

Corangamite Salinity Action Plan

Regional overview and development considerations



Background Report 1 (revised edition)
November 2005

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Corangamite Salinity Action Plan (2005 – 2008)

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Cover Photo: Aerial photograph showing the lower Barwon River, part of Reedy Lake, and suburban Geelong. (City of Greater Geelong, 2002).

Summary

In preparing this second generation salinity plan for the Corangamite Region, it is critical describe the context in which the plan is being developed. This context is vastly different to the understanding and expectations that existed when the first Corangamite salinity strategy, *Restoring the Balance*, was being developed in 1991. The significant changes include an improved knowledge of salinity processes; recognition that salinity is not the only issue in natural resource management for the region; increased emphasis on asset protection, partnerships and co-investment; and the Federal, State, and regional frameworks.

Salinity has been a feature of the Corangamite CMA region for at least 20,000 years. This primary salinity has resulted in the evolution of landscape features, such as the large clay lunettes at Lake Corangamite and Lake Murdeduke. The early European explorers and settlers documented the presence of primary salinity, and 'salt' is often used as a descriptive adjective for lakes and creeks in the region.

At present 20,538 hectares of salinity are mapped in the Corangamite CMA region although the mapping does not generally distinguish between primary and secondary. The largest mapped area is primary salinity in the Lake Connewarre reserve. The salinity mapping is regarded as incomplete and is believed that many hectares of salt affected land remain unmapped. Within the CMA region, water quality in many rivers, streams, lakes and wetlands has declined since European settlement. The flow weighted salinities of the Barwon, Leigh and Woody Yaloak exceed the Murray Darling Basin Commission benchmark and are generally greater than for streams in northern Victoria.

The overview recognises that the extent and severity of salinity in the Corangamite Region is influenced by a number of interactive processes. It is useful to consider these processes as those that cannot be readily modified such as the physical geography (geology and physiography) and climatic conditions (rainfall, evaporation and temperature) as opposed to the changes induced by human activity (land use and policy settings since European settlement).

The report summarises the management of salinity in the Corangamite CMA region, which dates back to the very earliest days of settlement, when a breakwater was constructed across the Barwon River in 1840 to prevent tidal salt reaching the new town of Geelong. It has culminated in the preparation of this second-generation Salinity Action Plan (SAP) under the Victorian Salinity Management Framework (2000) and the National Action Plan (NAP) for Salinity and Water Quality.

There is enormous potential to develop strong synergies between this second generation salinity plan and the range of natural resource management programs and industries currently in operation throughout the region. Communication and development of strong partnerships with existing catchment programs offers huge potential to "value add" to future salinity initiatives, which can achieve greater salinity benefits than that possible by acting as an isolated program. Essential to this process is an understanding of current catchment programs and identification of areas where mutually beneficial outcomes exist with the salinity program. These are explored in this document.

In the development of the SAP, the community engagement and participation process was carefully constructed to achieve ownership and subsequent adoption of desired actions in the plan whilst adequately consulting with the appropriate stakeholders. To avoid confusion and duplication with an extensive consultation process being conducted with the Corangamite Regional Catchment Strategy, the salinity consultation component was highly targeted. It was directed primarily at those areas where a change in practice is required and then securing key stakeholder investment to ensure landscape change occurs. These consultations were further updated in 2005 based on two year experience from service providers engaged to implement the draft SAP.

A key component in the SAP development is the use of a program logic model developed and later validated by the Corangamite salinity team in the late 1990's. Program logic is a cause and effect model to achieve a higher order outcome. The four components of targeted action, technology, attitude and capacity will form the strategic planning elements. Developing the detail below these four components creates the tactical and operational structures to achieve these actions.

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1 Overview

In preparing this second-generation salinity plan for the Corangamite Region, it is critical describe the context in which the plan is being developed. This context is vastly different to the understanding and expectations that existed when the first Corangamite salinity strategy, *Restoring the Balance*, was being developed in 1991 (Nicholson *et al.* 1992).

The significant contextual changes include:

- Improved knowledge regarding salinity and salinity processes.
- The recognition that salinity is only one, albeit important, issue in catchment management.
- Increased emphasis on prioritisation (asset / risk assessment), partnerships and co-investment.
- Frameworks that involve Federal, State, regional and local involvement.

More specifically, to develop a salinity plan that supports strategic natural resource management in the Corangamite Region requires:

- Knowledge of the region today and likely changes in the future that will impact on salinity management.
- Appreciating the past, current and future extent of salinity in the region.
- Understanding the physical processes that drive salinity in the Corangamite region.
- Understanding the evolution of salinity management intervention at a national, state and regional level.
- Appreciating the current strategies, approaches and policy positions of the various stakeholders who need to participate in the implementation of the plan.

1.1 Salinity in the context of the Corangamite region

The Corangamite Catchment Management Authority (CCMA) region covers 13,340 square kilometres (~ 1.3 million hectares) of south west Victoria, from the Bellarine Peninsula to the Curdies River and the Great Dividing Range to the coast (Figure 1.1). Nine local government municipalities lie within the region, including significant portions of the major provincial cities of Geelong and Ballarat.

The regional population is close to 400,000 people (NRE 2001, ABS 2002) and is growing at similar rates (5.2%) to that occurring at a State level (6.2%). However the population increase is unevenly spread, with the population becoming more urbanised in Ballarat and Geelong, expanding rapidly along the coastal areas and in the peri-urban fringe, within 40 km from the major centres of Geelong and Ballarat (ABS 2002). The rural population, despite farming more than two thirds of the land in the Corangamite Region, is at best stable, or falling – particularly in the broad-acre farming areas.

Secondary industry with its associated service and tourism sectors are large employers in the region. The tourism and recreation industries in particular are strongly linked to capitalising on the natural environment (coast, sea and forests). This sector is predicted to continue growing in the future (URS 2002). During the same period, the region's primary industries are expected to intensify their production systems.

This pattern of growth has important implications for future salinity management. Firstly, urban dwellers have different aspirations and concerns towards natural resource management to those held by rural people (URS 2002). For the urban and peri-urban communities, continued access to good quality water and ability to live in a 'non-degraded' environment will demand attention. Secondly, the tourism and recreation industries have created businesses largely based on the non-degraded nature of the natural environment. This sector will seek to preserve or enhance these natural assets in the future. Finally, intensification of the agricultural sector may result in less emphasis placed on the need to use saline land for production, as the other areas of the farm produce more.

The Corangamite Regional Catchment Strategy (RCS) has identified the deterioration of the quality of the regions water resources as a significant threat, though increasing salinity, reduced flow regimes and nutrient enrichment (CCMA 2003).

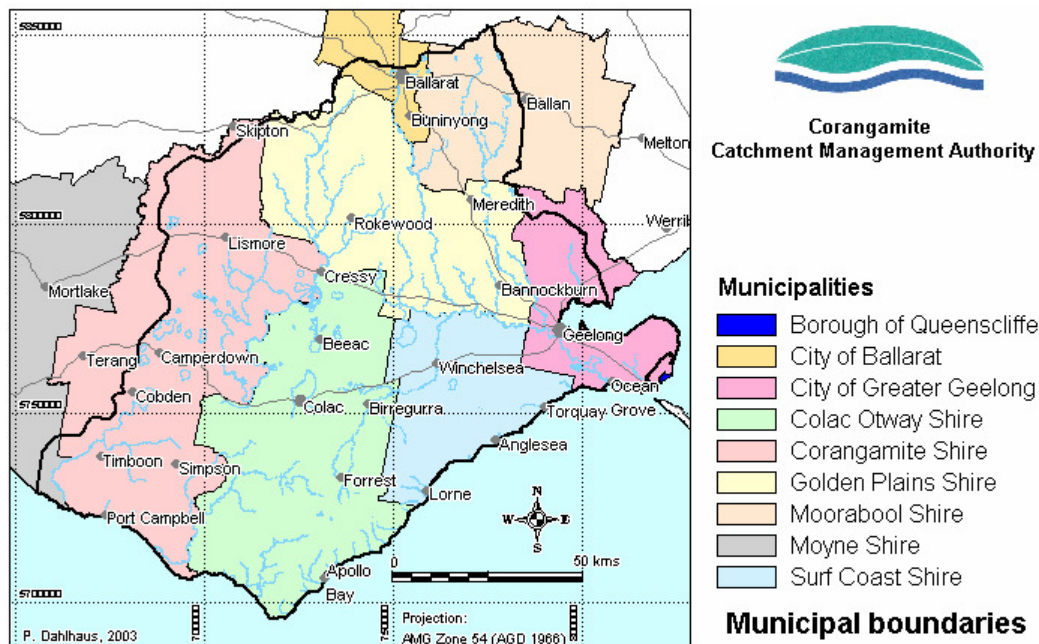


Figure 1.1 Municipal boundaries in the Corangamite CMA region

1.2 The past, current and future extent of salinity

1.2.1 Historic perspective of salinity in the Corangamite Region

Salinity has been a feature of the Corangamite CMA region for at least 20,000 years (Dahlhaus & Cox 2005). This salting, described as *primary salinity*, refers to the salinisation of land and water by natural physical and chemical processes (unlike *secondary salinity* that has been induced by human activities).

Historical evidence of primary salinity is documented in accounts of the early exploration and ‘salt’ is often used as a descriptive adjective for lakes and creeks in the region. The development of the large clay lunettes at Lake Corangamite and Lake Murdeduke testify to this historic salinity (Edwards *et al.* 1996; Dahlhaus & Cox 2005). Clay lunettes form during arid periods when the lake beds are dry salt pans, where salt accumulates by evaporation of groundwater discharge.

Humans have inhabited the Corangamite CMA region for at least 35,000 years (Mulvaney & Kamminga 1999) although little is known of the early inhabitants. Accounts of the region’s original inhabitants, the *Wathaurong*, *Gulidjan*, *Gadubanud*, *Djargurdwurung* and *Giraiwurung* Aboriginal communities, who occupied the area when white settlers first explored the region around the turn of the 19th Century (Clark 1990; Horton 2000), suggest that the region was a rich, diverse area. The grassy plains, rivers and wetlands provided an ample supply and variety of food. In particular, shellfish were gathered from the coast, fish and eels were hunted and trapped in significant quantities in the rivers, lakes and estuaries, land mammals and reptiles were hunted on the plains and birds (especially water birds) were taken from the lakes and estuaries (Marshall & Webb 1997; Flannery 2002).

Early contact with the Aboriginal communities by Europeans provides further insights into the distinction of primary and secondary salinisation. Convict William Buckley who escaped from a settlement at Sorrento in 1803 and lived in the region with the *Wathaurong* community (probably the *Wada wurrung balug* clan) for 32 years, provides the earliest documented observations of the landscape and water quality for the region. An example is Buckley’s inferred assessment of the water quality at one of his favourite camps – Thompson Creek which is now a saline stream.

Recent hydrogeological investigations support the premise that high groundwater (and salinity) was a natural part of the landscape. In some areas (e.g. Western Victorian volcanic plains, Heytesbury) the depth of the groundwater tables below the surface have been relatively unchanged over the past 200 years and other factors such as changes to soil waterlogging and regolith hydrology are implicated in the spread of salinity (Dahlhaus & MacEwan, 1997; Dahlhaus & Cox 2005). In areas where the rate of groundwater movement is very slow (e.g. Heytesbury) or the aquifers thin (eg. volcanic plains) and the rainfall is high, the groundwater systems are believed to be regulated by the rate of discharge, with recharge always in excess of discharge. The groundwater systems have been relatively 'full' for centuries.

This position contrasts with the widely held assumption that extensive clearing of native vegetation and its replacement with exotic species that use less water has mobilising the salts stored in the regolith and resulted in secondary salting.(NLWRA 2001).

The extent of the natural salting is impossible to accurately quantify because in many situations the naturally occurring salinity has been modified by human changes to the environment. However there is sufficient evidence which suggests that diverse and extensive areas throughout the Corangamite region were extensively salinised before European settlement (Dahlhaus & Cox 2005).

The current secondary salting is believed to be caused by land-use changes, where excessive water may have caused excessive soil waterlogging and shallow, temporal water flows in the near-surface (Dahlhaus & MacEwan 1997).

1.2.2 Current extent of salinity

At present 20,538 hectares of salinity are mapped in the Corangamite CMA region although the mapping does not distinguish between primary and secondary (often difficult) and does not include all estuarine areas, such as the Aire River estuary (CLPR 2000). The largest mapped area is primary salinity in the Lake Connearre reserve. The salinity mapping is regarded as incomplete and is believed that many hectares of salt affected land remain unmapped.

Water quality within the CMA region, in rivers and streams as well as lakes and wetlands has declined since European settlement (SKM 1996). The current flow weighted stream salinity for selected streams is given in Table 1.1. The flow weighted salinities of the Barwon, Leigh and Woody Yaloak exceed the Murray Darling Basin Commission benchmark and are generally greater than for streams in northern Victoria.

River and location	Flow weighted stream salinity as Electrical Conductivity (EC)
Moorabool River at Lal Lal	317 μ S/cm
Leigh River at Shelford	812 μ S/cm
Barwon River at Ricketts Marsh	1667 μ S/cm
Barwon River at Inverleigh	828 μ S/cm
Barwon River at Pollocksford	1078 μ S/cm
Woody Yaloak at Cressy	1489 μ S/cm
Kennedy's Creek at Kennedy's Creek	514 μ S/cm

Table 1.1 Flow weighted stream salinity at various locations (SKM 1996)

1.2.3 The prediction of salinity in the future

In 2001 the National Land and Water Resources Audit (NLWRA) released the Australian Dryland Salinity Assessment 2000. The predictions for Corangamite were dire (Table 1.2); with the worst-case scenario suggesting that 48.5% of agricultural land is at risk from shallow water tables by 2050, costing the region \$29 million per year and with over 40% of the region's wetlands threatened by 2050.

The predictions were based on a state-wide dryland salinity hazard assessment undertaken by Sinclair Knight Merz (SKM) for the Department of Natural Resources and Environment (NRE) (SKM 2000) and

their applicability have been questioned by researchers more familiar with the groundwater flow systems in the Corangamite region. The divergence in thinking arises from the general assumption used in the state-wide modelling, which does not consider the shallow, temporal water flows in the near-surface.

Nevertheless there is strong evidence land salinisation is expanding and will do so in the future (Auditor General 2001). In the past 10 years it was estimated the area of land affected by salinity increased by 11 per cent (Gardiner 2001). While further analysis of the data is required, initial indications would suggest some locations have expanded rapidly during the past decade but many other discharge areas have remained static or reduced in size, raising the possibility that in some locations, equilibrium may have been reached (Nicholson 2002).

A reassessment of six discharge monitoring reference sites in the Corangamite region in 2004 showed varied results (Clark & Hekmeijer 2004). The area of salinised land had decreased at Beeac (13%), Gerangamete control site (25%), Moriac (7%) and Wingeel (18%). However, the monitored discharge area had increased at Pittong (8%) and the Gerangamete agroforestry site (7%), even though the groundwater level at these two sites had fallen over the monitoring period (six years).

1.3 The physical processes that drive salinity in Corangamite

The extent and severity of salinity in the Corangamite Region is influenced by a number of interactive processes. For rational investment in salinity it is critical to firstly appreciate the different factors at work, understand their influence on salinity and realise to what extent future intervention may have on altering these processes.

It is useful to consider these processes as those that cannot be readily modified such as the physical geography (geology and physiography) and climatic conditions (rainfall, evaporation and temperature) as opposed to the changes induce by human activity (land use and policy settings since European settlement).

1.3.1 Physical geography

Understanding landscape processes such as salinisation begins with an understanding of the geology. The Corangamite CMA region has formed through landscape-building episodes of the past 600 million years in a variety of environments from the deep sea to explosive volcanoes. The current landscape is continuing to evolve and processes such as earthquakes, landslides, and even saline groundwater discharge are manifestations of this process.

These significant geological events, described in Appendix A, have been important in influencing the salinity processes. The movement of water, the development of soil, and the establishment of ecosystems have all been influenced by the past landscape history. They continue to be influenced by the present-day processes of landscape evolution.

Common descriptions of the landscape in the Corangamite region (the physiography) are derived from the underlying geology and landscape evolution processes (Figures 1.2 & 1.3). The recently completed Corangamite Land Resource Assessment (LRA) is a valuable database which describes over 200 soil-landform units, and, for each of these, the principal land elements are also described and presented in a series of tables (Robinson *et al.* 2003).

The three main physiographic units in Corangamite are described more fully in Appendix B. They are:

- Western Uplands (Midlands), in the northern highlands of the Corangamite CMA region.
- Southern Uplands, which form the deeply dissected Otway Ranges, moderately dissected Barrabool Hills and low hills of the Bellarine Peninsula
- Western Plains, comprising undulating plains formed on both volcanic and sedimentary rocks

Further information on the physiography and soils of the Corangamite region can be accessed via the Victorian Resources Online website (www.dpi.vic.gov.au/vro).

Area of land predicted to currently be in each depth to watertable class and percentage of CMA region with shallow water table								
Area of land (kha) in each watertable class (excluding forest, urban and irrigation areas)		Coastal	<2m	2-5m	5-10m	>10m	% <2m	
		9.9	51.2	333.3	545.0	91.5	5.0%	
Area and percentage of CMA in each salinity risk category for upper and lower limit trend values								
	No risk		Low risk		Moderate risk		High risk	
	Area (kha)	%	Area (kha)	%	Area (kha)	%	Area (kha)	%
Lower limit values	91.4	8.9%	554.9	53.8%	384.6	37.3%	0.0	0.0%
Upper limit values	52.9	5.1%	97.2	9.4%	557.8	54.1%	323.0	31.3%
	Areas of land and proportion of dryland agricultural land predicted to have shallow water tables in 1998, 2020 and 2050		Potential gross margin foregone for pastures and crops and all agricultural commodities due to shallow water tables and salinity		Potential length of road and rail network and number of towns (populations <10,000 occurring in areas with shallow water tables)			
	Area (kha)	%	Pastures & crops (\$M/y)	Total (\$M/y)	Road (km)	Rail (km)	Towns	
1998	51.2	5.0%	2.81	2.81	456	26	1	
2020 lower limit	50.9	4.9%	2.85	2.85	457	25	0	
2050 lower limit	54.7	5.3%	3.04	3.04	480	26	0	
2020 upper limit	213.3	20.7%	9.64	9.64	1386	93	6	
2050 upper limit	499.1	48.5%	24.10	29.40	4008	205	16	
	Total length of stream and perimeter of surface water body and number of surface water bodies predicted to be located in areas with shallow watertables		Percentages of threatened flora and fauna records in areas predicted to have shallow watertables		Potential area of RAMSAR wetlands, number of natural wetlands and percentage of regional and state natural wetlands in areas predicted to have shallow watertables			
	Length (km)	Number	Flora	Fauna	RAMSAR	Natural	%	
1998	1040	658	3.1	5.6	1306	476	15.5%	
2020 lower limit	1047	647	3.2	5.4	177	460	14.9%	
2050 lower limit	1096	652	3.3	5.4	177	463	15.0%	
2020 upper limit	2629	1222	9.0	20.6	31005	866	28.1%	
2050 upper limit	5447	1546	20.6	30.3	32020	1256	40.8%	

Table 1.2 NLWRA predictions for the Corangamite CMA region (SKM 2000).

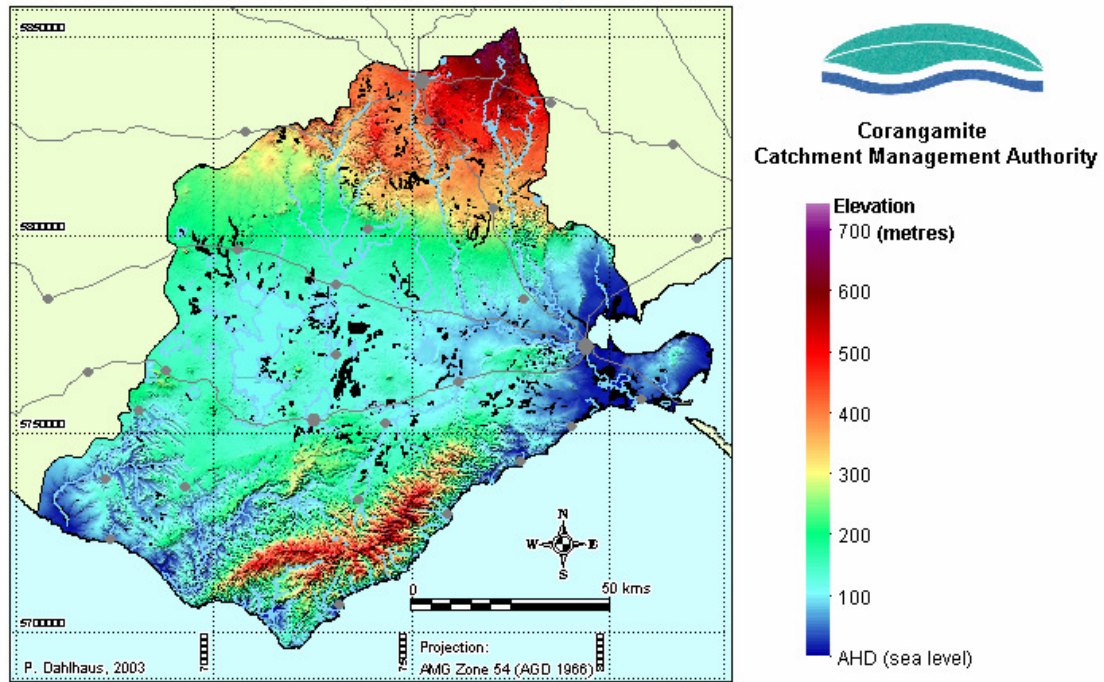


Figure 1.2 Physiography of the Corangamite region.

(Note: Mapped salinity is shown in black)

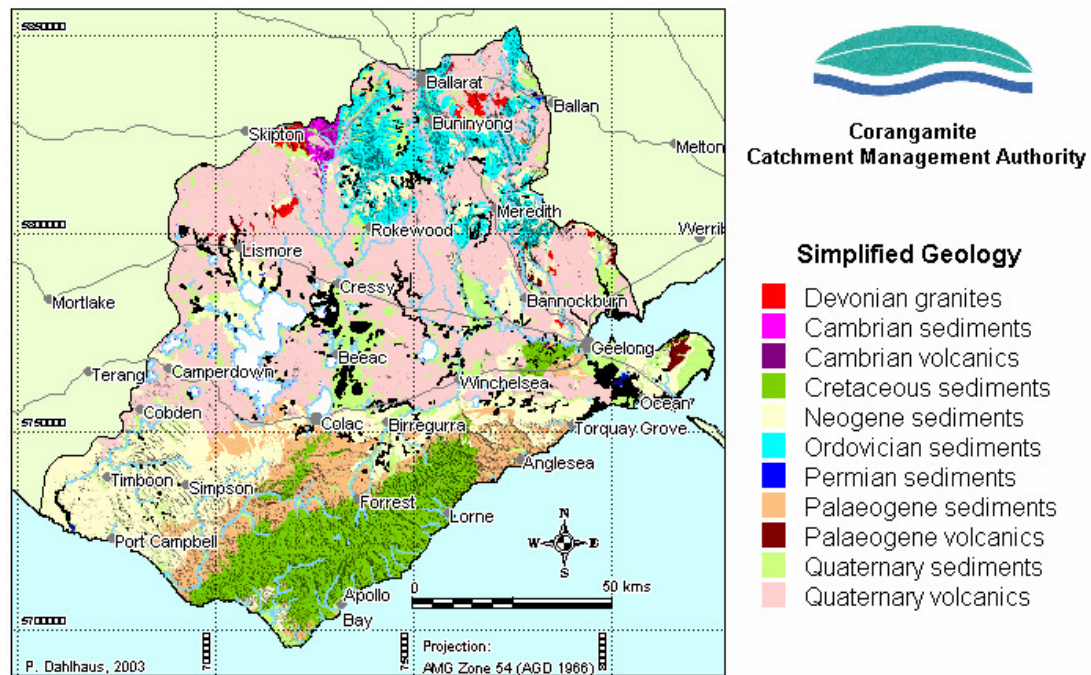


Figure 1.3 Simplified geology of the Corangamite region.

(Note: Mapped salinity is shown in black)

1.3.2 *Salt accumulation*

There are at least five sources of salt in the landscapes of the Corangamite CMA region, viz:

1. Cyclic salt. Cyclic salt is being added through rainfall, which contains small quantities of dissolved salt from the oceans. Studies have shown that the quantity of salt in rainfall is proportional to the distance from the ocean.
2. Depositional salt. Salts may be deposited with marine sediments (termed connate salt) or be accumulated by wind-blown salts from salt lakes, coastal flats, etc. Recent studies suggest that dust storms during the arid conditions of the last glacial period contributed significant quantities of salt to eastern Australian landscapes.
3. Mineral dissolution. The dissolution of minerals by groundwater and their alteration during weathering can be a source of salt.
4. Groundwater evaporation. Almost all of the groundwater in the Australian landscape contains salts, which can be concentrated by evaporation of discharge. Significant amounts can be added to the soil during centuries of groundwater discharge, even where the salt in the groundwater is present in low concentrations.
5. Anthropogenic. Salts can be added to the landscape through the application of fertilisers, stock manure and urine, irrigation waters, etc.

The majority of salt in the Corangamite landscape is regarded as cyclic and that evaporated from groundwater discharge. Depositional salt may be important in areas around the lakes of the Western Plains, as windblown salts will contribute to soil salinity of the adjacent areas when the salt lakes are completely dry.

1.3.3 *Climate*

Being situated between 37.4° and 38.9° South latitude, the region experiences a Temperate climate with dominant westerly winds, variable cloud, moderate precipitation and cool temperatures (Linacre & Hobbs 1997). Sixteen monthly and annual climate surfaces for the Corangamite CMA region have been modelled (Dahlhaus 2002) using ANUCLIM (Houlder *et al.* 2000). Of these, rainfall and evaporation are the most influential climatic factors in relation to salinity.

Rainfall across the region is closely related to elevation and latitude (Figure 1.4). The calculated average annual rainfall varies from 469 mm in the lee of the Lovely Banks Monocline to 1892 mm along the ridge of the Otway Range. The majority of rain falls in winter and spring, with August as the wettest month across the region. The Bureau of Meteorology (BoM 2000) records Weeaprounah with the highest mean annual rainfall (1937 mm) and Lovely Banks Reservoir with the region's lowest mean annual rainfall (526 mm). The occurrence of salinity shows a strong correlation to the rainfall surface (Figure 1.4).

Evaporation across the region is also closely related to altitude and latitude (Figure 1.5). Only four Bureau of Meteorology evaporation stations are situated in the CMA region. The seasonal balance between rainfall and evaporation is a critical factor in the hydrologic budget for salinity studies. Areas where evaporation exceeds rainfall for most months of the year are more likely to accumulate evaporative salts in the soil profile (Figure 1.6).

While temperature is not as important to the development of salinity, it is one of the deciding factors for selection of biological management options. Maximum and minimum climate surfaces for the region are shown in Figure 1.7.

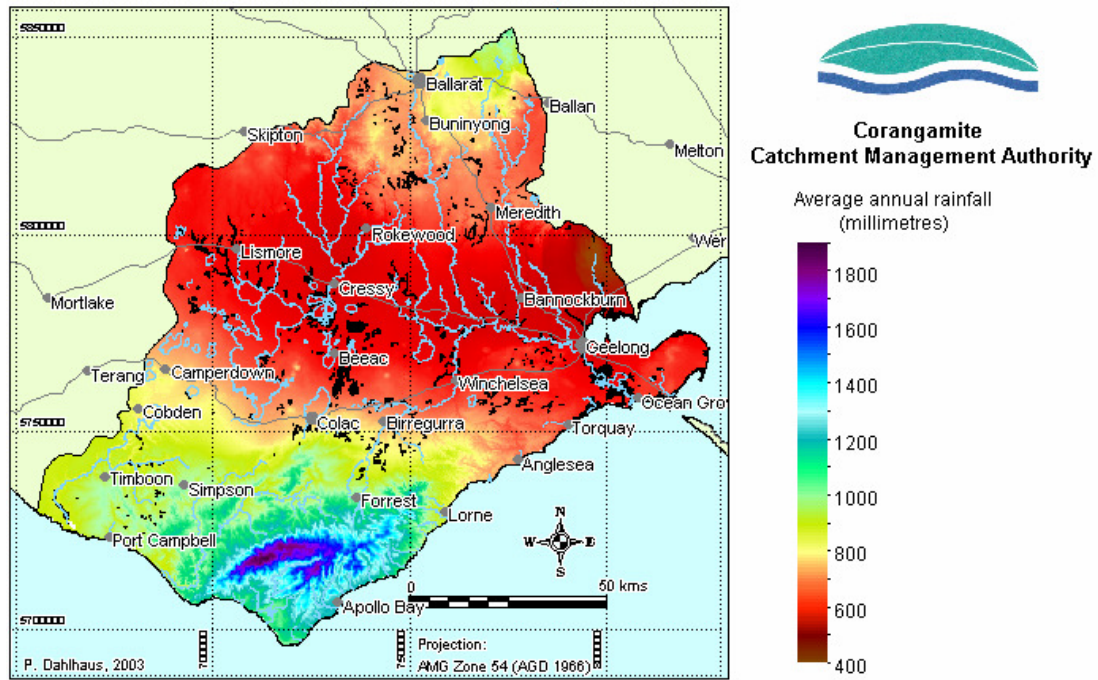


Figure 1.4 Average annual rainfall of the Corangamite region.
(Note: Mapped salinity is shown in black)

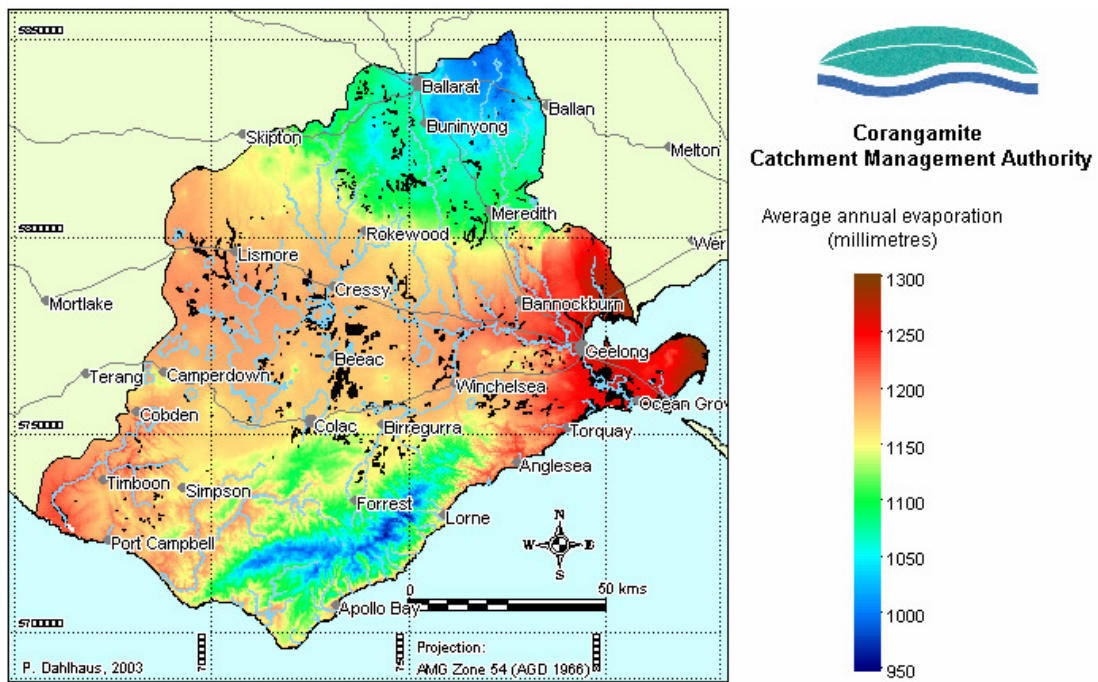


Figure 1.5 Average annual evaporation of the Corangamite region.
(Note: Mapped salinity is shown in black)

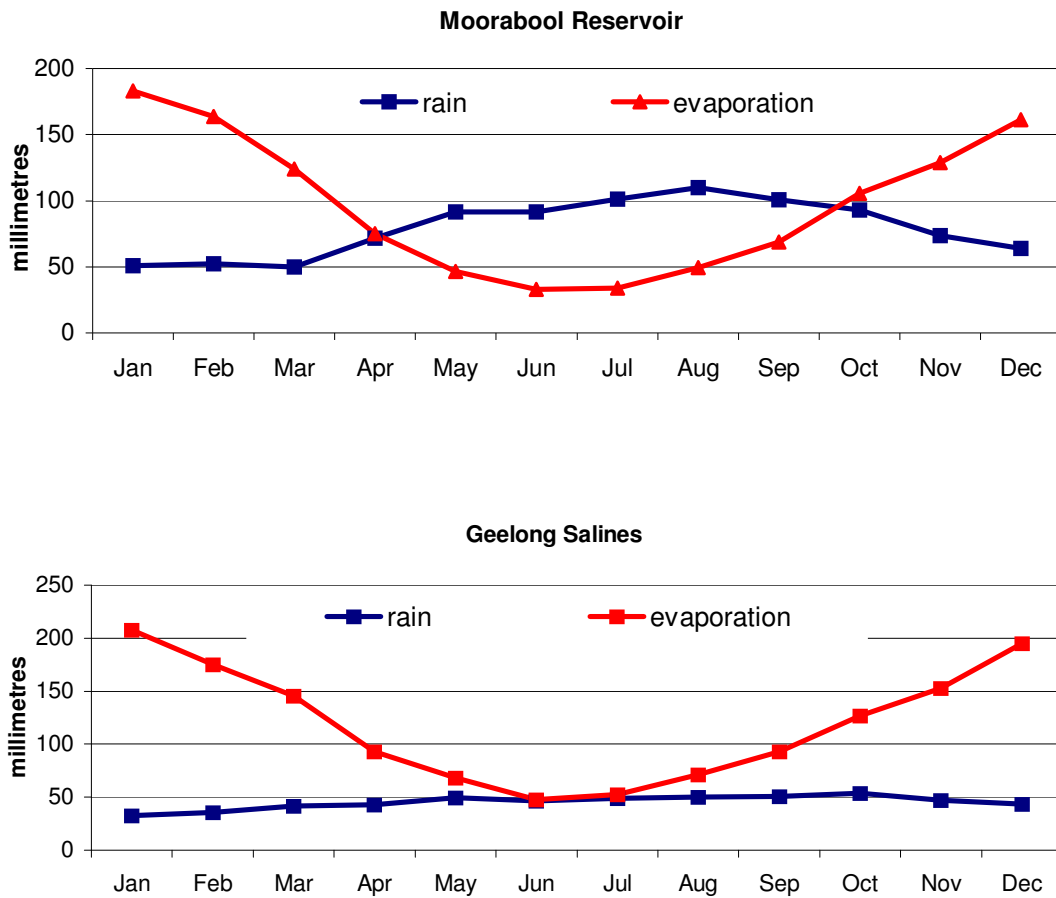


Figure 1.6 Average monthly evaporation and rainfall for two stations

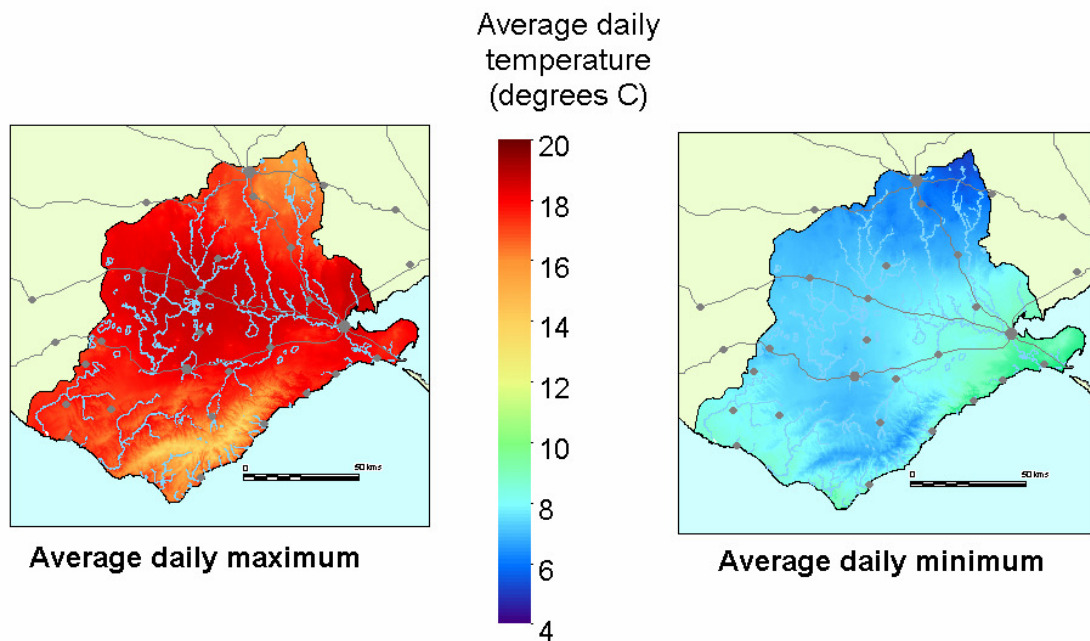


Figure 1.7 Average daily temperatures of the Corangamite region.

1.4 Major land use changes

The changes that have occurred post European settlement are those most likely to have contributed to the secondary salting in the region. Within the Corangamite Region there have been four distinct changes to land use.

1.4.1 Initial European settlement and grazing

Europeans first ventured westward from Geelong and Melbourne in 1837, when the Learmonth's explored the Lake Colac and Ballarat regions and in the same year McLeod 'discovered' Lake Corangamite. They were followed by Murray (who squatted at Colac), Scott (who squatted at Buninyong) and others, including the Manifolds who claimed 100,000 acres of country in the Purrumbete district in 1938. By 1841 most of the available grazing land on the volcanic plains was occupied by squatters.

The observations and experiences of the early settlers are important in establishing the extent of land-use change. For example, an 1839 account of the Western District Plains described them as "...wind-swept with wire-like grass and tussocks...no trees...in winter the land was soft and boggy and too poor and risky for sheep. It was possible to walk from Darlington to Geelong without stepping on grass." (McArthur, quoted in CPA 1957).

Over the subsequent decade, extensive properties were divided into smaller parcels and the land farmed more intensively. This increase in agricultural activity was aided through the various soldier settlement schemes. Currently the land is used primarily in the extensive agricultural industries of meat, wool, grains and milk, although more intensive industries such as grapes, pigs and poultry are expanding rapidly.

1.4.2 The discovery of gold and vegetation clearance

The discovery of gold at Buninyong and Ballarat in 1851 had a significant impact on settlement and land-use in the northern area of the Corangamite CMA region. Thousands flocked to the region and the native vegetation was rapidly cleared for mining, agriculture and timber supply. Grazing on the basalt plains around Ballarat gave way to cropping, as potatoes, wheat, oats and vegetables were produced and dairy herds established.

The end of the gold rush brought a demand for closer settlement. The 1860s Land Acts changed the distribution of land holdings and the land-use in the region. Clearing was accelerated as the holdings decreased in size, especially when the Closer Settlement and Soldier Settlement Schemes were implemented during the first half of the 20th Century.

1.4.3 Heytesbury settlement

The next large land-use change in the region was the Heytesbury Scheme, which cleared approximately 40,000 hectares (100,000 acres) of "unproductive bush" during the period from 1952 to 1971 (Fisher 1997). This region now forms productive dairy country, albeit with an increasing salinity and landslide problem.

1.4.4 Urban migration to rural areas, the peri-urban fringe

During the past 30 years the major cities of Ballarat, Colac and Geelong have continued to expand with a growing population acquiring significant parcels of land surrounding these centres and using these areas for 'hobby farming', lifestyle and recreational pursuits (URS 2002). The size of holdings has dramatically reduced and the land used for agricultural production has declined considerably.

1.5 The history of salinity management at a national, state and regional level

The management of salinity in the Corangamite CMA region dates back to the very earliest days of settlement, when a breakwater was constructed across the Barwon River in 1840 to prevent tidal salt reaching the new town of Geelong. A second breakwater was constructed in 1898 five miles downstream from the first, to prevent brackish water entering the Barwon and allow irrigation pumping upstream. This set a precedent in the Corangamite CMA region and during the late 19th and early 20th Century, salinity was seen as a water quality problem and as such was the responsibility of the various Water Boards and later the State Rivers and Water Supply Commission.

It was not until the establishment of the Soil Conservation Board, following the passing of the *Soil Conservation Act* 1940, that salinity was seen as a soil degradation issue. The Soil Conservation Board was superseded by the Soil Conservation Authority (SCA), established under the *Soil Conservation and Land Utilization Act* 1958, which gave the SCA much greater powers to implement soil erosion control measures. Soil salinity in the Corangamite region was first surveyed in 1952 (Cope 1955) and a landmark study published in 1958 by the SCA recorded over 10,000 acres (~ 4000 Ha) of salted land in Victoria, including sites in the Corangamite region. Sites included the Barrabool Hills, Berringa, Birregurra, Cressy, Mount Moriac, Murroon, Pitfield, Pittong, Ross Creek, and Winchelsea districts (Cope, 1958). At that time, salinity was regarded as one process in soil erosion and it was not until the mid to late 1970s that salinity was regarded as a separate issue. By 1979 rising groundwater was seen as the dominant cause of salinity and the Standing Committee on Soil Conservation formed a Working Party to report on the problem.

This was followed by the establishment of the Victorian Government Task Force on salinity in 1985, which resulted in the release of the first Victorian Strategy – *Salt Action: Joint Action* in 1988. The strategy established the Corangamite Salinity Control Region and initiated the development of the first Regional Salinity Strategy for the Corangamite region. The Corangamite Salinity Forum was established in October 1990 as a 14 member committee representing community and interest groups. A draft of the dryland salinity strategy – *Restoring the Balance* – was launched in December 1992 (Nicholson *et al.* 1992).

The Corangamite Salinity Forum was disbanded in 1995 and the Corangamite Salinity Implementation Group was established to oversee the implementation of the strategy. The Corangamite Catchment Management Authority was established in 1997 under the *Catchment and Land Protection Act*. The implementation of the salinity strategy was the responsibility of the Sustainable Agriculture and Land Management Implementation Committee (SALMIC) of the CMA.

The Victorian Government launched the second generation salinity management framework in August 2000, which supersedes the 1988 *Salt Action: Joint Action* document. The new Salinity Management Framework – *Restoring our Catchments* – recognises that although much has been achieved in the past decade, the ‘best practice’ agricultural systems in grazing and cropping cannot reduce recharge in high rainfall areas. It proposes that large-scale revegetation may be the only prospect for reducing groundwater recharge in these areas (e.g. much of the Corangamite CMA).

The initial step in developing the second generation salinity framework was a review of the 1992 Corangamite Salinity Strategy – *Restoring the Balance* (Nicholson 2002). This review identified (amongst other things):

- Almost 3,500 ha of trees and more than 16,000 ha of perennial pasture had been established and 1,130 ha of saline land treated since implementation of the strategy.
- A significant increase in the awareness of rural communities to salinity, from 35% to 65% of the population.
- Involvement of 10,000 students in the Saltwatch program.
- The collection of salinity and flow data so baseline water quality levels can be established.

- The establishment of an extensive monitoring network that includes 580 bores and 14 surface water monitoring stations.
- Research into groundwater, salinity impacts and revegetation options.
- Land salting continued to increase, albeit at approximately half the rate predicted in the original strategy. Lower than average rainfall, especially during the critical winter spring period was believed to be a factor the lower than predicted rate, but was also believed to be a major influence in the apparent rise in salinity in most lakes and waterways.
- The complexity and variation in the shallow and deep groundwater flow systems of the Corangamite Landscape. The generic recharge – discharge models used extensively at the start of the salinity program have largely been found to be inappropriate to describe the groundwater systems in the region.

In January 2001 the National Land and Water Resources Audit (NLWRA) released the Australian Dryland Salinity Assessment 2000, which predicted that 670,000 hectares of Victoria is at risk from shallow saline watertables, and that this could rise to over 3 million hectares by 2050 (NLWRA 2001). To address the gloomy predictions of the Audit, the State and Federal Governments committed \$314 million under the National Action Plan (NAP) for Salinity and Water Quality to six of Victoria's CMA regions. In southwest Victoria, the Corangamite CMA and the Glenelg-Hopkins CMA are NAP regions.

1.6 Strategies, approaches and information relevant to the development of the second-generation salinity plan for Corangamite.

The second-generation salinity plan for Corangamite must meet the goals, objectives and recommendations of a number of relevant documents. The critical documents are:

1. The **National Action Plan (NAP) for Salinity and Water Quality**, with the stated goal to motivate and enable regional communities to use coordinated and targeted action to:
 - Prevent, stabilise and reverse trends in dryland salinity affecting the sustainability of production, the conservation of biological diversity and the viability of our infrastructure.
 - Improve water quality and secure reliable allocations for human uses, industry and the environment.
2. The **Victorian Salinity Management Framework (2000)** which states:
 - By 2005, there will be representative coverage of monitoring, sufficient to account for the impacts of groundwater rise and river salinity.
 - By 2005 critical recharge zones within catchments will be identified with 50% of these critical areas revegetated by 2015.
 - By 2005 a quarter of agricultural production will be produced from natural resources that are managed within their capacity. By 2015 this will increase to half of all agricultural production.
 - By 2015 there will be a real reduction in the environment and economic impacts of salinity.
 - By 2015 Victoria will have investigated and, where practical, substantially reduced the impact of rising groundwater on the riverine environment and key wetlands.
3. The Victorian Government's white paper **Securing Our Water Future Together (2005)** which provides a comprehensive integrated approach to water use in the State over the next 50 years. Aspect of direct relevance to salinity management in Corangamite are:
 - The development of a comprehensive allocation system across all types of water.
 - Allocating a share of water resources to the environment.
 - The creation of an Environmental Water Reserve (EWR) that will (amongst other things) sustain biodiversity, ecological functioning and water quality.

- Allocations of funds to repair stressed rivers and aquifer systems.
4. The **Corangamite Regional Catchment Strategy (2003)** identifies six major forces that are likely to affect the Corangamite region. These forces and the likely consequences for salinity management include:
- Continuing urban migration, with the impact of increased competition for good quality water resources.
 - An intensification of agriculture, with grazing and cropping systems concentrating on the more productive land with some areas of land being managed less intensively or in an alternative way.
 - Growth of tourism and the associated expectation of rural land users to address degradation issues.
 - Competition for water, especially high quality, low salinity water.
 - Stronger environmental ethic, where the community demands something is done about 'the salinity problem'.
 - Greater complexity in natural resource management. The impact will be government taking a stronger 'risk based' approach to investment in natural resource management and placing greater demands on achieving outcome targets.
5. The **Corangamite Salinity Strategy review (2001)** which recommends:
- Dedicating more resources to defining the extent and importance of the salinity processes on water quality and biodiversity.
 - Establishing a dedicated research group responsible for the initiation and completion of projects, encouraging other organisations to contribute to the knowledge pool and to ensure the findings are considered during regular reviews of the plan.
 - Re-defining the locations for salinity control works based on a smaller scale, catchment descriptions and flow systems type approach.
 - Creating a mechanism where changing circumstances created either through new knowledge, new opportunities or changing political occurrences can allow for a simple review of the underlying assumptions of the Second Generation Salinity Plan, reset targets (if needed) and gain community endorsement for the changes.
 - Assigning the Corangamite CMA a pivotal role in facilitating the development of a comprehensive monitoring program for the region, which includes salinity activities as a subset of a wider program.
 - Exploring partnerships with other programs, industry groups and Authorities in the region where beneficial outcomes for salinity control can be established.
 - Re-creating a sub-group within the Corangamite Catchment Management Authority with clear roles and responsibilities for salinity implementation, including project endorsement, setting on-ground targets and budget allocation functions.

There are also three NAP foundation projects whose output has direct relevance to the development of the second-generation salinity plan for Corangamite. These are:

6. A **Review of Regional Drainage Schemes (2004)**, which examined the operation of the Woody Yaloak Diversion Scheme and the Lough Calvert Drainage Scheme, was undertaken by GHD Pty Ltd. The GHD study recommends implementing changes for the Woody Yaloak Diversion Scheme only. Their proposal is as follows:
- Continue operating the scheme under the current rules until June 2006;
 - Close 25% of the Woody Yaloak Diversion Scheme from July 2006 to June 2009 and target a rise in the level of Lake Corangamite to 115.28 m. AHD. The diversion channel operates only when the Lake exceeds 115.28 m AHD;

- Close the Woody Yaloak Diversion Scheme in July 2009 and purchase all private land up to 118.1m AHD. Maintain the current diversion channel and infrastructure to a bare minimum to be used whenever Lake Corangamite reaches higher levels.

Under this scenario the GHD study predicts that the salinity of Lake Corangamite will be maintained near the tolerance limit of most life living in the lake 45% of the time between July 2006 and June 2009, and 70% of the time after July 2009. Although the options would clearly improve the salinity management for Lake Corangamite (the icon asset in the CMA region), there are other effects such as the impact of raised lake levels on the regional water tables which will need to be considered.

7. **Moorabool River Water Resource Assessment (2004)** undertaken by Sinclair Knight Merz Pty Ltd. This study examined demands on the water resource of the Moorabool River and the impacts of the current allocations. The study examined 10 options for improving environmental flows in the river and concluded that there was no clearly favoured option. The key points for the development of the Salinity Action Plan are:
 - Although all of the 10 options considered will impact on the salinity of the river, it was not a major criterion in the weightings given to each option.
 - Until such time as the cause of the rising trend in salinity of the Moorabool River is known, salinity management actions cannot be formulated.
8. **Benchmarking saline flows in key rivers and streams for resource condition target development (2005)** conducted by Sinclair Knight Merz. This study analysed all available stream salinity data for the major basins in the CCMA area. Key findings were:
 - The existing salinity monitoring provides an invaluable resource for resource condition target setting (RCT) and location of end of valley (EOV) locations.
 - Gaps exist in some areas that prevent the development of resource condition targets.
 - Make specific recommendations to allow RCTs and EOV targets to be set in all landscape zones in the CCMA region.

Many other Federal, State, industry and locally funded projects have potential synergies with the Salinity Action Plan. These are listed (Appendix C) however their potential relevance will become apparent when target investment areas are chosen.

2 Links between salinity implementation and other natural resource management programs – areas of mutual benefit

There is enormous potential to develop strong synergies between this second-generation salinity plan and the range of natural resource management programs and industries currently in operation throughout the region. Communication and development of strong partnerships with existing catchment programs offers huge potential to “value add” to future salinity initiatives, which can achieve greater salinity benefits than that possible by acting as an isolated program. Essential to this process is an understanding of current catchment programs and identification of areas where mutually beneficial outcomes exist with the salinity program.

2.1 Relevant Regional NRM Strategies

The following provides a snapshot of *existing* programs and strategies within the Corangamite region and identifies potential areas of mutual benefit. The specific actions that may assist salinity management in the region are identified on a program basis (Table 2.1).

2.1.1 Corangamite draft River Health Strategy (2004)

The Corangamite draft River Health Strategy identifies and explains a wide range of key issues affecting waterway health in the Corangamite region, and provides strategic directions with recommended on ground actions. The waterway strategy deals predominantly with issues associated within waterways and issues associated with upper catchment activities are addressed via plans such as salinity and nutrient strategies. Salinity is identified as having a major impact on water quality within Corangamite waterways and successful salinity mitigation works are critical to achieving any future improvements to waterway health. Waterway monitoring forms a critical role for determination of salinity trends and impacts. Of direct significance to the development of the Salinity Action Plan is:

- Rising salinity in the west branch of the Moorabool River.
- The general concern of rising salinity in the Moorabool River catchment.
- Saline discharge into the Barwon River between Inverleigh and Winchelsea.
- Salt loads emanating from the diversion of drainage waters from the Lough Calvert Drainage Scheme and the Woody Yaloak Diversion Scheme.
- Altered flows into most of the nine Ramsar-listed lakes, most evident in Lake Corangamite where salinity has risen, water levels have fallen and the composition of biota changed.

2.1.2 Corangamite Nutrient Management Plan (2000)

The Corangamite Nutrient Management Plan focuses on addressing the nutrient loads within Corangamite waterway environments to reduce the incidence of Blue Green Algae blooms and associated impacts. Strong links exist between nutrient and salinity management where both programs aim to reduce concentrations of these waterway pollutants (within waterways and groundwater systems) via upper catchment activities such as adoption of best farm management practices and implementation of integrated whole farm plans. Community education and increasing general awareness of surface water qualities across the region is a key issue, which both the nutrient and salinity programs have in common.

Stormwater Management Plans (developed by local government) for improved water quality are also possible tools to address salinity and water management issues in urban areas where salinity is predicted to threaten urban infrastructure. Increased stormwater runoff can also create unnatural fresh water intrusions into primary saline areas.

Possible remedial salinity action ¹		Salinity management effect sought by adopting this action	Existing strategies, plans and programs								
			Regional					State			
			Waterway health strategy	Nutrient M'ment plan	Native Vegetation plan	Weed action plan	Rabbit action plan	Greenhouse strategy	Private forestry strategy	Biodiversity strategy	Flora & Fauna Guarantee strategy
Recharge management	Perennial pastures (native and introduced species)	Increase the area of soil water storage before deep drainage occurs.	Grasses & buffers for water-ways	Grasses & buffers for waterways	Enhancement of native grasslands	Used for weed suppression	Reduces impacts on pastures & native grasslands			Enhancement of native grasslands	Grassland community protection
	Trees and shrubs (native and plantation)	Increase areas of soil water storage before deep drainage occurs and to intercept lateral flow of groundwater	Revegetation along water-ways	Revegetation buffers to protect waterways	Vegetation protection & enhancement	Used for long term weed suppression	Precursor to revegetation activities	Increased investment in carbon sinks	Establishment of farm forestry and plantations on private land	Protection & connection of fragmented habitat	Habitat protection and enhancement for threatened species
	Drainage	Reduce surface-water ponding to minimise deep drainage.			Reduce waterlogging impacts on remnants					Reduce waterlogging impacts where vegetation threatened	Reduce waterlogging impacts where species threatened
	Sub-surface drainage	Intercepting non-saline water in the upper soil profile to prevent deeper drainage or lateral flows.	Possible reduction in stream salinity	Slowing/diverting runoff to sediment dams							Reduce waterlogging impacts where species may be threatened
Discharge management	Drainage	To prevent ponding of water to aid revegetation and salt accumulation through capillary rise.	Possible longer term salt reduction								Reduce waterlogging impacts where species are threatened
	Revegetation with salt tolerant species	To reduce capillary rise (salt accumulation) and surface run-off.	Protection buffers	Nutrient buffers	Assist protection of saltmarsh communities				Possible use of forestry for lowering saline watertable	Use native saline plants for revegetation	Possible protection of threatened saline vegetation
	Preservation & enhancement of naturally saline areas	Maintain current diversity of the saline area	Protection buffers	Nutrient buffers	Protect & enhance native saline vegetation	Reduce weed spread into marshland	Rabbit plan targets Ramsar wetlands			Protection of primary saline areas (Ramsar)	Protection of rare saline vegetation

Table 2.1 Correlation between possible salinity actions and complementary actions in existing NRM strategies and plans.

¹ This does not imply this control method is appropriate or will be adopted in the Corangamite Region.

2.1.3 *Corangamite draft Native Vegetation Plan (2003)*

The Corangamite draft Native Vegetation Strategy sets the strategic direction for future programs and frameworks for management of native vegetation and related biodiversity issues across the region. Overall the strategy aims to provide effective conservation of all vegetation communities represented within Corangamite, and details benchmarks and priority vegetation systems for action. The strategy aims to maintain and expand native vegetation to cover 30% of the region, with investment based on the concepts of regional importance and urgency to act. It embraces a 'net gain' approach in the extent and quality of native vegetation in the region. The primary driver for native vegetation management is biodiversity conservation.

Many aspects within the native vegetation strategy relate to the salinity program - wetland management and enhancement (surface water management regimes), protection of primary (natural) saline vegetation communities and effective planning frameworks to ensure no net vegetation loss across the region. The plan also highlights potential threats to priority vegetation communities by inappropriate landcare work (such as planting trees on native grasslands or planting Tall Wheat Grass near primary saltmarsh complexes). A key area of the plan relates to setting directions for wider native vegetation establishment to achieve improved catchment health, and links with the salinity plan are obvious.

Of particular relevance to regional salinity is:

- The 'net gain' can be achieved by active intervention to partially recover both the extent and quality of the vegetation.
- Priorities for investment are given to EVC protection, followed by enhancement and finally restoration.

2.1.4 *Corangamite Weed Action Plan (2001)*

The Corangamite Weed Action Plan is currently under review, however it is anticipated a key feature of the plan, namely integrated pest plant management as an integral part of good land and water use will be retained. The current recognition of the key association between longer-term weed control and improved vegetation management on farms (pasture, native vegetation, forestry) remains valid. Future pest plant and salinity programs have much to gain by working cooperatively in areas where priority weed and salinity control overlap.

2.1.5 *Corangamite Rabbit Action Plan (2001)*

The Corangamite Rabbit Action Plan is also under review. The plan recognises that rabbit control is not an outcome in itself but is an essential precursor to successful land and catchment management programs. The plan directs rabbit control programs to areas where high community benefit can be demonstrated, and highlights the need to reduce rabbit impacts in areas where priority salinity, nutrient and biodiversity values occur. There is much evidence to suggest that effective rabbit control is critical to ensuring the success and efficiency of larger scale revegetation (recharge and discharge) and forestry programs within priority salinity treatment areas. Future salinity and rabbit programs will gain great benefits by development of strong partnerships between programs.

2.1.6 *Corangamite Landcare Support Strategy (2004)*

The Corangamite Landcare Support Strategy provides strategic direction and outline key actions to support the extensive landcare movement across Corangamite. With over 130 individual landcare and natural resource management groups comprising 3000 members, the Corangamite landcare movement is a substantial vehicle for achieving local community adoption of improved land and catchment management practices. Many of these groups and networks were developed with support of the previous Corangamite salinity program, to assist in salinity control within salinity hotspot areas. Future salinity management must work closely with the landcare movement and in

many cases an effective network of skilled landcare officers and communities will be a prerequisite for instigating local actions as part of a wider regional salinity and catchment recovery program. Landcare can provide an important avenue to achieve salinity targets by:

- Encouraging community involvement and ownership of natural resource management issues.
- Developing and promoting partnerships with other key resource management organisations.
- Making regional knowledge more accessible by developing points of personal contact that function as a network of individuals and agencies.

2.1.7 *Corangamite draft Wetlands Strategy (2004)*

The Corangamite draft Wetlands Strategy provides a strategic framework for the conservation and wise use of regional wetlands so as to maintain, and where practicable, restore their ecological character. Due to the lack of data for up to 98 per cent of regional wetlands, the strategy does not contain comprehensive data analyses or prioritisation of individual wetlands, although salinity is acknowledged as having a major impact on wetlands in the region. Salinisation appears to be most threatening to lakes and wetlands that are naturally saline to some degree, where the threat is increased salinity to a level where the biological values of the lake are compromised. The strategy notes a decline in waterbird populations that can be directly attributed to increased salinities in some lakes. Of direct relevance to the Salinity Action Plan Development are:

- The need to develop specific resource condition targets for Ramsar lakes and wetlands by 2010
- The recognition that grazing was the most frequently recorded threatening process at significant wetlands
- Residential development is currently threatening wetlands close to existing developments, including the Ramsar wetlands near Lara and on the Bellarine Peninsula.

2.1.8 *Corangamite draft Soil Health Strategy (2005)*

The Corangamite draft Soil Health Strategy identifies salinity as a threatening process to soils in certain areas of the region. The strategy identifies and examines the links between salinity and other soil issues such as sodicity, waterlogging, landslides and soil structure decline. The actions and targets for the Soil Health Strategy are still being finalised.

2.1.9 *Corangamite draft Research and Development Strategy (2005)*

The Corangamite draft Research and Development Strategy is still being finalised. The draft strategy has established a comprehensive on-line bibliographic database which provides a link to all known salinity research and investigation publications. When finalised, the Research and Development Strategy will provide the process by a prospectus for research and investigations will be developed on an annual basis. The strategy aims to link salinity research with the knowledge gaps identified in the Salinity Action Plan and other strategies.

2.2 Relevant state-wide strategies

Other key natural resource strategies with links to salinity management include:

2.2.1 *Victorian Greenhouse Strategy (2002)*

The Victorian Greenhouse Strategy provides the blueprint for action to reduce Victoria's Greenhouse gas emissions. A key action states that the Government will encourage investment in carbon sinks, including nature conservation plantings and sustainable plantations, with an emphasis on maximising multiple benefits such as salinity mitigation and biodiversity enhancement. Active development of stronger links with greenhouse related programs and industries could see

major additional investment flow into Corangamite for use in landscape reforestation, which would be of great benefit to salinity management.

2.2.2 *Victorian Private Forestry Strategy (2002)*

The Victorian Private Forestry Strategy is an update of the 1998 Strategy –Towards 2020, which had an overarching aim to achieve a trebling of private forestry in Victoria by the year 2020. This current strategy aims to encourage expansion of farm forestry and plantations on private land, but with an increasing emphasis on enhancing the environmental and social benefits. Key linkages exist to encourage further private forestry expansion in those landscapes where salinity plans have identified as priority areas for reforestation. The Corangamite salinity plan must aim to provide strategic direction to where private forestry expansion is preferred for salinity benefit and engage in developing mechanisms to attract forestry to these areas. For example, the West Regional Forest Agreement Sawlog Farming Project is actively supporting hardwood sawlog plantation development on private lands, and increased cost-shares are offered where plantations are located on a salinity priority area. There is great potential to achieve larger scale reforestation within priority salinity areas via joint investment with private forestry expansion than offered by many traditional revegetation grant schemes.

Central Victorian Farm Plantations – is a committee which oversees the appropriate development of farm forestry across Corangamite. The committee's vision is to expand private forestry with particular emphasis on achieving integrated plantings that deliver multiple benefits. The committee's membership and aims tie in very closely to that of the salinity program. The Corangamite Farm Forestry Project and the Otways Agroforestry Network are very active in promoting integrated farm forestry development throughout the region.

2.2.3 *Victorian Coastal Strategy*

The Victorian Coastal Strategy plus the regional plans under the ECC Marine, Coastal and Estuarine Investigation contain the key directions for future management of Victorian coastal areas. There is also a Southwest Estuaries Coastal Action Plan in draft form. The Central and Western Coastal Boards currently oversee the strategic development of these plans within Corangamite, and Coast Action staff are key support agents within the state government departments. Of relevance to the salinity program is the issue of improved water quality and land management in areas adjoining and upstream from estuarine systems. The Swan Bay Integrated Catchment Program is a great local example of a cooperative project bringing together catchment and coastal management issues. Salinity management practices in upper catchments must extend their vision to ensure lower estuarine environments are also enhanced as part of the overall salinity program.

2.2.4 *Victoria's Biodiversity Strategy (1997)*

Victoria's Biodiversity Strategy developed the goals for biodiversity conservation and management within Victoria. The development of the Corangamite Native Vegetation Strategy is seen as a key activity to provide the relevant biodiversity management blueprint within this region, and links with salinity are mentioned in the summary of that plan.

2.2.5 *Flora and Fauna Guarantee Strategy (1992)*

The Flora and Fauna Guarantee focuses on managing flora and faunal assets across Victoria, with emphasis on developing partnership and management agreements for potentially threatened species and threatening processes which pervade throughout Victoria. Salinity programs have links where native plants or animals are threatened by salinity or salinity management practices. As an example, the rare Adamson's Bentgrass occurs on some saline discharge sites within the basalt plains of Corangamite. Reducing grazing pressure on these sites is highly desirable; however the establishment of exotic salt tolerant pasture species could represent a direct threat to the survival of this rare species on these important sites. The Flora and Fauna program within the Department of

Sustainability and Environment can provide valuable support to the salinity program for development of jointly beneficial programs.

2.2.6 *Victorian Groundwater Management Strategy (1993)*

The State Groundwater Management Strategy aims to ensure efficient, equitable and sustainable use and conservation of Victoria's groundwater resources for the maximum benefit of the community and the environment. The strategy recognises the need for balanced groundwater management, in particular the need to control groundwater levels for salinity mitigation purposes whilst allowing sufficient recharge to occur for high value fresh groundwater systems of great importance for irrigation of intensive agricultural industries. Southern Rural water is the government agency currently responsible for groundwater management. An increasing issue will be discussions surrounding the potential over commitment of groundwater resources which can lead to reduced baseflow into streams and subsequent changes or increases in stream salinities.

2.2.7 *Victorian Inland Fisheries Strategy (1997)*

The State Inland Fisheries Strategy aims to outline fisheries management arrangements for inland water bodies. Of potential to the salinity program is the issue of saline aquaculture where productive uses of saline water are required. Also of relevance is the potential for wetland creation on farms and the subsequent development of productive fisheries could be a key driver to encouraging private wetland expansion across suitable areas within the Corangamite region.

2.3 Key stakeholders in salinity management within Corangamite

The specific actions of key stakeholders that may assist salinity management in the region are identified (Table 2.2).

2.3.1 *Corangamite Catchment Management Authority (CCMA)*

The CCMA provides the strategic direction for natural resource management throughout the Corangamite region via the development of the Regional Catchment Strategy. The CCMA Board Regional Implementation Committee and Operational Portfolio Groups ensure strong community representation at this strategic level. Responsibilities of the CCMA include waterway health and management, floodplain and rural drainage management, coordination of dryland salinity management and ensure the coordination of Natural Heritage Trust, National Action Plan and regional catchment grant processes. The CCMA has the lead role in development of the Corangamite salinity control strategy.

2.3.2 *The Department of Sustainability and Environment (DSE) and the Department of Primary Industries (DPI)*

The DSE is largely responsible for strategic direction of public and crown land management, forestry and fire management on public land, flora and fauna management, environmental flow, water monitoring and greenhouse issues. DSE is the state government's purchaser of natural resource management and catchment management services.

The DPI maintains a focus on activities such as mining and extraction industries, agriculture and fisheries programs. The DPI is the state government's provider of natural resource management and catchment management services. A key role of the DPI is the delivery of extension services (salinity, soil conservation, pest management, agriculture and vegetation) via the Catchment and Agriculture Services business and this group has been largely responsible for management and delivery of salinity plan implementation under the previous Corangamite Salinity Strategy. Utilising and incorporating the valuable skills and experience of existing salinity extension staff will be a key to developing an effective and practical approach to future salinity management programs.

Primary Industries Research Victoria (PIRVic) is the research organisation of the DPI. PIRVic have been a lead agency in providing hydrogeological support and salinity research under the previous Corangamite salinity management plan.

2.3.3 *Parks Victoria*

Parks Victoria manages Victoria's parks and conservation reserve network, including the regional RAMSAR lakes and wetlands which have close ties with upstream and adjoining salinity management. Management and protection of primary saline land and associated salinity on public land are aspects which previous salinity plans have largely ignored however future plans will need to involve Parks Victoria as an increasingly important asset manager charged with protection and management of these internationally recognised wetland systems.

2.3.4 *Southern Rural Water (SRW)*

SRW is the agency responsible for management of water allocations to private and industrial users, streamflow management plans, waterway determinations and groundwater allocation and monitoring, all issues, which have close association with salinity management. SRW has a critical role in balancing the use of freshwater surface and groundwater resources with longer-term downstream impacts which can affect salinity levels within river systems.

2.3.5 *Water Authorities - Water Supply Catchments*

The Corangamite region is home to Victoria's two largest regional population centres and the development of reliable and high quality water resources for current and future urban development are key issues for this region. The regions water authorities include Barwon Water, Central Highlands Water and Southwest Water Authorities. These organisations have undertaken much planning and development in improving water quality supplies, and managing or reducing the salinity impacts within water supply catchments will be a priority within future salinity plans. These authorities are also the referral agent for statutory planning within proclaimed water supply catchments. Strong cooperative partnerships must be developed with these water authorities to take proactive actions within catchments where salinity threatens drinking water supplies.

2.3.6 *Local Government*

Shires within the Corangamite Region include the City of Greater Geelong, City of Ballarat, Corangamite, Moorabool, Golden Plains, Colac-Otway, Surfcoast, Queenscliff and parts of Moyne and Pyrenees Shires. Local government is increasingly taking a lead role in the development of resource management strategies within their boundaries and effective salinity management will require key support from this key level of government. Local governments oversee and deliver statutory planning responsibilities (under the Department of Infrastructure) and as such they can play an active role in directing preferential landuse change within priority areas identified within the salinity control program. Some shires already have salinity overlays within their Municipal Strategic Statements and Local Planning Policies. Local government has also played an active role in supporting the previous salinity program by way of assisting employment and administration support for salinity field staff, largely with great effect. There is a great need to continue to develop closer working partnerships between the salinity program and the local governments within Corangamite.

2.3.7 *VicRoads*

Manage the major freeway and highway infrastructure within the region. Municipal roads are managed by local government. Salinity and shallow groundwater have can have a major impact on the life expectancy of road infrastructure, a regional asset which has not been previously evaluated in terms of the potential salinity impacts. In a region that is highly populated, the impacts of salinity on transport infrastructure could be very high and the issue warrants investigation within the salinity program.

2.3.8 *Landholders and Industry Groups*

Through the Corangamite Industry Partnership project, areas of common interest between meat, wool, grain, dairy, forestry and natural resource organisations are being identified and mechanisms proposed to enhance joint work on those common areas will be developed. Groups such as DPI (research, extension, and policy), Best Wool 2010, Sustainable Grazing Systems, Southern Farming Systems, West Vic Dairy, Victorian Farmers Federation, various consultants and landcare have many common links with salinity management. Many of these groups have common goals that relate to increased production as well as improved sustainability (water, soil, nutrient use). In the context of the salinity plan, developing partnerships with these industry and landholders will be critical to enhancing the uptake of improved land use practices across the region. Developing stronger partnerships with these groups in the delivery of the salinity management plan must form a key program within the region.

2.3.9 *Natural Resource and Environment Organisations*

There are many more important players within Corangamite's natural resource management arena. Organisations such as local landcare groups and networks, Greening Australia, Trust for Nature, Australian Conservation Volunteers, Coast Action Groups, Field Naturalists, local environment and friends groups, Fishcare and Victorian Field and Game Association, Society for Growing Australian Plants, lake committees plus many more are working tirelessly to improve the state of their local environments. Many of these groups have developed their local plans and strategies and are keen to access support to implement their plans. Developing partnerships and harnessing this network of knowledge, skills and enthusiasm will need to be a key objective of the salinity program.

2.3.10 *Tertiary Education Institutions*

The Corangamite region has tremendous assets in the form of tertiary education centres (Deakin University, University of Ballarat, The University of Melbourne – Creswick campus, and the regional TAFE institutions in Ballarat and Geelong) and future salinity programs have much to gain from developing cooperative partnerships and research links with these local institutions.

2.3.11 *Aboriginal/Indigenous Community*

Aboriginal culture in Corangamite has strong links to many of the wetlands and waterways within the region. The protection and management of archaeological sites is a key issue for the indigenous community and salinity programs must undertake consultation and cooperation with local cultural heritage organisations to ensure appropriate implementation measures are used in and near all significant sites.

Possible remedial salinity action ²		Salinity management effect sought by adopting this action	Existing stakeholders												
			Regional												
			CCMA	DPI (CAS)	DSE	Parks Vic	SRW	Water Authorities	Local Government	VicRoads	Agricultural industry groups	Resource and environment organisations	Tertiary education institutions	Aboriginal / Indigenous community	
Recharge management	Perennial pastures (native and introduced species)	Increase the area of soil water storage before deep drainage occurs.	Oversee protection of native grassland	Extension services for pastures/ grassland	Oversee protection of native grassland							Encouraging exotic perennial pastures			
	Trees and shrubs (native and plantation)	Increase areas of soil water storage before deep drainage occurs and to intercept lateral flow of groundwater	Oversee vegetation strategies	Involved in vegetation extension, farm forestry	Vegetation protection and planning	Revegetation buffers for parklands		Revegetation in water catchments	Vegetation clearance. Some involved in landcare programs.	Vegetation mgmt on roads	Increased trees for farm benefits	Increased revegetation a key activity	Research required on trees & water use, locating in correct sites	Bushfoods	
	Drainage	Reduce surface-water ponding to minimise deep drainage.	Oversee drainage operations across region	Raised bed cropping	Issue to preserve wetlands	Impacts on RAMSAR wetlands	Impacts on water diversion, water laws	Impacts for water quality	Impacts on road drainage	Impacts on road drainage	Mainly cropping (raised beds). Pasture drainage emerging		Raised bed research underway		
	Sub surface drainage	Intercepting non-saline water in the upper soil profile to prevent deeper drainage or lateral flows.	Oversee drainage issues		Issues with disposal of water		Issues with disposal of water	Issues with disposal of water			Links with increased profitability		Research required	Possible impacts on cultural sites	
Discharge management	Drainage	To prevent ponding of water to aid revegetation and salt accumulation through capillary rise.	Oversee drainage issues		Issues with disposal of water		Issues with disposal of water	Issues with disposal of water					Research required		
	Sub surface drainage	To intercept shallow saline watertables.	Oversee drainage issues				Issues with disposal of water	Issues with disposal of water						Possible impacts on cultural sites	
	Revegetation with salt tolerant species	To reduce capillary rise (salt accumulation) and surface run-off.	Use of native plants	Active in discharge treatment	Support native species	Concerns with Tall W- Grass		Improve water quality			Increased profitability for saltland				
	Preservation & enhancement of naturally saline areas	Maintain current diversity of the saline area	Supports native saltmarsh protection	As a part of salinity reveg projects	Protects native salt vegetation	Supports their management of saline lands						Protects native saline areas	Research required for more native species		

Table 2.2 Correlation between possible salinity actions and existing stakeholders.

² This does not imply this control method is appropriate or will be adopted in the Corangamite Region.

3 Community engagement and participation

3.1 Community engagement in 2003

The community engagement and participation process used in the development of the draft Salinity Action Plan in 2003 was carefully constructed to achieve ownership and subsequent adoption of desired actions in the plan whilst adequately consulting with the appropriate stakeholders. The consulting team was acutely aware of the extensive community consultation occurring with the Regional Catchment Strategy review and renewal process as well as the multitude on foundation projects underway as part of the NAP foundation year. The current level of community engagement as part of the NAP process placed considerable pressure on stakeholder groups and the wider community.

To avoid confusion and duplication, the salinity consultation component was highly targeted, primarily at those areas where a change in practice is required and then securing key stakeholder investment to ensure landscape change occurs. A three-tier approach is used.

3.1.1 Parties with a stake in high risk assets

The first tier engaged those groups who reside in priority investment areas or manage assets within these areas. Identification of these parties was derived from:

- Identifying the high priority assets that are at risk from salinity in the future by using the output from the Geospatial Salinity Hazard and Asset Risk Prioritisation (GSHARP) project (Heislers & Brewin, 2003).
- Identifying the existing stakeholders who are currently delivering salinity outcomes, either directly through targeted programs or indirectly where the outcomes from their current activities could have salinity benefits in a future program. The results listed in Table 2.2 assist in this identification.
- Identifying existing non-salinity programs that are currently delivering outcomes that have may salinity benefits in a future program. The results listed in Table 2.1 assist in this identification.

Engagement with these groups was designed to clearly focus on the asset under threat from salinity. Background to this engagement was the current understanding of the anticipated forces affecting the Corangamite Region in the future and the regional goals as derived from the regional review and renewal process.

The process involved discussions on an individual basis and in joint workshop sessions. In these discussions key components necessary for the development of the salinity plan were examined. These included:

- Benchmarking the current state of the asset.
- Describing the salinity processes that are threatening the asset.
- Articulating a vision, objectives and outcomes for the future state of the asset or assets currently under threat.
- Identifying actions that will allow the vision to be achieved. This will consider the strategic planning elements described in Section 4.
- A tactical plan to implement the actions, including the investment of resources and assigning of responsibilities.

Endorsement was sought for each of the steps outlined above. This resulted in a commitment of the agreed course of action by those parties with an interest in the asset at risk.

3.1.2 *Stakeholders providing support for site specific asset protection*

The second tier involves engaging stakeholders who were not directly responsible or involved with an asset at risk, but provide essential infrastructure, planning and support for others to implement actions.

Identification of these groups was assisted by the descriptions in Table 2.2 and through the outcomes of engagement with the parties with a stake in the high-risk assets.

Parties that need to support the proposed vision and actions from the first tier consultation were briefed on the suggested approach from the stakeholders directly involved with the asset. There was a need to gain in principle support for the proposed vision actions.

Discussions with these stakeholder groups used an amalgamated vision, objectives and triple bottom line outcome, derived by the consultation and endorsement from the specific priority asset areas.

Important to this tier of engagement was discussions with groups and organisations who may no longer be deemed to be in a high investment area (though the outcomes of the GSHARP study) and/or where their current actions are no longer appropriate to achieving the desired outcomes of the Salinity Action Plan. This was an essential component of the community engagement process, so the past efforts of these groups were recognised, acknowledged and the reasons for the change in emphasis explained.

The CCMA played a pivotal role in endorsing the changes in priority.

3.1.3 *Wider community input*

Given the extent of consultation through the RCS process and the highly targeted approach taken in the first two tiers of the consultation process, engagement of the wider community not directly affected by salinity was to be achieved by inviting comment on the draft salinity plan.

Opportunities to comment on the public drafts were provided during 2004.

3.2 Community engagement in 2005

The draft Salinity Action Plan was used to guide the development of the Corangamite Regional Catchment Investment Plan in 2004/2005 and 2005/2006. In finalising the plan in 2005, the following additional engagement was conducted:

- Providing a written response to those who engaged in the stakeholder and wider community process (Dahlhaus & Nicholson, Salinity Action Plan Background Report No.7, 2005)
- Meeting with Mr Shayne Annett, Senior Policy Analyst, Landscape Change, Landcare & Sustainable Landscapes Branch, DSE.
- Meetings with service providers engaged in deliver the draft SAP in 2004 and 2005. This consultation added to the 'market research' conducted previously (Nicholson et al. 2003, Salinity Action Plan Background Report 4). The results of these consultation meetings have been added to a revised version of Background Report 4 (Nicholson et al. 2005).

4 Strategic planning elements to achieve the vision

The elements to be explored in the strategic planning process will be drawn from the key component of a program logic model developed and later validated by the Corangamite salinity team in the late 1990's.

Program logic is a cause and effect model to achieve a higher order outcome. The model dictates that unless all the next lower order elements are being achieved, success with the higher order outcome will be diminished. The higher-level framework is described below:

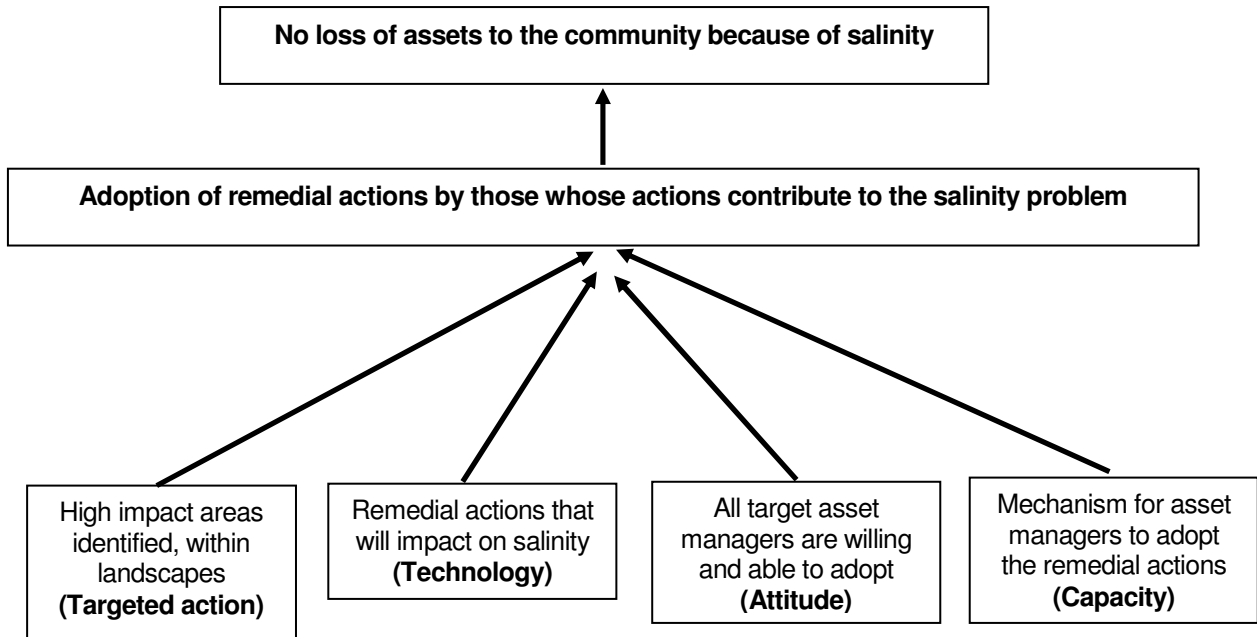


Figure 4.1 Program Logic framework

The four components of targeted action, technology, attitude and capacity will form the strategic planning elements. Developing the detail below these four components creates the tactical and operational structures to achieve these actions. Specific questions in relation to this framework will rely on recent work in the Sustainable Grazing Systems (SGS) program (Nicholson *et al.* 2002).

4.1 Prioritisation

The high priority (impact) areas for salinity control are identified using three tools, *viz*: disaggregation of the landscapes into management units (the groundwater flow systems); identification of threats to assets (the GSHARP process), and identifying trends in salinity (GAM analysis). These tools are used to identify the physical location to undertake focussed discussions with the key stakeholders. However within these high priority areas there will also be a need to target physical on-ground actions to locations that will have a *direct* impact on the salinity processes that are threatening the asset. In some cases these may not be well defined or the confidence in the location of treatments in the landscape may be unclear.

This is a critical step in ensuring future investment has a chance of achieving a salinity outcome. It is possible a result of examining this planning element will be the need to provide a rapid appraisal of the high priority area to assist stakeholders in the targeting of actions.

4.2 Technology

A key requirement is to have actions (technologies) that, if implemented, will have an influence on the salinity processes that are operating. The existing actions used in the Corangamite Region such as revegetation with trees, deep-rooted perennial pastures and saline revegetation may still be applicable to manage the salinity process. Conversely there may be a need to explore new actions that may not be well researched or may not currently exist. It is possible new actions may have to be 'invented' as part of the technology element.

The consultation process will need to explore the following issues:

- Describing the current understanding of the processes at work at an appropriate scale to allow actions to be considered.
- Exploring and examining current options and possible alternatives.
- Identifying who are the appropriate parties to develop and test alternative approaches.

Describing monitoring and evaluation systems to confirm the actions are having the desired impact at a local sub-catchment and regional scale.

4.3 Attitude

Motivation of asset managers in high impact areas is crucial to achieving the desired outcome. Traditional approaches such as awareness raising events, community education, client research studies and visioning exercises are important in creating the attitudinal shift towards *sustained* participation but are only part of a comprehensive picture.

Recent research (Barr & Cary 2000) examines some of the real challenges to natural resource management programs that not only helps explain why past programs have struggled to encourage widespread adoption of salinity mitigation practices, but also the factors that need to be addressed if voluntary participation is required. For salinity control issues such as recognising degradation (if the process is slow to occur), anticipating future degradation, the incompatibility of desired salinity control actions with current land use practices, the 'faith' that landholders need to have that the options will eventually have an impact and the 'irreversibility' of some control actions are attitudinal dis-incentives to participation.

In exploring this element of the strategic planning process there is a need to examine 'non-traditional' and lateral approaches to motivating people to participate. The approaches may not be directly related to salinity although the consequence of their subsequent actions may achieve the desired salinity outcome. These will include issues such as:

Can the necessary salinity actions be couched in terms of achieving a positive gain (rather than the common salinity approach of preventing a future loss)?

- Can the actions be assigned a short-term financial benefit?
- How can the actions be integrated into current practices with minimal disruption?
- Can other parties also promote the adoption of these desired actions?
- What external parameters provide an incentive or dis-incentive to participate eg policy settings, commodity price incentives?
- What simple tools and activities can help in assessing their current situation so they can compare against 'best practice'?
- How does a long term vision or plan help in maintaining a positive attitude and when should it be developed?

Another commonly unrecognised element of sustaining a positive attitude is the support mechanism required to maintain confidence and commitment to the actions when circumstances

change. This may be due to external influences such as drought, changes in commodity prices, changes to business or organisational structures and where the anticipated impact of the actions are slow to see or the positive results are less than anticipated.

4.4 Capacity

This relates to the human and physical capacity of any asset manager to engage in the remedial actions.

The physical resources that need to be explored include:

- Technical advice, especially how it should be delivered and by who.
- The importance of financial assistance in purchasing materials and reducing the 'investment' risk. This includes the most appropriate means of providing access to this funding eg Government grants, reduce interest loans through financial institutions, alterations to land rates etc.
- Access to machinery and possibly additional labour needed to undertake the task.
- The time to undertake the necessary actions.

The human resources relate to the skills and understanding to undertake the task. The development of this understanding often relies on a combination of trialling, innovative experimentation and sharing of the results from these activities. Examination of the appropriate resourcing of the human elements will include discussing:

- The best ways of developing an understanding of the processes at work and the appropriate solutions?
- The best ways of understanding the 'knock-on' effects if the salinity actions are implemented?
- What is the appropriate combination of expert advice and active experimentation, either within groups or on an individual basis to develop skills and understanding?
- What social mechanisms are required to support whole farm practice change?

References

- ABS, 2002. Population for Local Government Areas: 30 June 2001, preliminary. www.abs.gov.au
Australian Bureau of Statistics
- AUDITOR-GENERAL 2001. Managing Victoria's growing salinity problem *Performance Audit Report 76*, Auditor-General Victoria, 160p.
- AUSLIG, 2000. Australian River Basin Boundary. MapInfo tables, Australian Land Information Group
- BARR N & CARY J., 2000. *Influencing Improved Natural Resource Management on Farms. A guide to understanding factors influencing the adoption of sustainable resource practices*. Bureau of Rural Sciences, Canberra, Australia.
- BIRD E.C.F., 2000. *Coastal Geomorphology. An Introduction*. John Wiley & Sons Ltd., Chichester, 322p.
- BOM, 2000. *Climate Data: Australia*. Data extracted from the Australian Data Archive for Meteorology in June 2000 (on CD), Bureau of Meteorology, Kent Town, South Australia.
- CCMA 2003. Corangamite Regional Catchment Strategy 2003-2008, Corangamite Catchment Management Authority, 232p.
- CLARK I.D., 1990. *Aboriginal Languages and Clans: An Historical Atlas of Western and Central Victoria, 1800-1900*. Monash University, Clayton,
- CLARK R.M. & HEKMEIJER P. 2004. Victorian Salinity Monitoring: reassessment of six reference discharge monitoring sites in the Corangamite region *Centre for Land Protection research report 43*, Primary industries Research, Victoria, 70p.
- CLPR, 2000. Corangamite Salinity MapInfo tables, Centre for Land Protection Research Department of Natural Resources and Environment, Bendigo.
- COPE F. 1955. Catchment Salting in Victoria. M.Agr.Sc. thesis (unpublished). University of Melbourne.
- COPE F., 1958. *Catchment Salting in Victoria*. Soil Conservation Authority of Victoria, 88p.
- CPA, 1957. *Corangamite Region. Resources Survey*. Central Planning Authority and Corangamite Regional Committee, 197p.
- DAHLHAUS P.G., 2002 Atlas of GIS data: unpublished report for the Corangamite Catchment Management Authority, Colac.
- DAHLHAUS P.G. & COX J.W. 2005. Geomorphic and historical evidence of salinity in the Corangamite region, Australia - Implications for current salinity management. *Poster Presentation Abstracts, Managing Saline Soils and Water: Science, Technology, and Social Issues. Proceedings, International Salinity Forum, Riverside, California, April 25-27, 2005*. pp.47-50
- DAHLHAUS P.G., HEISLERS D.S. & DYSON P.R., 2002. Groundwater Flow Systems. Consulting report CCMA 02/02, Dahlhaus Environmental Geology Pty Ltd, for the Corangamite Catchment Management Authority. 75p.

DAHLHAUS P.G. & MACEWAN R.J., 1997. Dryland salinity in south west Victoria: challenging the myth in: *Collected Case Studies in Engineering Geology, Hydrogeology and Environmental Geology*, (McNally G.H., ed.) Third series, Environmental, Engineering and Hydrogeology Specialist Group of Geological Society of Australia, Sydney, pp.165-180.

DSE 2005. Victorian Government White Paper: Securing Our Water Future Together.

EDWARDS J., LEONARD J.G., PETTIFER G.R. & MCDONALD P.A., 1996. Colac 1:250 000 map *Geological report 98*, Department of Natural Resources and Environment, Melbourne. 168p.

FISHER H., 1997. *Heytesbury: Once in a Lifetime*. Spectrum Publications, Melbourne,

FLANNERY T., 2002. *The Life and Adventures of William Buckley*. Text Publishing, 200p.

GARDINER B. 2001. Salinity Discharge Mapping in the Corangamite Region *Report*, Department of Natural Resources and Environment, 29p.

GHD 2004. Draft Review of Regional Drainage Schemes Summary Document for Public Comment. *Consultant report to the Corangamite Catchment Management Authority*, GHD Pty Ltd, 37p.

HEISLERS D.S. & BREWIN D. 2003. Corangamite Salinity Hazard and Assets Risk Assessment. *Centre for Land Protection Technical Report 6*, Department of Primary Industries, 90p.

HORTON D., 2000. *Aboriginal Australia*. 1:4,700,000 Map, 3rd edition, Canberra.

HOULDER D.J., HUTCHINSON M.F., NIX H.A. & MCMAHON J.P., 2000 ANUCLIM User Guide, Version 5.1. <http://cres.anu.edu.au> Centre for Resource and Environmental Studies, Australian National University, Canberra

LINACRE E. & HOBBS J.E., 1977. *The Australian Climatic Environment*. John Wiley & Sons Ltd., Brisbane, 354p.

MARSHALL B. & WEBB C., 1997. Aboriginal Archaeological Investigations at Barwon Heads Park, unpublished report by Austral Heritage Consultants, 29p.

MULVANEY D.J. & KAMMINGA J., 1999. *Prehistory of Australia*. Allen & Unwin Pty Ltd, St. Leonards, 480p.

NICHOLSON C. 2002. Review of the Corangamite Salinity Strategy "Restoring the Balance". *Consulting report by Nicon Rural Services*, Corangamite Catchment Management Authority, 58p.

NICHOLSON C., BARR N., KENTISH A., DOWLING P., McCORMICK L., PALMER M., SIMPSON I., SIMPSON K. & WALSH J., 2002. A research -extension model for encouraging the adoption of productive and sustainable practices in high rainfall areas. *Australian Journal of Experimental Agriculture*. 43.

NICHOLSON C., STRAW W., CONROY F. & MACEWAN R. 1992. *Restoring the Balance. Dryland salinity strategy for the Corangamite Salinity Region*. Corangamite Salinity Forum, 49p.

NICHOLSON C., ANDERSON G., & STEPHENS M. 2003. Asset manager consultation, preferred methods of implementation and management targets. *Corangamite Salinity Action Plan Background Report 4*, Corangamite Catchment Management Authority.

NLWRA, 2001. *Australian Dryland Salinity Assessment 2000*. National Land and Water Resources Audit, 129p.

NRE, 2001. Local Government Area MapInfo table (lga.tab), Department of Natural Resources and Environment, Melbourne.

NRE, 2002. Healthy Rivers, Healthy Communities & Regional Growth. Victorian River Health Strategy. draft, Department of Natural Resources and Environment, Melbourne. 156p.

REES D., 2000. Land Systems of Victoria. January 2000. Edition 3 *Technical Report 56*, Department of Natural Resources and Environment, 134p.

ROBINSON N., REES D., REYNARD K., MACEWAN R.J., DAHLHAUS P.G., IMHOF M., BOYLE G., & BAXTER N. 2003. A land resource assessment of the Corangamite region. *Primary Industries Research Victoria report*, Department of Primary Industries, 131p.

SKM, 1996. Corangamite Region surface water salinity. Consulting report by Sinclair Knight Mertz Pty Ltd, Armadale. 20p.

SKM, 2000. Extent and impact of dryland salinity in Victoria. Consulting report by Sinclair Knight Mertz Pty Ltd, Armadale.

SKM 2004. Moorabool River Water Resource Assessment. Final report. *Consultant report for Corangamite Catchment Management Authority Final 2*, Sinclair Knight Merz, 22/10/2004, 404p.

SKM 2005. Benchmarking saline flows in key rivers and streams for resource condition target development. Salinity monitoring in the Moorabool, Barwon, Lake Corangamite and Otway basins. *Consultant report for Corangamite Catchment Management Authority Draft a*, 30 June 2005, Sinclair Knight Merz. 67p.

URS, 2002. Guide to Mega-Communities in the region. Consulting report to the Corangamite Catchment Management Authority compiled by URS Australia Ltd and AgInsight, November 2002.

Appendix A Geological evolution of the Corangamite region

The origins of the Palaeozoic sedimentary and igneous rocks of the Corangamite CMA region commenced about 600Ma when it formed part of the deep sea floor. Sand and mud transported by rivers from an ancient continent to the west, slowly built up to form thick piles of sediment. These sediments were subsequently deformed into mountain chains by east-west compression during a series of tectonic plate collisions commencing around 500Ma million years ago. This tectonism resulted in the rock being tightly folded (north-south trending folds), faulted and injected by quartz veins, some of which were mineralised. Around 350Ma the sedimentary rocks of this mountain chain were injected with magma, which subsequently slowly cooled at depths of around two to five kilometres to form granites. Subsequent erosion of several kilometres thickness of rock has exposed the present day landscapes, including the granites, in the northern Corangamite CMA region.

During the Permian (~ 260Ma) the region lay close to the South Pole and was subjected to glaciation which further eroded the rocks. At the conclusion of the glaciation, the major drainage direction in the region was to the north. The next significant event was the break-away of Australia from Antarctica, which started with the formation of a large rift valley in the south of the CMA region around 140Ma. Sediments washed into the rift valley by large braided river systems now form the rocks of the Otway Ranges and Barrabool Hills. The Australian – Antarctic break-up resulted in a down-warping to the north, creating the Murray Basin and the uplift that formed the drainage divide of the Great Dividing Range.

As the break-away proceeded a sea-way opened between the two continents and series of marine sediments began to accumulate, which now form the underlying rocks of the southern Corangamite CMA region. As the sea-way developed into the Southern Ocean the depositional environments varied spatially and temporally, changing from terrestrial to littoral and marginally marine to finally depositing the Port Campbell Limestone in shallow warm seas during the Miocene.

From the mid-Miocene (~15Ma) the direction of movement of the Australian Plate changed, resulting in a change in regional stress from extensional to compressional. This change resulted in renewed block faulting which has been responsible for the formation of the major physiographic features of the CMA region. The faulting formed the Central Highlands, Barrabool Hills, Bellarine Peninsula and Otway Ranges. Many of these faults remain active and seismicity (earthquake activity) continues to the present day.

The events of the Pliocene (~ 4Ma) – an invasion of the sea and the commencement of volcanism – have had a dramatic influence in shaping the detail in today's landscapes. The volcanism in particular was responsible for disrupting and changing drainage and continued to around 50,000 years before present. The courses of all of the major rivers in the region were changed by volcanic activity during the past 2 million years and the majority of the large lakes and wetlands were formed during this period.

The climate changes during the past million years, especially the arid period of the mid-Pleistocene (~500 ka) and the relatively dramatic changes in sea levels – up to 140 metres – since the last Glacial (~18 ka) have left significant imprints in the regolith development and soil profiles. The result is that the landscapes of the Corangamite CMA region vary from ancient, deeply weathered sedimentary rocks to volcanic rocks just a few thousand years old.

Appendix B Geomorphic units of the Corangamite region

These units form the basis of the Land Systems of Victoria (Rees 2000), and are currently under review. The geomorphic units that form the basic components of the land systems of the Corangamite CMA region are listed in Table 2.

Western Uplands

The Victorian Western Uplands (Midlands) form the northern highlands of the Corangamite CMA region. The highest elevations in the CMA region are the volcanic cones of Mt Buninyong (745 m), Mt Warrenheip (741 m), and Tipperary Hill (743 m). The sedimentary rocks generally form the drainage divide along the northern eastern boundary of the CMA region and rise to a high point of 740 metres north of Barkstead. In general, the landscapes of the Palaeozoic sedimentary rocks are characterised by undulating low hills dissected by a dendritic drainage pattern that forms the upper catchments of the Moorabool River, Leigh River, and Woody Yaloak Creek drainage systems. The primary drainage trends parallel to the strike of the bedrock strata and the secondary drainage is controlled by geological boundaries (i.e. lithological boundaries) and rock structures (i.e. faults, joints).

The larger landscape elements are remnants of the deeply weathered Palaeogene palaeosurface. At Ballarat, the weathering extends up to 100 metres below the surface, with secondary mineral development (eg. kaolin clay) producing the typical bleached and pallid regolith profiles in the Palaeozoic rocks. The oxidation of iron-rich groundwaters has precipitated iron cement into joints and the upper regolith materials.

The Palaeozoic granites generally form subdued landforms such as those around Yendon and Lismore. In some areas the metamorphic aureoles around the granites are resistant to weathering and form prominent wooded to cleared ridges, such as the range south of Linton.

The recently formed volcanic landscapes in the Western Uplands contrast with the older landscapes as the basalts of the Newer Volcanics fill many of the large ancient valleys. Elongate planar basalt plains are usually fringed by streams of the displaced drainage, although occasional basalt gorges (eg. Devils Kitchen, Lal Lal Falls) have developed where streams have cut into the basalt flows. The eruption points from prominent scoria cones, lava cones and the odd maar (eg. Hardies Hill).

Soils are directly related to the underlying geology and subsequent landform evolution. The Palaeozoic sedimentary rocks generally have duplex soils, often with well developed, bleached A₂ horizons. However, the geologically recent landscape development and the significant land-use change of the past 150 years have stripped the profile in many places. Intensive shallow gold mining has disturbed many hundreds of hectares such that the original profile no longer exists and new profiles have started to form. The granites generally have developed sandy soils, with profiles varying from uniform or weakly gradational sands to strongly duplex ferruginised podsollic soils. The soils on both the sedimentary rocks and the granites are regarded as agriculturally 'poor' compared to the soils of the Newer Volcanics, which exhibit gradational clayey chocolate soils and kraznozems on the younger rocks to coarsely structured duplex soils on the older rocks.

Southern Uplands

The southern portion of the Corangamite CMA region is dominated by the Victorian Southern Uplands, which form the deeply dissected Otway Ranges, moderately dissected Barrabool Hills and low hills of the Bellarine Peninsula. All three landscapes have formed by the uplift of a structurally controlled block of lithic sedimentary rocks of the Lower Cretaceous Otway Group.

Significant uplift of the Otway Ranges has occurred in the recent geological past along two reverse faults: the westerly dipping Torquay Fault to the east and the easterly dipping Bambra Fault to the west. The continued uplift of the Otway block is partially responsible for the incision of steep river valleys. The crest of the range forms a drainage divide which trends north east from Moonlight Head, through Lavers Hill to Mount Chapple (550m), then easterly to Mount Sabine (583m), and northeast to parallel the coast through the highest point at Mount Cowley (686m) to Anglesea.

On both sides of the divide rugged topography has developed comprising ridges and spurs separated by deeply dissected steep valleys. The drainage is strongly controlled by the geological structure. Parallel to the south east coast, the drainage is generally south east and north west, whereas west of Mount Sabine, the drainage is generally north and south. The depth of dissection is less along the ridge, while the south eastern flanks of the ranges have developed the steepest topography, probably in response to the fluctuations in sea level over the past million years that have changed the base level of the rivers and streams that drain the landscapes. The coastline has been eroded within the past 6000 years, and the recession has been estimated as 105 metres on mudstones and 53 metres on sandstones along the Otway coast (Bird 2000).

Besides creating dramatic changes along the coast, the fluctuation in sea level and the associated uplift of the Otway Ranges has resulted in the rapid development of steep valleys of tributaries to the Gellibrand and Barwon Rivers. Both erosional processes have resulted in numerous large landslides, with probably more activity in the past 6,000 years since the slight drop in stream base levels (renewed erosion) and warmer (and therefore wetter) climates have prevailed.

North of the Bambra Fault, the landscapes comprise more gently undulating hills formed on Tertiary age sediments. This area has not experienced the same tectonic uplift as the Otway Ranges, so the degree of dissection is much lower. The wide flood plain of the Barwon River has developed in response to the changes in base levels associated with the periodic damming of the river by Newer Volcanic basalt flows around Winchelsea and the fluctuating sea levels of the Quaternary.

The Barrabool Hills and Bellarine Peninsula are smaller fault-bounded uplift blocks of Cretaceous Otway Group rocks. These blocks are at lower elevations than the Otway Ranges and are generally more planar, sometimes tilted and less deeply dissected. The Barrabool Hills are bounded to the north by the Barrabool Fault and dissected by tributaries of the Barwon River on the north and east of the block. The Bellarine Peninsula has more variety in rock type with basalts of the Older Volcanics and Pliocene marine sands more prevalent than the Otway Group.

The geological units of the Southern Uplands vary considerably in their degree and depth of weathering. The Otway Group rocks west of Cape Otway and in the Barrabool Hills are very fractured and bleached compared to the rock exposed in comparable landscape positions east of Cape Otway. The rocks are mostly made up of fragments of volcanic rocks, calcic feldspars and very little quartz. These minerals that make up the rocks are quickly and easily weathered when exposed to the elements (except quartz), producing a clay-rich soil. Soils vary from shallow stony loams in the steep and actively eroding parts of the landscapes to brown and yellow gradational soils and colluvium on the slopes. Thick deposits of colluvium and landslide debris are common.

Western Plains

The central Corangamite CMA region lies within the Victorian Western Plains, comprising undulating plains formed on both volcanic and sedimentary rocks. The landscapes of this physiographic unit are formed on some of the youngest rocks of the CMA region.

The volcanic plains were built up by sporadic volcanic eruptions over a period of about 5 million years. The eruptions resulted in lobes of lava flowing from the eruption points, which overlap to form a variable thickness of basalt, interleaved with sporadic pyroclastic deposits of scoria and tuff. At times, lengthy breaks between eruptions allowed soils to form on the upper surface of the basalt flows which were subsequently covered by later eruptions, forming buried palaeosol horizons.

Drainage across the volcanic plains is generally poorly developed. The uplift of the Otway Ranges and the disruption of drainage by the volcanic eruptions resulted in the formation of a shallow basin in the central Corangamite CMA region, where the majority of lakes, including Lake Corangamite, are situated. The fluctuating lake levels during the Pleistocene resulted in lunette formation, especially prominent in the Beeac-Eurack district.

Like all fluid, lava from the volcanic eruptions flows to the lowest point on the landscape and often resulted in blocking the drainage systems. The Curdies River and Barwon Rivers were probably the most affected and their present day courses have been strongly influenced by the eruptive history of the region. North of Birregurra, the Barwon River has been diverted around the edge of the basalt and was blocked for a time at Winchelsea and Lake Connewarre.

The stony rises represent the most recent volcanic activity, the most prominent of which forms the platform from which the Mount Porndon scoria cones rise. This feature has been dated as 59 ka, placing it among the youngest landforms in Australia. The most obvious features – scoria cones, lava cones and maars – indicate the places of last eruptive activity. Some of these contain lakes, such as Lake Purrumbete, Lake Bullen Merri and Lake Gnotuk.

The sedimentary plains mainly comprise the marine sands deposited by the retreating Pliocene sea and the exposed underlying Gellibrand Marls and Port Campbell Limestone. In the Heytesbury region the drainage has been strongly influenced by the deposition of strand lines from the retreating sea, forming parallel arcuate tributaries perpendicular to rivers draining southwest. The deep dissection has resulted in numerous landslides in the marl, many of which remain active. Remnants of the undissected plain are preserved along ridge lines and further north to Colac. Along the coast near Port Campbell, the limestone plain has developed many karstic features, particularly sinkholes. Spectacular cliffs formed by the rising sea levels over the past 15 ka mark the edge of the plain at the Southern Ocean.

Soils on the Western Plains reflect the underlying lithology and age of the rocks. The youngest landscapes – the stony rises – have very thin skeletal soils, whereas the older basalts have developed clay-rich soils varying from gradational kraznozems to coarsely duplex. The finely brown gradational soils developed on the scoria around Red Rock represent some of the most valuable cropping country. The soils developed on the Pliocene sand plains are often sandy, sometimes ferruginised or podsollic soils. Further south on the marls and limestones, the soils vary from clay-rich gradational to strongly duplex soils, generally heavy clays.

Tier	Name
2	Western Uplands
<i>2.1</i>	<i>Dissected uplands</i>
2.1.1	Ridges, plateaux, hills and valley slopes underlain by Palaeozoic sedimentary and metamorphic rock (including greenstone) (eg. Dereel)
2.1.2	Ridges and plateaux, hills and valley slopes associated with granitic rocks and aureoles (eg. Pittong)
2.1.3	Plateaux and low rises underlain by Cainozoic gravel (eg. Meredith)
2.1.4	Volcanic landforms, including plains, plateaux, valley flows, scoria cones, and lava shields (eg. Mt. Buninyong)
2.1.5	Alluvial terraces and floodplains (eg. Upper Woody Yallock Creek)
3.0	Southern Uplands
<i>3.1</i>	<i>Deeply-dissected upland</i>
3.1.1	Plateau (eg. Beech Forest)
3.1.2	Dissected ranges (eg. Forrest)
3.1.4	Alluvial terraces and floodplains (eg. Aire River)
<i>3.2</i>	<i>Dissected upland</i>
3.2.2	Dissected ranges (eg. Barrabool hills)
3.2.3	Alluvial terraces and floodplains (eg. Carlisle River)
<i>3.3</i>	<i>Dissected low hills</i>
3.3.1	Plateau (Bellarine Peninsula)
3.3.2	Rolling hills (eg. Barwon Downs)
3.3.3	Alluvial terraces and floodplains (eg. Birregurra)
6.0	Western Plains WP
<i>6.1</i>	<i>Volcanic plains</i>
6.1.1	Eruption points, including maars, scoria cones and lava shields (eg. Red Rock)
6.1.2	Stony rise (eg. Pombomeit)
6.1.3	Plains with poorly developed drainage (eg. Wingeel)
6.1.4	Plains with well developed drainage (eg. Cressy)
6.1.5	Lakes, swamps, lunettes (eg. Lake Corangamite)
6.1.6	Alluvium. Terraces and floodplains (eg. Lough Calvert)
<i>6.2</i>	<i>Sedimentary plains (eg. Hanson Plain)</i>
6.2.2	Dissected plains (eg. Heytesbury)
6.2.3	Karst plains with depressions (eg. Port Campbell)
6.2.4	Plains and plains with low rises (eg. Duck Hole Plain)
6.2.5	Alluvium, alluvial terraces, floodplains and coastal plains (eg. Moolap Sunklands)

Table B.2 Geomorphic Units of the Corangamite CMA region
(*Geomorphology Reference Group of Victoria, 2002, unpublished*)

Appendix C Anticipated connections with the Salinity Action Plan

Source: Tim Corlett, CCMA - version 11/09/02

