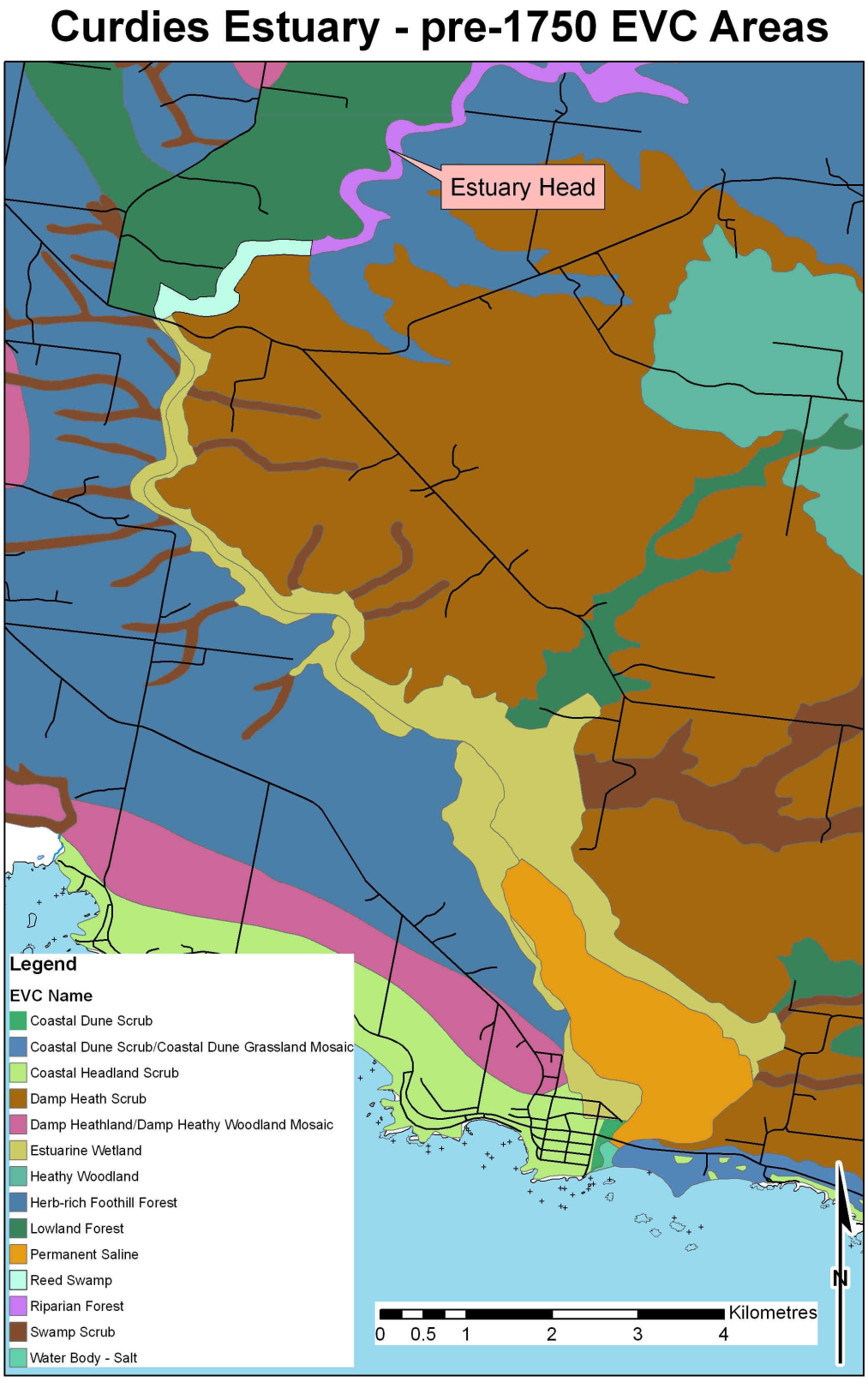
Distribution: Scattered.

Vegetation Quality: Not relevant.

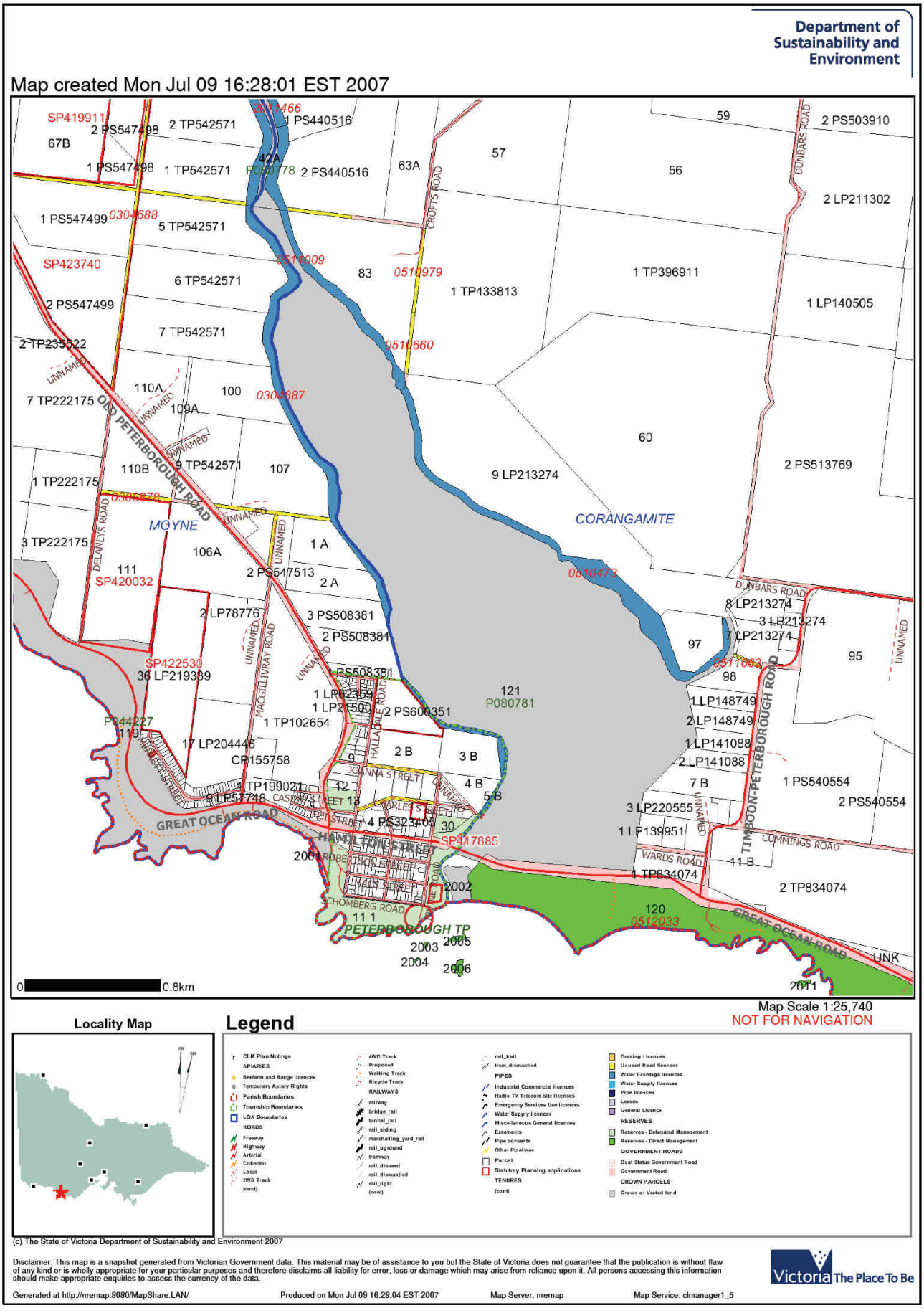
Comments: Areas lacking vascular vegetation can be of high ecological value as wetland habitat.

8.3 Appendix 3: Pre-1750 EVC for Curdies estuary and surrounds

Source data: DSE



8.4 Appendix 4. Land Tenure Maps


Department of Sustainability and Environment
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2 PS503910
DUNBARS ROAD
2 LP211302
1 PS547499
0304688
5 TP542571
CROFTS ROAD
SP423740
6 TP542571
0510009
83
0510979
1 TP396911
1 TP433813
1 LP140505
2 PS547499
7 TP542571
2 TP235522
0510660
UNNAMED
110A
100
0304687
7 TP222175
OLD PETERBOROUGH ROAD
UNNAMED
109A
UNNAMED
60
110B
9 TP542571
107
9 LP213274
2 PS513769
1 TP222175
0508679
MOYNE
UNNAMED
CORANGAMITE
3 TP222175
DELANEYS ROAD
106A
1 A
UNNAMED
111
SP420032
2 PS547513
2 A
0510472
DUNBARS ROAD
8 LP213274
3 LP213274
7 LP213274
2 LP78776
3 PS508381
2 PS508381
UNNAMED
MACGILLIVRAY ROAD
UNNAMED
97
95
UNNAMED
SP422530
36 LP219389
1 PS508381
0511062
98
1 LP62359
1 LP21500
2 PS600351
121
P080781
1 LP148749
2 LP148749
P044227
119
1 TP102654
17 LP204446
CP155758
HALLAHANS ROAD
1 LP141088
2 LP141088
9
2 B
3 B
JOANNA STREET
4 B
5 B
7 B
1 PS540554
2 PS540554
1 TP199021
1 LP57748
CASTING STREET
13
12
4 PS323405
30
3 LP220555
UNNAMED
GREAT OCEAN ROAD
SP417885
1 LP139951
TIMBOON-PETERBOROUGH ROAD
CUMMINGS ROAD
WARDS ROAD
11 B
1 TP834074
2 TP834074
2002
SCHOMBERG ROAD
120
0512033
GREAT OCEAN ROAD
PETERBOROUGH TP
2003
2005
2004
2006
UNK
2011
0
0.8km
Map Scale 1:25,740
NOT FOR NAVIGATION
Locality Map
Legend
CLM Plan Notings
APIARIES
Beefarm and Range licences
Temporary Apiary Rights
Parish Boundaries
Township Boundaries
LGA Boundaries
ROADS
Freeway
Highway
Arterial
Collector
Local
2WD Track
(cont)
4WD Track
Proposed
Walking Track
Bicycle Track
RAILWAYS
railway
bridge_rail
tunnel_rail
rail_siding
marshalling_yard_rail
rail_uground
tramway
rail_disused
rail_dismantled
rail_light
(cont)
rail_trail
tram_dismantled
PIPES
Industrial Commercial licences
Radio TV Telecom site licences
Emergency Services Use licences
Water Supply licences
Miscellaneous General licences
Easements
Pipe corseats
Other Pipelines
Parcel
Statutory Planning applications
TENURES
(cont)
Grazing Licences
Unused Road licences
Water Frontage licences
Water Supply licences
Pipe licences
Leases
General Licence
RESERVES
Reserves - Delegated Management
Reserves - Direct Management
GOVERNMENT ROADS
Dual Status Government Road
Government Road
CROWN PARCELS
Crown or Vested land
(c) The State of Victoria Department of Sustainability and Environment 2007
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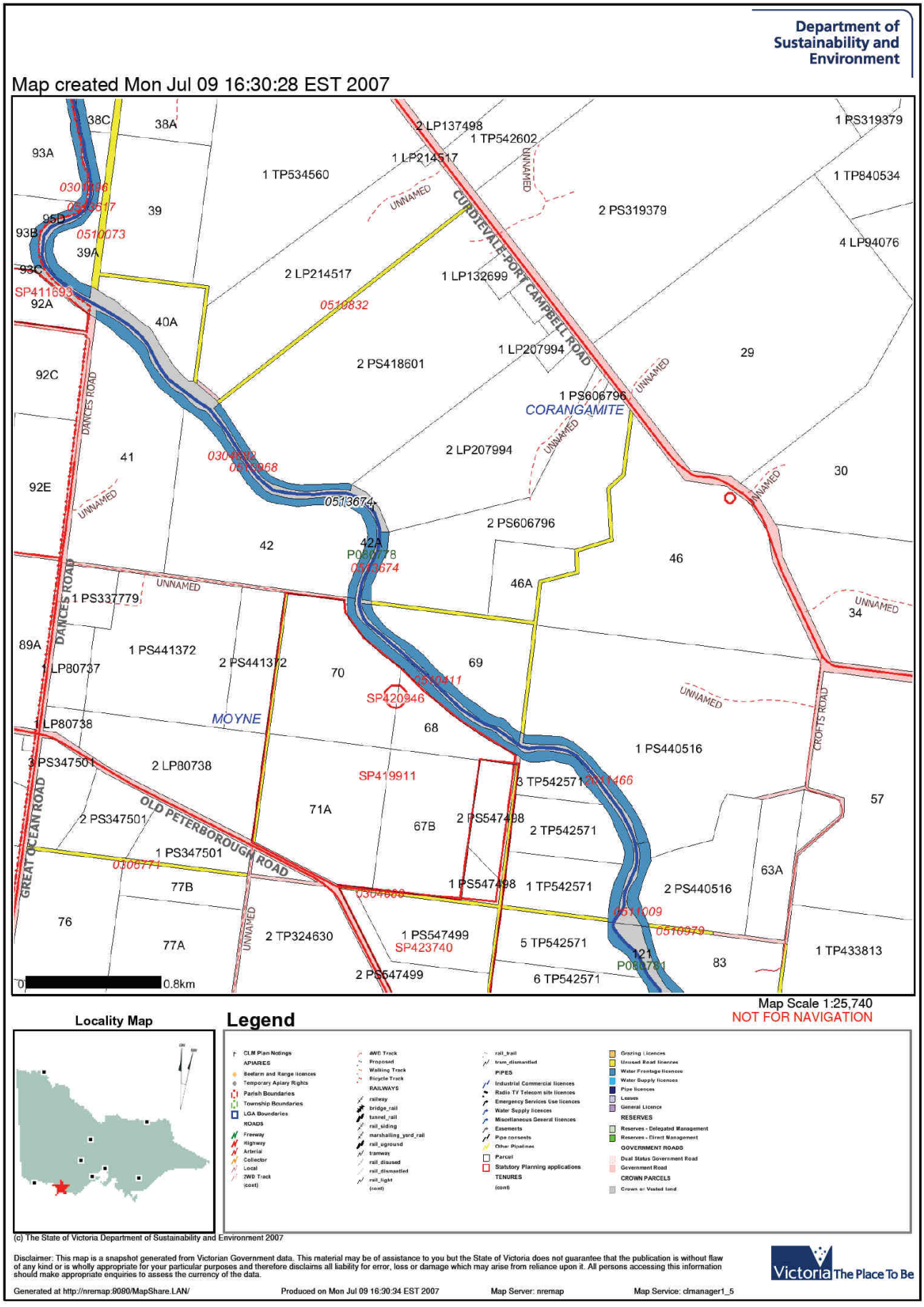
Map Server: nremap
Map Service: dlmanager1_5
Victoria The Place To Be


Department of Sustainability and Environment
Map created Mon Jul 09 16:30:28 EST 2007
CURDIEVALE-PORT CAMPBELL ROAD
CORANGAMITE
MOYNE
DANCES ROAD
CROFTS ROAD
OLD PETERBOROUGH ROAD
GREAT OCEAN ROAD
UNNAMED
0.8km
Map Scale 1:25,740
NOT FOR NAVIGATION
Locality Map
Legend
(c) The State of Victoria Department of Sustainability and Environment 2007
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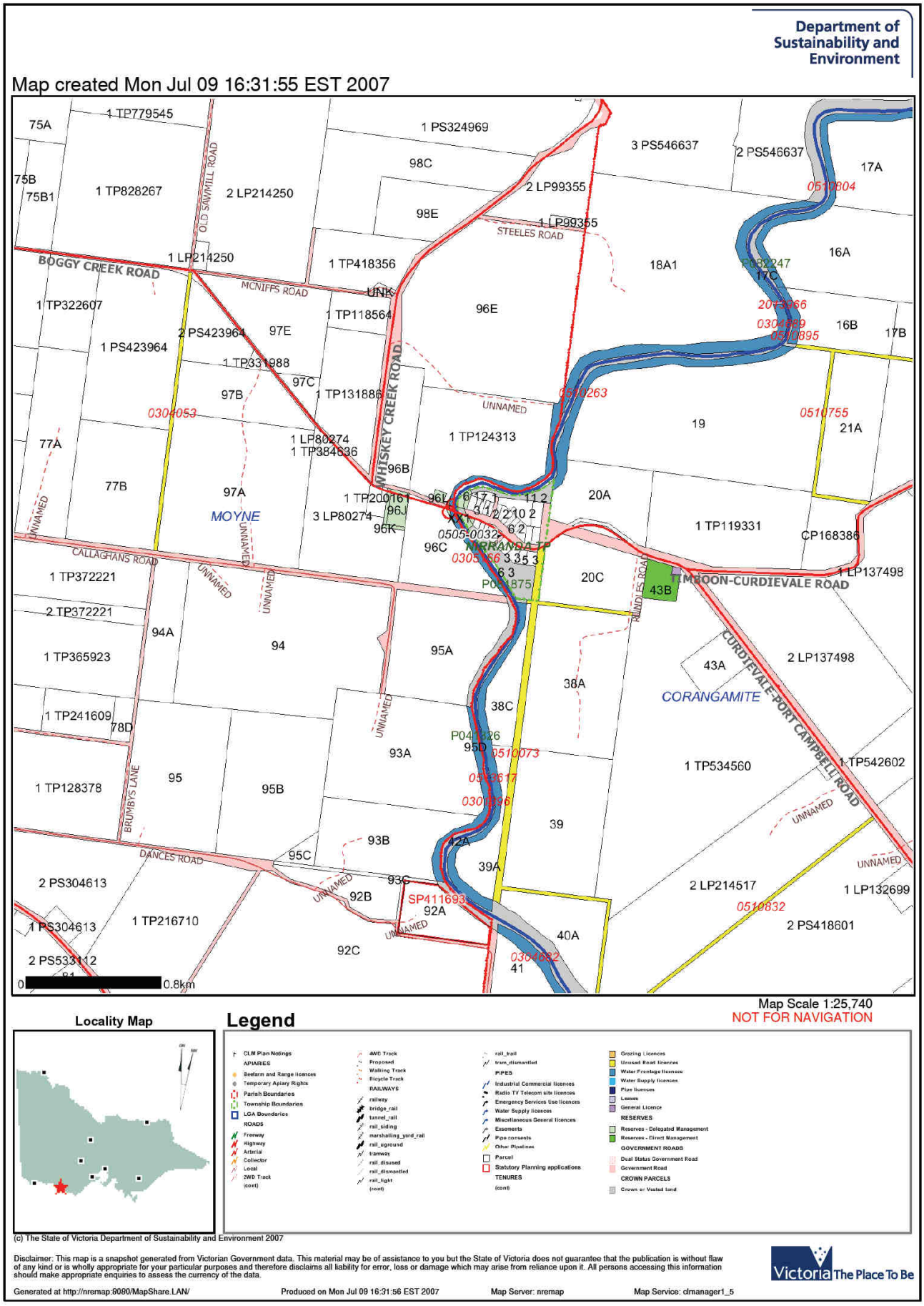
Map Service: dmanager1_5
Victoria The Place To Be


Department of Sustainability and Environment
Map created Mon Jul 09 16:31:55 EST 2007
BOGGY CREEK ROAD
MCNIFFS ROAD
OLD SAWMILL ROAD
STEELES ROAD
WHISKEY CREEK ROAD
CALLAGHANS ROAD
BRUMBYS LANE
DANCES ROAD
TIMBOON-CURDIEVALE ROAD
CURDIEVALE-PORT CAMPBELL ROAD
MOYNE
CORANGAMITE
UNNAMED
0 0.8km
Map Scale 1:25,740
NOT FOR NAVIGATION
Locality Map
Legend
(c) The State of Victoria Department of Sustainability and Environment 2007
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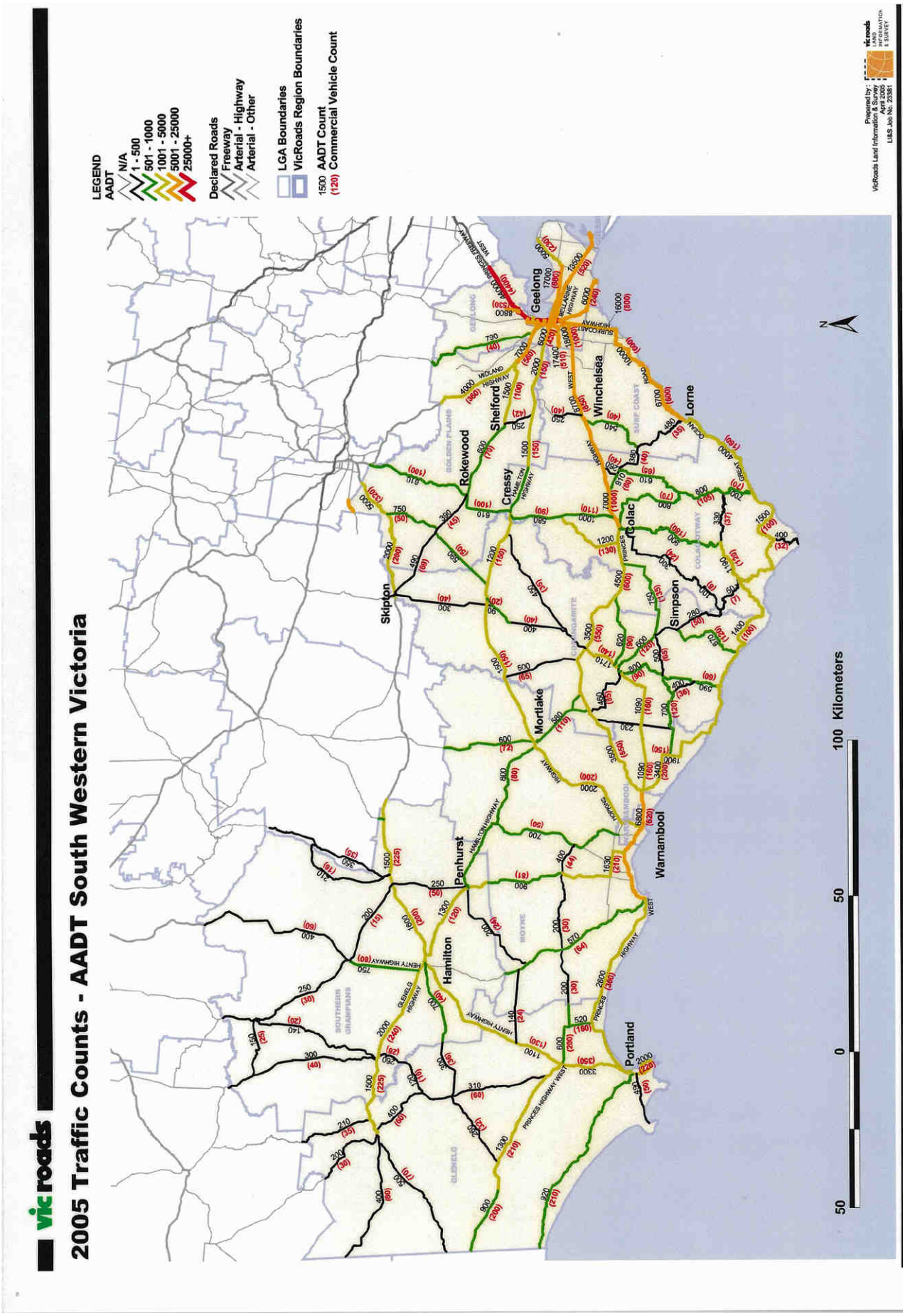
Victoria The Place To Be

8.5 Appendix 5. Vic-Roads Traffic Count Data.


vicroads
2005 Traffic Counts - AADT South Western Victoria
LEGEND
AADT
N/A
1 - 500
501 - 1000
1001 - 5000
5001 - 25000
25000+
Declared Roads
Freeway
Arterial - Highway
Arterial - Other
LGA Boundaries
VicRoads Region Boundaries
1500 AADT Count
(120) Commercial Vehicle Count
Geelong
Winchelsea
Lorne
Shelford
Rokewood
Cressy
Colac
Skipton
Simpson
Mortlake
Warrnambool
Penhurst
Hamilton
Portland
100 Kilometers
50
0
50
N