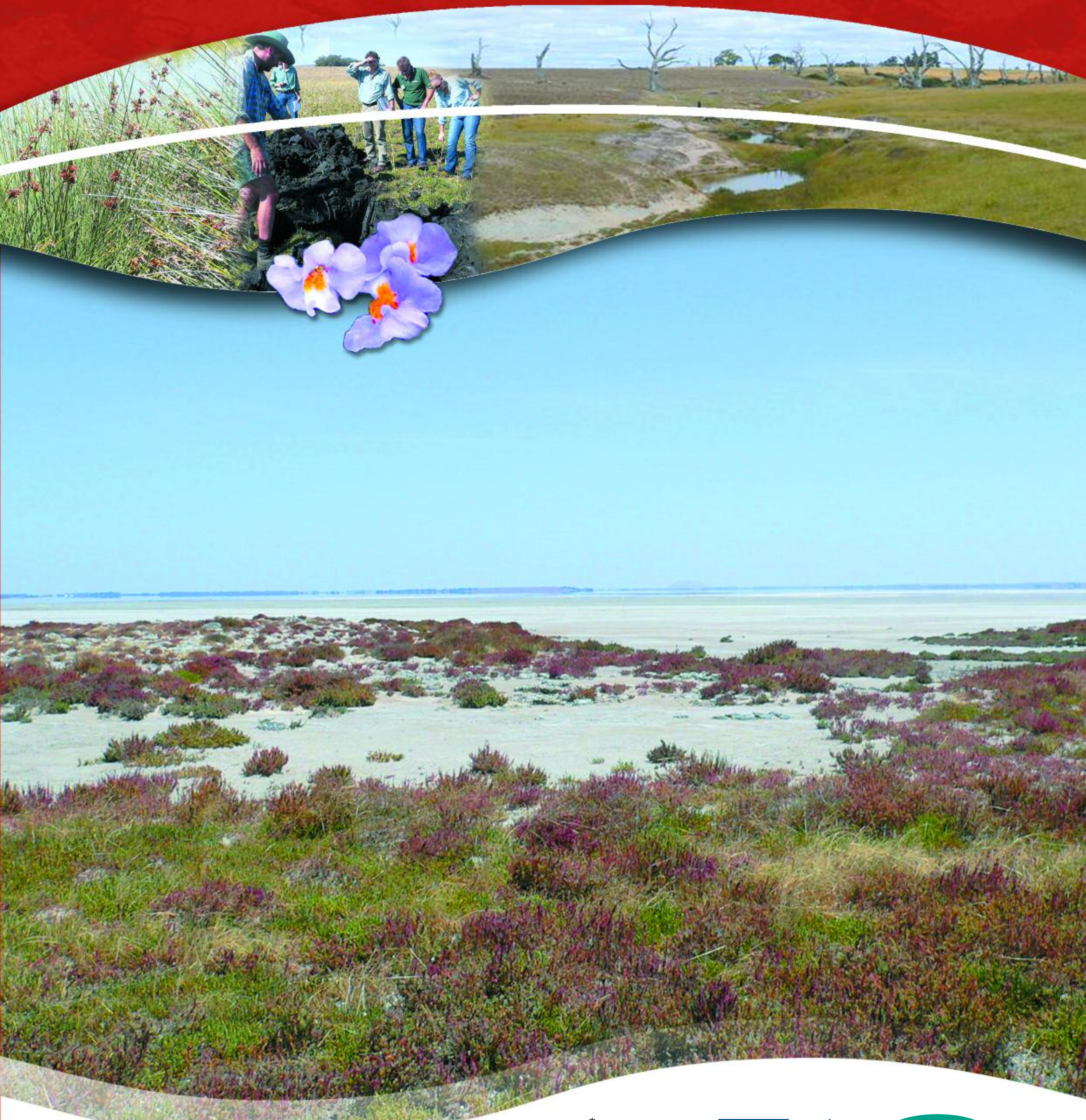
Corangamite Salinity Action Plan

2005-2008



Australian Government

Victoria The Place To Be

CORANGAMITE CMA
HEALTHY CATCHMENTS - HEALTHY WATERWAYS

Corangamite Salinity Action Plan 2005-2008

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Cover Photo: Lake Cundare, Werneth, Lal Lal Reservoir (P. Dahlhaus, February 2006)

Foreword

To visitors from drier parts of Australia, Corangamite CMA region's green and pleasant land may seem an unlikely place for serious salinity problems. Yet some five per cent of the region is already affected by salinity – some of it natural, much of it induced by land-use changes – and it is increasing steadily. In the Moorabool River, for example, average salinity has nearly doubled over 20 years, causing a decline in water quality to Geelong's water supply, valued currently at over $8 million per year. In other places, naturally saline wetlands are suffering from groundwater extractions, with consequent losses in bio-diversity.

The Plan set out herein is Corangamite CMA's response to this serious problem. Its aim is to manage the problem so that it does not become irreparable – as in some other parts of the country. Building on its 1991 predecessor, the Plan uses an eclectic array of the latest knowledge and expertise available. It identifies and values assets (such as urban water supplies; agricultural land; transport and communications infrastructure; primary saline wetland ecosystems and native vegetation); it uses path-breaking knowledge on groundwater flow systems to predict how such assets will be devalued by salinity unless intervention occurs; it presents options for intervention, and tests their realism with asset managers; it estimates costs (some $7 million over five years) and benefits in a "triple-bottom-line" analysis; and it arrives at a set of target zones and remedial actions which should yield cost-effective results. In short, the Plan is state-of-the-art.

Inevitably, the Plan's recommendations being specific to zones may lead to disappointment among residents whose district, while affected by salinity, is not identified as a priority zone. I can readily sympathize with that view, but would seek acceptance that the process adopted by the Plan is clear, transparent and fair. As time goes on and progress is monitored and new knowledge accumulates, past priorities will be subject to scrutiny and revision. The salinity problem will not disappear overnight, and there will always be room for improvement.

The Plan does more than set out the steps summarized briefly here. It contains a wonderful source of new and interesting data and information on the region's geology; hydrology, climatology; land-use history and development; and many other subjects that make for worthwhile reading in their own right.

Many acknowledgements are due: Firstly, to the Victorian and Australian Governments for funding (through the National Action Plan for Salinity and Water Quality). Secondly, to the consultants who prepared the report and the asset managers and researchers that they engaged with, for their expertise and diligence. Also, to those involved in various consultations over the long and careful gestation period of the Plan. And finally, to staff of Corangamite CMA who guided the whole process.

Readers should be aware that some statements by authors quoted in the document are controversial and not necessarily represent the view of the Board. Nonetheless, I recommend the Plan itself and trust that those who are affected directly or indirectly by its implementation will digest its contents and give it whatever support they can.

Dr Peter Greig
Chairman

Corangamite Catchment Management Authority

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Dear Dr Greig

CORANGAMITE SALINITY ACTION PLAN

It is with pleasure that I advise that the Government supports and endorses the Corangamite Salinity Action Plan 2005-2008.

The process undertaken by the Corangamite Catchment Management Authority and regional stakeholders in the development of the plan is to be commended. It is clear that significant and strategic effort has been invested in understanding key regional assets and appropriate management actions. I also commend the CMA's approach of implementing the plan through partnerships between community and government agencies.

The plan demonstrates leadership in the management of diverse areas, from the protection of highly significant Ramsar listed wetlands to reducing the extent of land salinisation and improving the health of waterways.

I would like to commend the efforts of the Corangamite community in the development of this plan and I am sure this will be a positive step forward in the management of salinity in the region. I look forward to seeing the plan move into the implementation phase.

Yours sincerely

John Thwaites

JOHN THWAITES, MP
Minister for Water, Environment and Climate Change

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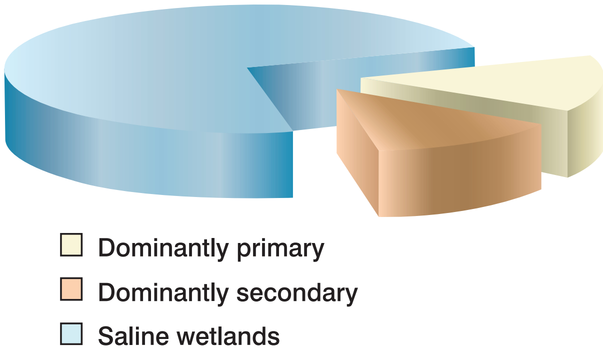
Executive Summary

The Corangamite Salinity Action Plan is the second-generation salinity management program for the Corangamite CMA region. The context for the development of the plan has been the National Action Plan for Salinity and Water Quality, the Victorian Salinity Management Framework and the Corangamite Regional Catchment Strategy 2003–2008. This document is supported by nine background reports which detail the information used to develop the plan and document the logic and assumptions applied.

In line with the rationale for investment adopted by the state and regions for natural resource management projects, an asset-based approach was used to identify the location and priority for salinity investment. Five primary and 17 secondary asset classes were used to identify those potentially threatened by salinity. The asset values described in the Corangamite Regional Catchment Strategy were used to inform a relative ranking of assets based on perceived value. This asset valuation was completed prior to the commencement of the Salinity Action Plan through a separate process conducted by the Centre for Land Protection Research (now Primary Industries Research Victoria), using the GSHARP (Geospatial salinity hazard and asset risk prediction) model. Two secondary asset classes were valued subsequent to this initial process, *viz:* the region's waterway assets, which were assessed using an analysis of salinity trends completed with the assistance of CSIRO and native vegetation assets which used data that only recently became available to discriminate the very high and high conservation significance potential areas.

Salinity appears in the Corangamite CMA Region as either saline land, saline wetlands or as changes in water quality in waterways and water storages. Land salting is the most obvious manifestation of salinity in the Corangamite CMA Region. It is estimated there is 17,250 ha of land salting, occurring at 1,500 locations in the landscape. This estimate is confounded by the presence of both primary (natural) and secondary (induced) salinity. The most recent estimate suggests that just over half the mapped land salinity is dominantly primary in origin. If the integrity of this natural salting is intact, these areas need to be viewed as environmental assets. In terms of area, saline wetlands are the most extensive expression of salinity the Corangamite CMA Region. Approximately 72% of the salinity in the region occurs as semi-permanent or permanently saline wetlands. Most wetlands receive a considerable volume of groundwater discharge, such that they vary in their salinity range from brackish to hypersaline.



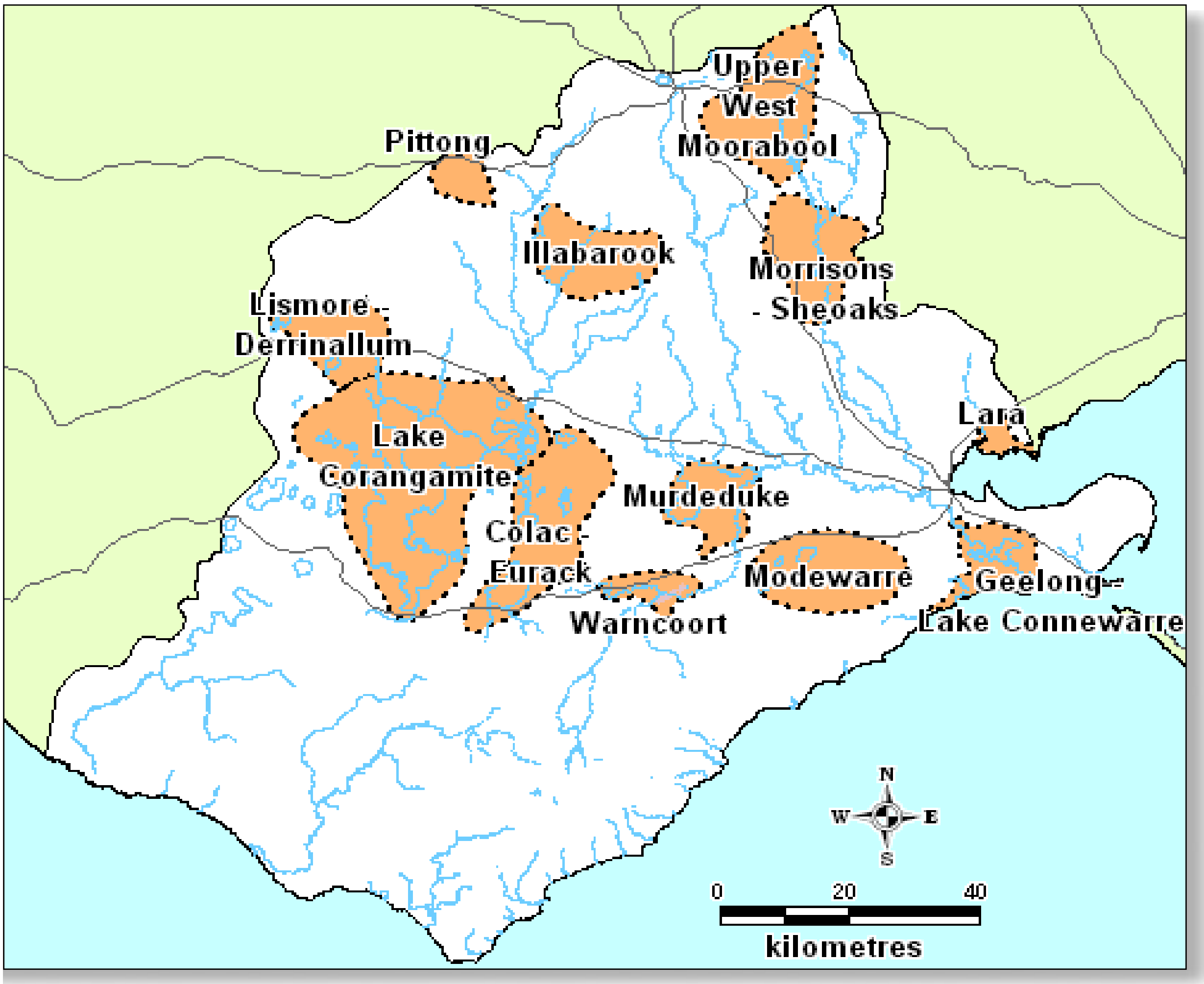
Waterways in the Corangamite CMA Region carry a considerable tonnage of salt. Measured over the past 30 years, an average of 495 tonnes per day (~180,000 tonnes per year) is carried out to sea by the Barwon River. Salinity monitoring data is available for 38 gauging stations in the region's waterways and all show a statistical change in salinity, by either becoming more or less saline. The most dramatic is the Moorabool River at Batesford where over the period from November 1976 to February 2005, the salinity (measured as Electrical Conductivity or EC) rose by 23.7 $\pm$ 6.0 μS/cm/yr (microSiemens per centimetre per year). Over the same period, the mean salinity value of the river has almost doubled from 1218 μS/cm to 2133 μS/cm EC and is predicted to reach over 2400 μS/cm EC by 2012.

The major economic threat posed by increasing salinity is to the urban water storages that supply significant quantities of water to Geelong and Ballarat, the two major population centres of the Corangamite CMA Region. The cost of increasing salinity in water is borne by individual households as well as major industries, especially in Geelong where concerns have been expressed about the quality of the water supplied. The current cost is calculated at $8.1 million per year, rising to $9.2 million per year by 2010. However, salinity is also having an impact on the productivity of agricultural land. It is estimated there is more than 8,000 ha of land affected by secondary salting, with the majority of this area on private holdings. This land is primarily used for grazing and broad acre cropping, where salinity is reducing potential yields by as much as 90%. The annual cost is more than $1.0 million.

Everyday infrastructure such as buildings, roads, railways lines and utilities including telephone, electricity and gas are currently threatened by salinity. The City of Colac is currently confronted with proposed development of peri-urban areas on the southern fringe of the city being subdivided for urban housing. This area has existing land salting and rising watertables. It is estimated 61 km of sealed and unsealed roads are currently salt affected and this is predicted to rise. Managers of utilities such as telephone, electricity and gas conduits currently adopt preventive salinity measures to protect their assets, but this comes at an increased cost.

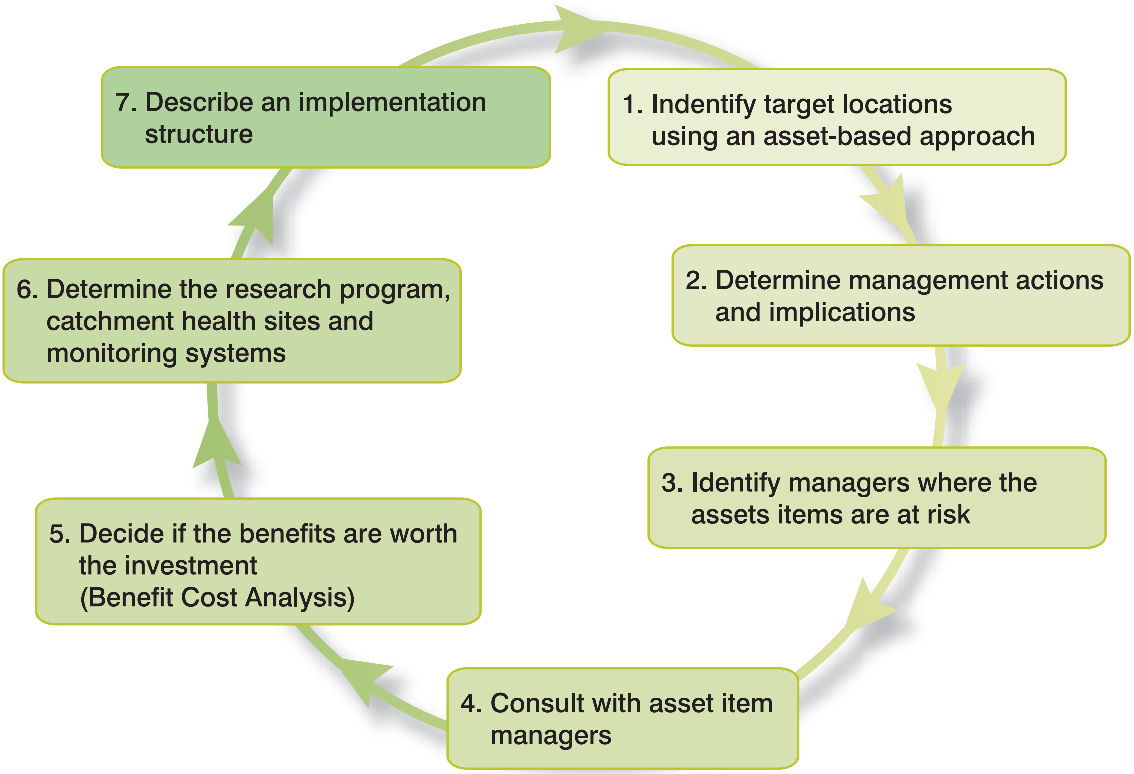
There is evidence that changing salinity is affecting the integrity of wetland ecosystems, including wetlands of international importance and native vegetation communities. The threat may be from increasing salinity or decreasing salinity. Recent assessments indicate more than 6,400 ha of very high and high conservation significance vegetation intersect with mapped salinity. In some cases the presence of salinity may be critical to the stability of these vegetation areas, such as halophytic herblands, but in other locations, secondary salting is likely to threaten salt-sensitive vegetation classes. Similarly, recent research has highlighted the sensitivity of groundwater-dependent ecosystems and how the lowering of groundwater tables through extraction for irrigation or for recharge control can devastate the integrity of saline wetlands. The implications for the Salinity Action Plan are that lowering of saline watertables is not always the most appropriate management action.

Twelve target areas are identified as a result of the asset-based approach to salinity investment. These 12 areas encompass more than 80% of the primary salting, 87% of the saline wetlands and 63% of the secondary salting in the Corangamite CMA Region. A description of the assets threatened by salinity, the salinity trends and predictions, management options and impact of proposed treatments have been described for each target area.



Target areas for salinity management identified using the asset-based approach.

The asset-based approach to identify target areas for salinity management was the first in a seven-step approach to develop the Corangamite Salinity Action Plan. Within each step of the process-appropriate tools, models and/or frameworks were used. The seven-step planning and investment process was designed to provide an approach that could be revisited as new knowledge and information becomes available, thus creating a 'living' plan.



Three main sources of information were used to determine the appropriate salinity management actions. The first was to model the changes to salinity under different treatment scenarios using appropriate numerical models. The second was to use site-specific research results from university and departmental activities. The third was to use evidence provided by experienced salinity extension officers, who had first-hand exposure to the effects of a range of management options. The management suggested focussed either on engineering, planning or biological solutions.

The asset-based approach to select the target locations allowed specific asset items to be identified, together with appropriate treatment option and enabled key asset managers to be identified in each target area. Asset manager engagement was based on a highly targeted consultation approach, with one-to-one or group discussions conducted with parties whose assets were directly affected by salinity or by whose participation is required to implement proposed semi-structured interview processes, using a program logic approach as a framework. This resulted in each area being assessed for:

- The capacity of asset managers within each area to undertake the task
- The attitude (or motivation) of asset managers to want to address the salinity issue
- The availability of technologies and techniques to treat the salinity
- The ability for asset managers to target where salinity treatment actions need to occur.

A summary of this assessment was made for each target location using a five-level scale from low to high. Low represents an inability of the asset manager in the area to currently meet this need, and by inference where intervention is required. Conversely a high rating implies a very strong degree of confidence by the asset manager that this aspect of the salinity treatment is adequately addressed. There should be no need to provide additional resources or intervention, other than what is already occurring.

Wider community consultation occurred to key stakeholders, other interested parties and the wider community after the release of a draft Corangamite Salinity Action Plan in July 2003. A total of 163 comments were received, with the majority of those comments coming from various groups within the government departments and water authorities. An additional background report was prepared to document the response to each comment.

A benefit-cost analysis was completed to assess the difference between a 'No-Plan' scenario and a 'With-Plan' scenario. This benefit-cost analysis considered the Net Present Value and Benefit-Cost Ratio of implementing the salinity management actions and programs outlined in this plan for assets that have market value, such as urban water supplies, agricultural lands, infrastructure and utilities. However, in the Corangamite CMA region the non-market benefits such as Ramsar-listed wetlands and lakes, stream ecology and significant vegetation classes are the dominant assets under threat from salinity. This made assessment and prioritisation difficult.

As a result, priorities were determined using a three-step approach, *viz:*

1) rank the target areas based on the benefit-cost analysis
2) rank the target areas based on non-market and unquantifiable criteria, and
3) combine the two rankings to provide overall priorities.

The Benefit-Cost Ratio of implementing the Corangamite Salinity Action Plan was 0.98 discounted at 4%. The ratio is less than one but is not surprising given the significant non-market and unquantifiable benefits.

Funding of $7,242,083 is required for the first three years of the program. This includes $2,819,400 required for support programs, $1,068,332 for research and investigation projects, $226,250 for new and on-going monitoring programs and $3,128,101 for public on-ground works and the public's share of private on-ground works.

The aspirational target for the Corangamite Salinity Action Plan was set by the Corangamite Catchment Management Authority and other invited stakeholders at a workshop held in Colac on May 29 2003. The workshop participants agreed on the following aspirational target:

Corangamite CMA will – by ongoing measurement, monitoring and experimentation – attempt to sustainably manage the region's salinity impacts.

Rank	Market ranking	Non-market ranking	Overall ranking
1	Lismore – Derrinallum	Lake Corangamite	Lake Corangamite
2	Murdeduke	Morrisons – Sheoaks	Morrisons – Sheoaks
3	Modewarre	Upper West Moorabool	Upper West Moorabool
4	Morrisons – Sheoaks	Colac – Eurack	Colac – Eurack
5	Pittong	Geelong – Lake Connewarre	Geelong – Lake Connewarre
6	Illabarook	Pittong	Lismore – Derrinallum
7	Lake Corangamite	Illabarook	Illabarook
8	Colac – Eurack	Lismore – Derrinallum	Pittong
9	Geelong – Lake Connewarre	Modewarre	Murdeduke
10	Warncoort	Murdeduke	Modewarre
11		Warncoort	Warncoort
12		Lara	Lara

Thirty-seven resource condition targets were established for the target areas in line with the National Framework for Natural Resource Management Standards and Targets.

They are grouped into four broad categories, viz:

Land salinity:
Resource Condition Targets have been set as no net gain in secondary salinity over 2005 levels in the eight target areas where land salinity has been identified as a threat to assets.

Surface water salinity:
These Resource Condition Targets are set in two categories:

a) a quantitative end-of-valley target for those target areas where there is sufficient data to determine a trend; and

b) a stated action to establish a target for those target areas where more data is required before a trend can be determined.

Aquatic and estuarine ecosystem integrity:
Two distinct types of Resource Condition Targets have been set to maintain the integrity of aquatic ecosystems:

a) actions to establish a range for the salinity of specific lakes identified as threatened by increasing or decreasing salinity, and

b) no net loss of primary salinity in target areas where primary saline ephemeral wetlands have been identified as under threat from changed hydrology and salinity.

Infrastructure integrity:
Resource Condition Targets have been set to protect:

a) roads in target areas where they have been identified as threatened by salinity, and

b) a reduction in the urban infrastructure at risk in the City of Colac.

Management action targets outlining quantities of on-ground works were also set, including targets to achieving protection and enhancement of very high and high conservation significance areas of vegetation. Resource condition targets were reconciled with proposed management action targets. Only two of the 37 Resource Condition Targets may not be achieved, as these depend on future decision in relation to the recommendations for the Woady Yaloak Diversion Scheme and raising the level of Lake Corangamite. In addition, a degree of uncertainty remains with respect to the targets related to the no net loss of saline wetlands, as their current condition and best management are yet to be determined.

A monitoring program has been developed to measure progress towards achieving the Resource Condition Targets. The program focuses on the matters for target and indicators as described in National Natural Resource Management Monitoring and Evaluation Framework.

Throughout the development of the Salinity Action Plan a number of research and investigation projects were identified. The research is required to improve the asset - based approach to targeting investment (i.e. improved assessment of both the threats and assets), understand the salinity processes, improving treatment options and quantifying the effects of the treatment. Many of these knowledge gaps were identified during the asset manager consultation and stakeholder feedback stages of the project. Research has already commenced for some of the listed projects, and is pending for other projects.

Primary responsibility for the implementation of the Salinity Action Plan should rest with the Corangamite Salinity and Soils Portfolio Group in the Catchment Management Authority. However, given the obvious synergies with waterways and biodiversity as well as the practical delivery requiring involvement of pest plant and animal and landcare, an integrated approach is required.

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Corangamite Salinity Action Plan: Regional overview and development considerations.
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Corangamite Salinity Action Plan: Setting resource condition targets.
Background Report 9 *(Dec 2005)* Corangamite Catchment Management Authority, Colac, Victoria.

1. The Corangamite CMA Region

The Corangamite Catchment Management Authority (CMA) region covers more than 1,334,000 ha or 6% of the State of 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.

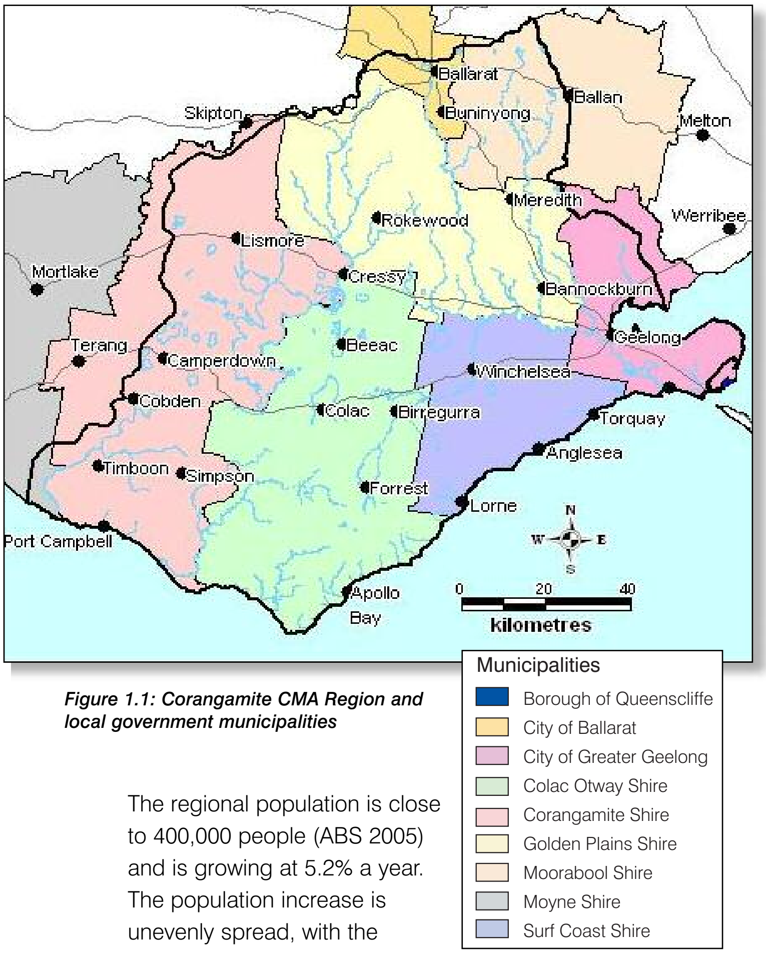


Figure 1.1: Corangamite CMA Region and local government municipalities

The regional population is close to 400,000 people (ABS 2005) and is growing at 5.2% a year. 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 40km from the major centres of Geelong and Ballarat (ABS 2005). The rural population, despite farming more than two thirds of the land in the Corangamite CMA region is, at best stable or falling – particularly in the broad acre areas.

Secondary industry with its associated service sector and tourism 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 2003). During the same period, the region's primary industries are expected to adopt different agricultural systems such as cropping and forestry as well as intensify their existing enterprises.

Physical geography, climate and land use changes affect the processes that influence the extent and location of salinity in the Corangamite CMA region. Understanding these influences is critical to designing a program that is likely to have a positive effect in salinity management. These features have been extensively examined in Background Report 1 (Dahlhaus *et al.* 2005) and articulate the suggested treatment options.

1.1 What has been done about salinity in the past?

Salinity was first tackled in a co-ordinated way in 1992 with the launch of a strategy called *Restoring the Balance* (Nicholson *et al.* 1992). This strategy was part of the Victorian Government's salinity initiative *Salt Action – Joint Action* (Salinity Bureau 1988) and was developed by the Corangamite Salinity Forum, a group of 11 community members from the Corangamite CMA region along with representatives from three state agencies. A draft salinity strategy was presented for public comment in December 1992 and after extensive community consultation the strategy received interim government endorsement in July 1994.

Implementation of the plan attracted more than $8.4 million dollars in state funding, $630,000 from the Federal Government and many millions in landholder, industry and community contributions (Nicholson 2002). Extensive revegetation, community education, monitoring and research actions were conducted. Key achievements included:

- The establishment of almost 3,500 ha of trees, more than 16,000 ha of perennial pasture and the treatment of 1,130 ha of saline land. Pasture targets were exceeded by 16% while the quantity of tree and saline revegetation fell 18% and 23% below targets.
- 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 that baseline water quality levels could be established.
- The establishment of an extensive monitoring network that included 580 bores and 14 surface water-monitoring stations.
- Research into groundwater, salinity impacts and revegetation options.

A comprehensive review of *Restoring the Balance* in 2002 (Nicholson 2002) highlighted the uncertainty in many of the assumptions used in the original strategy and made a series of recommendations that need to be addressed in this Salinity Action Plan (SAP).

These included:

- Dedicating more resources to defining the extent and importance of the salinity processes on water quality and biodiversity.
- Re-defining the location for salinity control works based on a smaller scale, catchment descriptions and groundwater-flow systems.
- 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.
- 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 SAP, 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 CMA with clear roles and responsibilities for salinity implementation, including project endorsement, setting on-ground targets and budget allocation functions.

Current salinity implementation is the responsibility of the Salinity and Soils Operational Portfolio Group of the Corangamite CMA.

1.2 Differences between this Salinity Action Plan and *Restoring the Balance*

The context for developing the SAP for Corangamite 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 contextual changes include:

- Improved knowledge regarding salinity and salinity processes.
- The recognition that salinity is only one, albeit important, issue in natural resource management of the region.
- Increased emphasis on prioritisation (assessment of salinity risk and protecting threatened assets), partnerships and co-investment.

Recently released federal, state and regional frameworks provide additional guidelines that need to be met. At a federal level, the **National Action Plan (NAP) for Salinity and Water Quality**, (CoAG 2000) has a goal to motivate and enable regional communities to use co-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.

The **Victorian Salinity Management Framework** (DNRE 2000) 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.

At a regional level, the **Corangamite Regional Catchment Strategy 2003 - 2008** (CCMA 2003a) has identified six major forces that are likely to affect the Corangamite CMA 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 and 'disposal' of urban stormwater.
- 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 outcomes.

The pattern of growth described at the start of this chapter has important implications for future salinity management. Increased urbanisation will intensify demands for good-quality water, alter stormwater flow regimes and increase wastewater disposal issues. For peri-urban communities the ability to live in a 'non-degraded' environment will demand attention. The tourism and recreation industries have created businesses largely based on the non-degraded nature of the natural environment, including some of the saline wetlands, lakes and waterways. This sector will seek to preserve or enhance these natural assets in the future. Changes to the agricultural sector will influence run-off from paddocks and rates of water infiltration.

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

There is enormous potential to develop strong synergies between this SAP 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 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.

Relevant Regional NRM Strategies

The following provides a snapshot of *existing* programs and strategies within the Corangamite CMA 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 1.1)*, with further description of several of the key strategies and plans.

Corangamite draft River Health Strategy (2004)

The Corangamite draft River Health Strategy (CCMA 2004a) identifies and explains a wide range of key issues affecting waterway health in the Corangamite CMA 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 SAP 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 Woady 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.

Corangamite Nutrient Management Plan (2000)

The Corangamite Nutrient Management Plan (CCMA 2000) 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 are key issues, 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 run-off can also create unnatural fresh water intrusions into primary saline areas.

Corangamite Native Vegetation Plan (2005)

The Corangamite Native Vegetation Plan (CCMA 2005a) aims to strategically direct future action in the protection, enhancement and restoration of the region's native vegetation. The underlying direction for management of native vegetation in the Corangamite CMA region is to achieve over time *'a reversal, across the entire regional landscape, of the long-term decline in the extent and quality of native vegetation, leading to a Net Gain'*. 'Net Gain' is defined as the outcome for native vegetation and habitat where overall gains are greater than overall losses and where individual losses are avoided where possible. The Plan identifies three broad goals to achieve the vision of net gain.

1. *Protect – To maintain the extent of all native vegetation types to at least 2002 levels.*
2. *Enhance – To enhance the quality of existing native vegetation by managing 90% of native vegetation cover on both public and private land to best management practices by 2010.*
3. *Restore – To strategically increase overall cover of each Ecological Vegetation Class (EVC) to at least 10% of pre-1750 levels by 2020.*

Many aspects within the Native Vegetation Plan 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 native vegetation 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.

Corangamite Weed Action Plan (2001)

The Corangamite Weed Action Plan (CCMA 2000a) 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.

Corangamite Rabbit Action Plan (2001)

The Corangamite Rabbit Action Plan (CCMA 2000b) 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.

Possible remedial salinity action[1]		Salinity management effect sought by adopting this action	Existing strategies, plans and programs								
			Regional				State				
			River Health Strategy	Nutrient Management 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 waterways	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 waterways	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 run-off 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 1.1: 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 CMA Region.

Corangamite Landcare Support Strategy (2004)

The Corangamite Landcare Support Strategy (CCMA 2004b) provides strategic direction and outlines 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.

Corangamite draft Wetlands Strategy (2005)

The Corangamite draft Wetlands Strategy (Sheldon 2005) 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% 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 SAP 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 currently threatening wetlands close to existing developments, including the Ramsar wetlands near Lara and on the Bellarine Peninsula.

Corangamite Soil Health Strategy (2005)

The Corangamite Soil Health Strategy is under development but 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.

Corangamite Research & Development Strategy (2005)

The Corangamite Research and Development Strategy is still being finalised. The 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 mechanism for a prospectus for research and investigations to be developed on an annual basis. The strategy aims to link salinity research with the knowledge gaps identified in the SAP and other strategies.

Relevant state-wide strategies

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

Victorian Government White Paper on Water (2004)

The Victorian Government White Paper on Water "Securing our water future together" (DSE 2004a) is an integrated approach to water use in Victoria and was released in June 2004. The White Paper outlines a program of initiatives, incentives, regulations, legislation, pricing and education to reduce demand for water and increase recycling and environmental flows. The allocation and use of water in the Corangamite CMA region has been identified as the most critical factor in the salinity trends over the past half century, especially in relation to the salinity of rivers and wetlands. The improved management of water resources, both surface water and groundwater, will have significant impacts on the management of water salinity in the near future.

Victorian Greenhouse Strategy Action Plan (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 reafforestation, which would be of great benefit to salinity management.

Victorian Private Forestry Strategy (2002)

The Private Forestry Strategy in Victoria 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 been identified as priority areas for reafforestation. The Corangamite SAP 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 reafforestation 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 Otway Agroforestry Network are very active in promoting integrated farm forestry development throughout the region.

Victorian Coastal Strategy (2002)

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 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.

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.

Flora and Fauna Guarantee Act (1992)

The *Flora and Fauna Guarantee Act* focuses on managing flora and fauna 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.

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.

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 CMA region.

Key stakeholders in salinity management within Corangamite

The specific actions of key stakeholders that may assist salinity management in the region are identified *(Table 1.2)*.

Corangamite Catchment Management Authority (CCMA)

The CCMA provides the strategic direction for natural resource management throughout the Corangamite CMA 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 SAP.

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 has been a lead agency in providing hydrogeological support and salinity research under the previous Corangamite salinity management plan.

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.

Southern Rural Water (SRW)

Southern Rural Water (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.

Water Authorities - Water Supply Catchments

The Corangamite CMA 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 region's water authorities include Barwon Water, Central Highlands Water and Southwest Water (recently became part of Wannon 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 agents 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.

Local Government

Shires within the Corangamite CMA Region include the City of Greater Geelong, City of Ballarat, Corangamite, Moorabool, Golden Plains, Colac Otway, Surf Coast Shires, Borough of Queenscliffe 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 land-use 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 need to continue to develop closer working partnerships between the salinity program and the local governments within Corangamite.

VicRoads

VicRoads manage the major freeway and highway infrastructure within the region. Municipal roads are managed by local government. Salinity and high groundwaters 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.

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, Grain and Graze, 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 industries 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 SAP must form a key program within the region.

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, 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.

Tertiary Education Institutions

The Corangamite CMA 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.

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 Govt	VicRoads	Agricultural industry groups	Resource & 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 revege-tation 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 Wheat Grass		Improve water quality			Increased profitability for salt-land			
	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 its management of saline lands						Protects native saline areas	Research required for more native species	

Table 1.2: 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 CMA Region.

2. Regional assets and threats from current and future salinity

An asset-based approach was used to identify the location and priority for salinity investment. This methodology is a key part of the rationale for investment adopted by the State and Regions for Natural-Resource Management (NRM) projects (DSE, 2004b, DSE, 2006).

The conceptual model used for asset-based NRM investment is illustrated *(Figure 2.1)*.

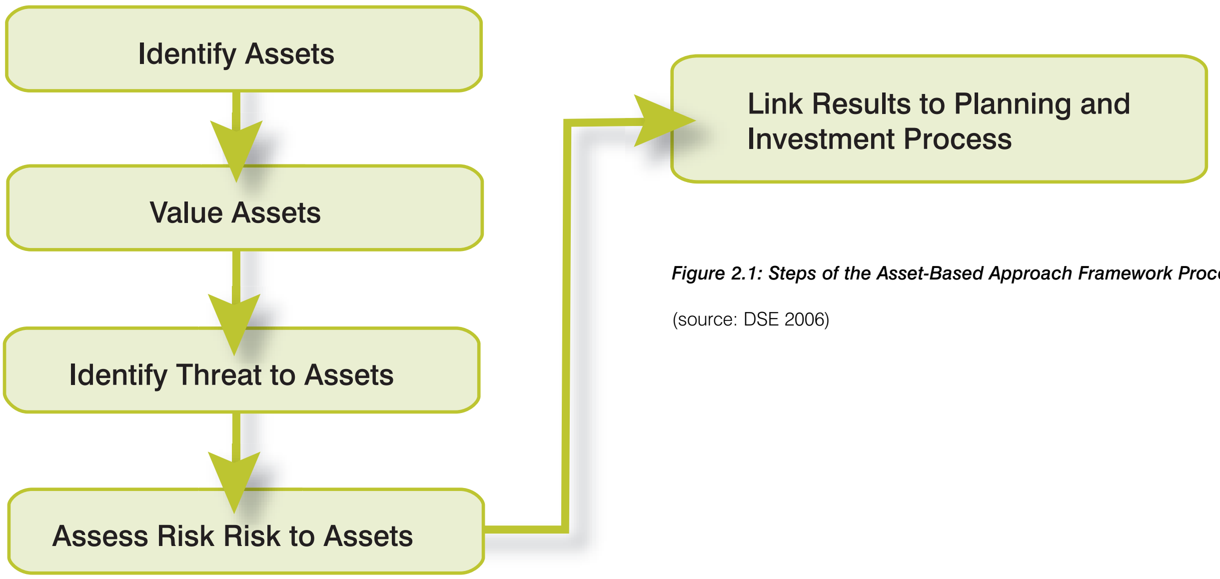


Figure 2.1: Steps of the Asset-Based Approach Framework Process

(source: DSE 2006)

2.1 Identification of Regional Assets

The first stage in the asset-based approach is to identify the biophysical items in the Corangamite CMA Region that have productive, social or natural value.

Assets identified in the Corangamite Regional Catchment Strategy

The Corangamite Regional Catchment Strategy describes the Region's assets from an economic, environmental and social perspective (CCMA, 2003a). This description illustrates the broad mix of natural features such as the Great Ocean Road and Otway Ranges, extensive agricultural and manufacturing industries and a rapidly growing population migrating from the city to Victoria's two largest provincial cities of Geelong and Ballarat and their surrounds.

It is not intended to repeat descriptions of all the assets identified in the Regional Catchment Strategy. Instead only the economic, environmental and social natural assets of the Corangamite CMA Region that could potentially be threatened by salinity or salinity related processes are described *(Table 2.1)*.

Built assets were identified separately in the Corangamite Regional Catchment Strategy (RCS). These included roads, railways, ports, power supplies, water supplies and buildings (residential, commercial, industrial, urban community and farm). All these built assets, with the exception of ports, are considered assets that could be potentially threatened by salinity and have been included in the assessment process.

This more specific identification of secondary asset classes enables identification and description of specific asset items to be made.

Natural regional asset groups as described in the Regional Catchment Strategy	Relevant natural regional assets potentially threatened by salinity
Waterways	Water in the Moorabool, Barwon and Lake Corangamite river basins.
Hydrogeology	Groundwater flows underlying the Volcanic Plains bioregion and isolated freshwater aquifers.
Lakes and wetlands	Extensive lake and wetland system, with 13 listed under the Ramsar Convention.
Terrestrial resources	
Land use	Land used primarily for agriculture (extensive grazing and cropping).
Indigenous and cultural heritage values	In particular scarred trees and burial sites.
Biodiversity	
Native vegetation	Changing salinity status for vegetation existing on the Central Victorian Uplands, Otway Plain and Victorian Volcanic Plains bioregions.
Native fauna	Changing salinity status for aquatic fauna residing on the Central Victorian Uplands, Otway Plain and Victorian Volcanic Plains bioregions.
The coastal and marine environment	
Port Phillip Bay	Shoreline wetland and seagrass meadows, home to the critically endangered Orange-Bellied Parrot.
The estuaries	Protection of the saline estuarine wetlands of the lower Barwon River, and other significant estuaries.

Table 2.1: Natural regional assets as described in the Corangamite RCS

Assets identified for use in the Corangamite Salinity Action Plan

The regional assets described in *Table 2.1* are broad, which makes resource allocation for action planning difficult. To enhance the targeting of resources to the asset item level, the assets identified in the Regional Catchment Strategy have been realigned based on five primary and 17 secondary classes *(Table 2.2)*.

Primary asset class	Secondary asset class
Land	Agricultural land Public lands
Biodiversity	VROTS/ AROTS Native vegetation conservation significance (potential)
Cultural heritage	Aboriginal Historic Natural
Infrastructure / utilities	Built environment Roads and road infrastructure Rail and rail infrastructure Main electricity supply lines Main gas pipelines Main water pipelines Main telecommunication cables and exchanges
Water quality	Urban water supplies Waterways Wetlands

Table 2.2: Primary and secondary asset classes

Land assets

A variety of landscapes and soils occur in the 1.34 million hectares of the Corangamite CMA region. The Corangamite Land Resource Assessment recognises over 200 soil-landform units, indicating the diversity of the soil resource (Robinson *et al.* 2003). The broad soil types are related to the underlying geology and cover a diversity of profiles including sodic duplex soils of the granite and sedimentary rocks of the Central Highlands, shallow stony soils of the Otway Ranges, the leached sands of the Coastal Plains and well-structured gradational soils of the Volcanic Plains, just to name a few. The Corangamite region has among the most agriculturally productive soils in Australia, especially the finely-structured volcanic soils (kraznozems and brown earths) used for cropping.

Approximately 70% of the land is privately owned. Broadacre grazing and cropping are the main enterprises, with significant production of wool, beef and sheep meats, milk, cereal and oilseeds. Intensive agricultural industries including viticulture, vegetables, pigs, eggs and chicken meat are also expanding.

The dense temperate rainforest of the Otway Ranges is the largest area of public land in the region and remains largely forested. Other large areas of public land are located around Ballarat.

Biodiversity assets

The Corangamite CMA region is recognised for its diversity of landscapes and habitats and is home to many national and Victorian rare or threatened species (AROTS or VROTS). The region contains 50 floral and 19 fauna AROTS and more than 300 Victorian rare or threatened flora and fauna species (CCMA 2003a).

The five bioregions in Corangamite vary in their current extent of native vegetation cover. The most intact is the Otway Ranges bioregion, with more than 80% still forested, in contrast to the Victorian Volcanic Plain bioregion which has only 3.6% of its original vegetation remaining (CCMA 2005a). The Corangamite CMA region has 74 Ecological Vegetation Classes (EVC) across the five bioregions. Four of these EVCs are classified as rare and 36 as endangered.

Cultural and heritage assets

Identification of all the Aboriginal, historic and natural assets in the region is far from complete. It is likely that humans have inhabited the Corangamite CMA region for at least 35,000 years (Mulvaney & Kamminga 1999) although little is known of the early inhabitants. Archaeological studies show a correlation of the locations and numbers of artefact sites and salinity of the lakes around which they are found, suggesting that the availability of fresh water is the singularly most important limiting factor for past Aboriginal land-use of the Corangamite CMA region (McNiven 1998). People moved out across the landscapes during winter and spring (wet) to take advantage of the diverse food and water supplies, and during summer and autumn (dry) remained close to the permanent fresher water bodies. This pattern of land-use is broadly supported by the early ethno historical observations, which suggest that the region was a rich and diverse area which supported an indigenous population estimated to be between 2,500 and 4,000 persons (Clark 1990). 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. Given their presence in such a rich and diverse landscape with plentiful food and water, it would be logical to assume the region contains many scarred trees, middens, quarry area, mounds, stone arrangements and burial sites.

More than 450 significant heritage assets in the region are included on the Register of the National Estate. These vary widely from historic buildings, town precincts, gardens, road and rail bridges, basalt stone walls, lakes, volcanic cones and other natural features such as the Twelve Apostles.

Infrastructure and utility assets

The infrastructure and utility assets are extensive throughout the Corangamite CMA region as the road and rail networks support a large manufacturing industry and population of close to 400,000 people (ABS 2005). Significant infrastructure supports the utilities and services, such as gas, electricity, telephone and water.

Among the major infrastructure assets are the urban centres of Geelong (pop. 204,891) and Ballarat (pop. 88,777). Both these cities support a variety of manufacturing industries including automotive and agricultural machinery, food processing, fabrics and carpets, petrochemicals and fertilisers and metal smelting and construction materials. Geelong has port facilities which service both the manufacturing and surrounding agricultural industries.

The Corangamite CMA region is serviced by over 11,000 kilometres of road, the vast majority of which are managed by local government. Major utilities include a gas pipeline from Port Campbell to Lara to supply Melbourne with gas from the offshore supplies in the Otway Basin; and a major power line network to carry power from Geelong to Portland. Extensive optic fibre, microwave and conventional telecommunication networks, reticulated water networks and sewage schemes service the region.

Water quality asset

The quality of water in the Corangamite CMA region has been selected as the asset that could be potentially threatened by salinity. Water quality is often directly related to the quantity of water available, as altered water volumes can either dilute or concentrate salt in the water. However, the SAP has focused on the threat of *changing* the salt concentration in the water. This change in water quality is commonly perceived as rising salinity, but equal consideration needs to be given to the difficulties created by excessive freshwater potentially diluting naturally saline areas, resulting in altered ecosystems. Issues related to water volumes, flows and allocations are being addressed through other initiatives within the Corangamite CMA *(refer to section 1.3).*

Three secondary asset classes are identified where changing water quality is a threat to the asset. The first is urban water supplies. Management of these assets is the responsibility of Barwon Water and Central Highlands Water. These two water authorities supply 55,000 ML of water per year to urban and industrial users throughout the region (BW 2005; CHW 2005). The main stores of this water are the Lal Lal, White Swan, Wurdee Boluc and West Barwon reservoirs.

The region's waterways are the second asset class potentially under threat from saline surface run-off or groundwater inflows. The region has 2,083km of rivers, 16,237km of streams and 1,261km of drains and channels mapped at 1:25,000 scale, totalling nearly 20,000km of waterways. The majority of these waterways are concentrated in the elevated areas of the Otway Ranges and Central Highlands. Many of them are permanent streams that provide habitat for a variety of aquatic species, including mammals, fish, crustaceans and aquatic invertebrates.

The Corangamite CMA region has more than 1,500 wetlands which cover 65,000 ha or approximately 5% of the region. The majority (58%) are smaller than 5 ha in size and many (74%) less than 10 ha (Sheldon 2005). Saline wetlands constitute the largest area, being approximately 45,000 ha, the vast majority of which occur on the Victorian Volcanic Plain bioregion. Lake Corangamite is the largest at 23,000 ha and is one of 13 Ramsar and 340 significant wetlands identified. Many of these wetlands are naturally saline, with two thirds of the total surface area covered by wetlands being classified as semi-permanent or permanently saline.

The majority (90%) of the saline wetlands are under public tenure. It is thought that the number of permanent and semi-permanent saline wetlands has increased since European settlement. Permanently saline wetlands have increased from 59 (in 1788) to 76 (in 1994), although the total area has decreased from 38,227 ha (in 1788) to 35,781 ha (in 1994). Semi-permanent wetlands have increased from 256 to 358 over the same period, with an increase in area from 7,848 ha to 8,433 ha (Sheldon 2005).

2.2 *Valuation of Regional Assets*

The region's assets potentially threatened by salinity have been described. These assets provide many services and are used in a variety of ways. It also means they have a value. If they have a value, then theoretically they can be compared and ranked in importance. Unfortunately asset valuation is inherently difficult because not all of the services can be valued in the same way.

Asset valuation in the Corangamite Regional Catchment Strategy

The Regional Catchment Strategy provided only broad descriptions of the value of the assets in the Corangamite CMA region (CCMA, 2002). These valuations were not quantitatively described and are insufficient to allow comparisons between assets.

No attempt was made in the Regional Catchment Strategy to price the assets under consideration. Instead asset 'valuation' was completed as part of an assets versus threats exercise based on community perception. This provided a relative value score of assets compared with each other for a suite of threatening processes. In relation to the salinity threat, the identified assets which received a rating are listed *(Table 2.3)*.

The high rating for land and land use is likely to be a reflection of the monetary value participants would have assigned to the productive loss of the land. In contrast, calculating a value to the water and vegetation assets would have been more difficult and may explain the relatively lower rating.

Asset class	Specific asset	Score
Economic	Water/water use	8
	Land/land use	24
Environmental	Surface waters	9
	Groundwater	4
	Vegetation / flora / Ecological communities / habitats	4
	Soil	8
Social	The community	1

Table 2.3: Relative importance of specific assets to salinity defined by the Corangamite RCS

Asset valuation in the Salinity Action Plan

The values described in the Regional Catchment Strategy were used to inform a further refinement of asset classes, allowing an asset ranking, based on perceived value, to be established. This asset valuation was completed prior to the commencement of the SAP, through a separate process conducted by the Centre for Land Protection Research (CLPR), now Primary Industries Research Victoria (PIRVic). The GSHARP (Geospatial salinity hazard and asset risk prediction) model used had much greater accuracy and detail of asset data when compared to its predecessor ICSRP (Integrated catchment salinity risk prioritisation), which had been used by a number of CMAs across Victoria (Heislers & Brewin 2003).

The GSHARP asset valuation conducted by the CLPR was used in the identification and prioritisation of assets under threat from salinity (Dahlhaus 2003a). The relative value of the secondary asset classes assigned by the GSHARP model is presented *(Table 2.4)*.

Urban water supplies were given the highest rating in the PIRVic analysis in 2002. This created some contention at the time but recent investigation shows the assets of Barwon Water and Central Highlands Water are listed at $1.52 billion dollars, with combined revenue from water sales for the 2005 financial year at $137.5 million (CH 2005, BW 2005).
This would justify the rating given in 2002.

Secondary asset class	Relative value
Agricultural land	3
Public land	3
VROTS/ AROTS	3
Native vegetation conservation significance (potential)	Not valued at this time
Aboriginal	1
Natural	1
Built environment	2
Roads and road infrastructure	2
Rail and rail infrastructure	2
Main electricity supply lines.	1
Main gas pipelines	1
Main water pipelines	1
Main telecommunication cables and exchanges	1
Urban water supplies	4
Urban water supplies	4
Waterways	Not valued at this time
Wetlands	3

Table 2.4: Relative value for asset classes potentially threatened by salinity (Source: Heislers & Brewin, 2003)

Two secondary asset classes were not valued through this initial process. The first was the region's waterway assets, where there was a need to discriminate between various reaches of rivers and streams. Unfortunately, comprehensive data from the Corangamite River Health Strategy (CCMA 2004a) was not available at the time. To overcome this limitation, an analysis of the trend in the water salinity measured at stream gauging stations was conducted by the CSIRO (Dahlhaus 2003b). Reaches with high salinity and rising salinity trends were identified and these locations cross-referenced with knowledge of the value of the reach of the waterway. While the reaches identified were not the highest-valued waterway assets in the region (Greg Peters, pers comm.), the water flowing from them was a source of degradation to two highly valued assets, namely the water supplies to the provincial cities of Geelong and Ballarat, and Lake Corangamite.

Native vegetation was also not valued through the GSHARP process, as the mapping of Ecological Vegetation Classes (EVC) had not been completed at the time. However, like waterway reaches, there was a need to discriminate between the value of various vegetation classes. This required information from the recently completed Corangamite Native Vegetation Plan (CCMA 2005a). This has been rectified by including the very high and high conservation significance (potential) areas (DSE 2006) but only for the target areas identified through the initial CLPR process.

The paucity of suitable data to enable individual asset items to be accurately described and therefore valued is recognised as a serious limitation in this process. High-priority research projects have been identified in the SAP (Dahlhaus *et al.* 2005b) to rectify these deficiencies before the next planning cycle occurs. However, to achieve this, a clear and consistent methodology to value and rank these assets is required.

2.3 Salinity threats

The salinity threat in the Corangamite CMA region is caused by a change in the water balance, which usually results from changes in land use or climate. The threat may be due to a rise in saline watertables to within a critical distance from the soil surface, usually less than two metres. This rise in watertables can appear as increased land salting, the emergence of saline springs or increased saline groundwater flows into waterways. Alternatively, the threat may stem from a drop in watertables around a saline lake or wetland, causing it to dry out with permanent changes to the ecology. Changes in the amount of salt in the water can also threaten surface water and groundwater resources and saline wetland ecosystems. All of these salinity threats, in turn, have an impact on various other economic, social and environmental assets of the Corangamite CMA region.

To identify the appropriate treatments that modify or remove the threat to the asset, there is a need to understand the threatening process and what activity may be exacerbating this process.

Processes that drive the salinity threat

The extent and severity of salinity in the Corangamite CMA 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 induced by human activity (land-use and policy settings since European settlement).

Geography and groundwater flows

Understanding landscape processes such as salinisation begins with an appreciation 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 Background Report 1 (Dahlhaus *et al.* 2005a) 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 CMA region (the physiography) are derived from the underlying geology and landscape evolution processes. There are three main geomorphic units in Corangamite (Dahlhaus *et al.* 2005a). They are:

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

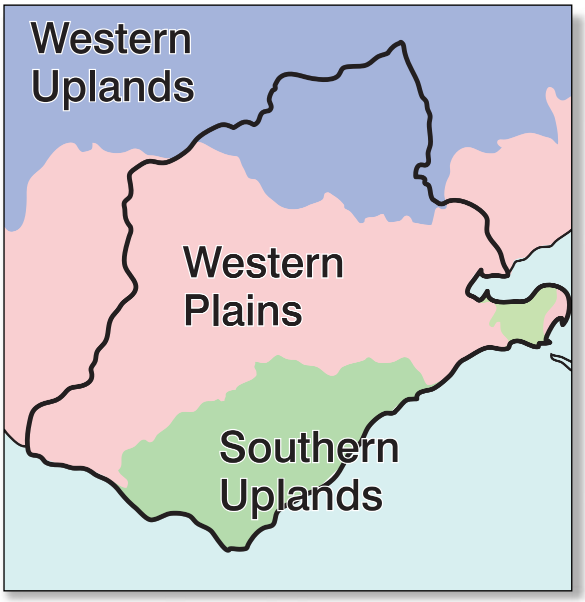


Figure 2.2: Major geomorphic divisions of the Corangamite CMA region

Understanding the geology enables the region to be disaggregated into similar groundwater systems to provide consistency for modelling salinity management. This was completed in 2002 (Dahlhaus *et al*. 2002) and resulted in 17 flow systems. Nine of these flow systems were considered local, meaning groundwater flows (from recharge to discharge) occur over distances of less than five kilometres and are within the confines of a catchment. They respond rapidly to increased groundwater recharge, with watertables rising rapidly, and saline discharge typically occurs within 30 to 50 years of clearing native vegetation for agricultural development.

In contrast, water flows in the five regional systems occur over distances exceeding 50 kilometres at the scale of river basins. These systems have a high storage capacity and changes take much longer to develop, probably more than 100 years after clearing native vegetation. The full extent of change may take thousands of years to eventually show. The groundwater flows systems of the Corangamite CMA region are presented *(Figure 2.3)*.

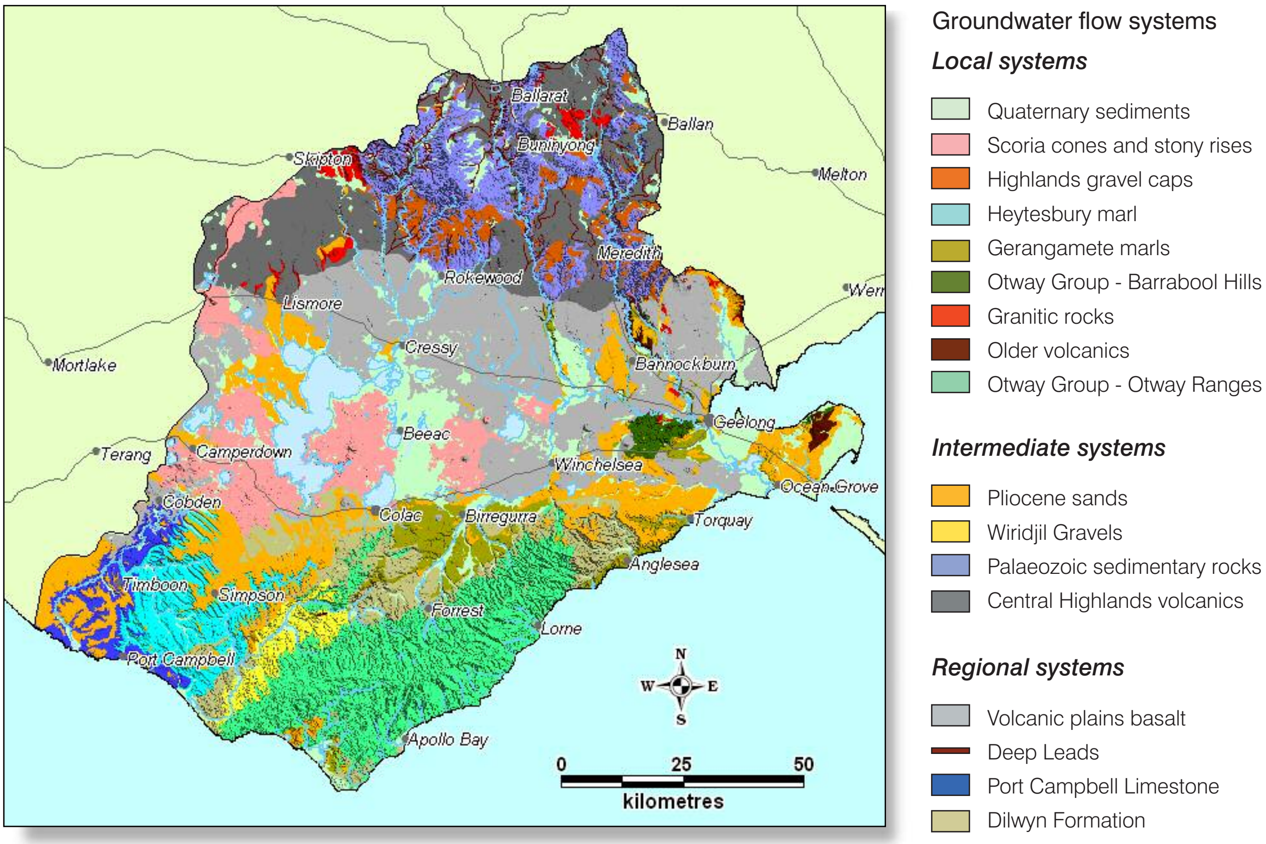


Figure 2.3: Groundwater flow systems of the Corangamite CMA Region.

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. 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.

Climate

Being situated between 37.4^{o} and 38.9^{o} south latitude, the region experiences a temperate climate with dominant westerly winds, variable cloud, moderate precipitation and cool temperatures. Sixteen monthly and annual climate surfaces for the Corangamite CMA region have been modelled using ANUCLIM (Dahlhaus 2002). Rainfall and evaporation, which are both closely related to altitude, are the most influential climatic factors in relation to salinity *(Figures 2.4 and 2.5).*

The majority of rain falls in winter and spring, with August as the wettest month across the region. The highest mean annual rainfall (1937 mm) is recorded at Weeaproinah and the region's lowest mean annual rainfall (526 mm) at Lovely Banks Reservoir (BoM 2005).

Only four Bureau of Meteorology evaporation stations are situated in the Corangamite 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 2.5)*

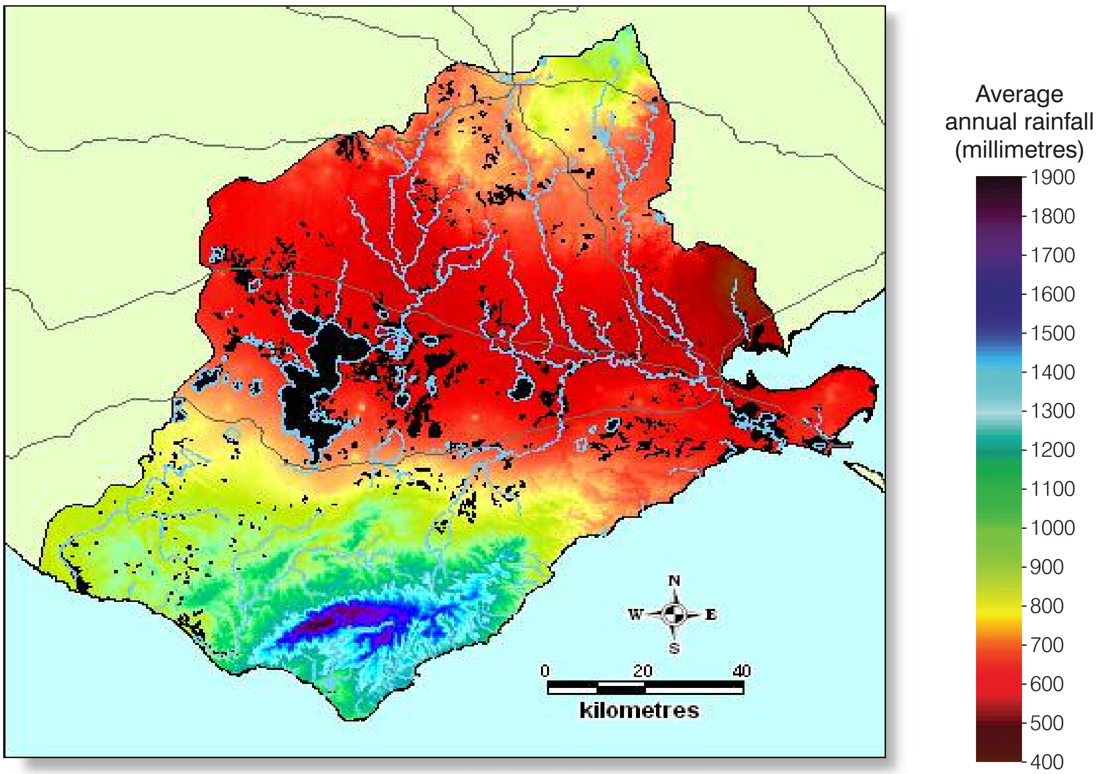


Figure 2.4: Average annual rainfall.

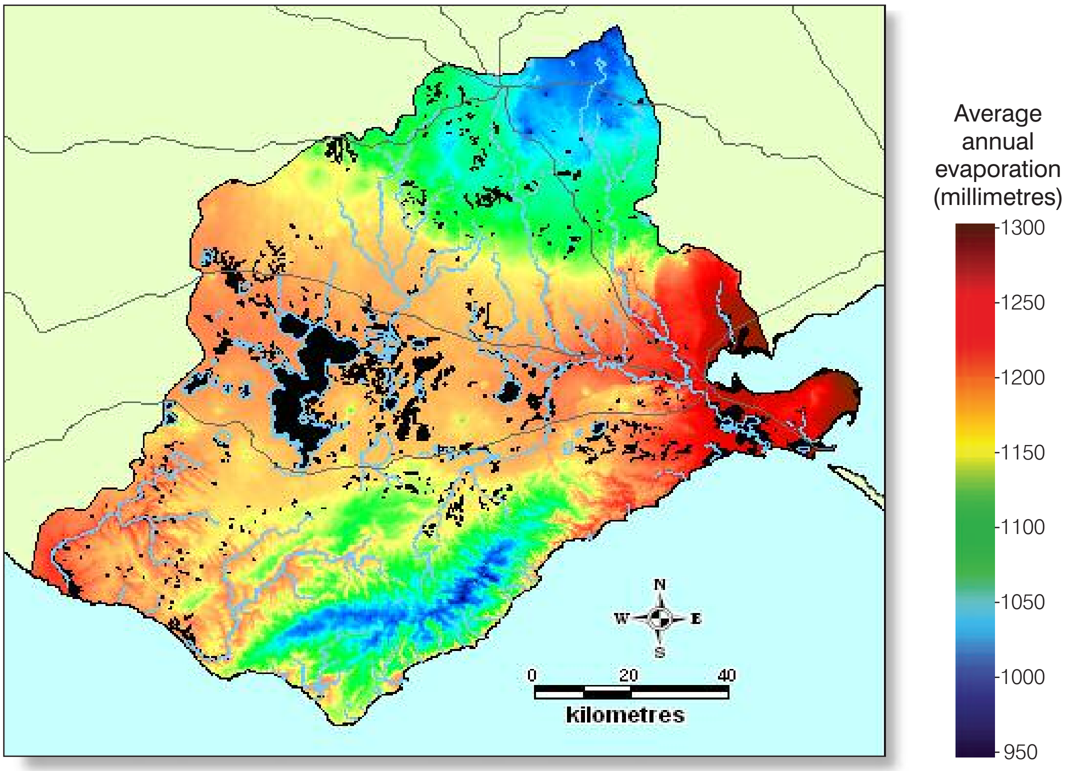


Figure 2.5: Average annual pan evaporation. (Mapped salinity is shown in black)

Altered land use and vegetation cover

The vegetative cover in the Corangamite CMA region has changed dramatically since European settlement. These changes occurred in four main phases.

The first was the initial settlement and establishment of large areas for grazing, particularly on the grassy plains which attracted the first pastoral settlers who arrived in 1835 and quickly established sheep runs. The Learmonth brothers first ventured west and north from Geelong in 1837, exploring the Western Uplands and settling the Ballarat region. 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 1838. By 1840 the squatters had ventured to all parts of the Corangamite CMA region, many parts of which were immediately available for agriculture without the need to remove trees and well watered with rivers,

"…everlasting waterholes, and many fine and valuable springs." (Fyans 1853, in Bride 1898).

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).

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 of people flocked to the region and the native vegetation was rapidly cleared for mining, agriculture and timber supply. Forestry and grazing on the volcanic basalt landscapes around Ballarat gave way to cropping as potatoes, wheat, oats and vegetables were produced and dairy herds established. It was during this time that the first water supply reservoirs were built and the water boards commenced the regulation of rivers.

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.

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.

Urban migration to rural areas is the final chapter in the dramatic land-use changes of the region. In 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 2003). The size of these peri-urban properties has significantly reduced and the land used for agricultural production has declined dramatically.

A consequence of close to 200 years of changed land use has been in the loss of approximately one million hectares of pre-existing vegetation. This has primarily been replaced with exotic shallow-rooted plant species for grazing and the construction of urban environments.

Altered surface water flows in the Corangamite CMA region

Commensurate with the change in land use has been the modification to surface water run-off. Many of the lakes, wetlands and waterways were saline before European settlement, suggesting groundwater inflows and salt run-off from saline land was a natural part of the hydrologic cycle. Intervention during the past 150 years has dramatically altered the quantity and quality of surface water flows.

As an example, dramatic changes have been where water has been harvested for urban consumption, such as the Moorabool River. A recent study has calculated that 61% of the available water is harvested, leaving only 39% available for the environmental flows (SKM 2004). Harvesting the fresh water for urban and agricultural use has an impact on the river, as saline groundwater contributes proportionally more of the remaining river flow. Approximately half of the harvested water is ultimately discharged to neighbouring river catchments (e.g. the Leigh River), with a resulting impact on the salinity in the receiving catchments.

Altered surface water can also adversely impact on the environmental integrity of wetlands and estuaries. The opening of the Woady Yaloak River diversion to the Barwon River in 1960 has increased the salinity of Lake Corangamite, with an adverse effect on ecosystem health (Williams 1995). By contrast, the inflow of fresh stormwater from the hard-paved surfaces in urban areas has diluted the salinity of the estuarine wetlands around Corio Bay, also adversely altering the ecosystems.

How salinity appears in the Corangamite CMA region

Salinity appears in the Corangamite CMA region as either saline land, saline wetlands or as changes in water quality in waterways and water storages.

Land salting

Land salting is the most obvious manifestation of salinity in the Corangamite CMA region. It is estimated there is 17,250 ha of land salting, occurring at 1,500 locations in the landscape (Dahlhaus *et al.* 2005b). This estimate is confounded by the presence of both primary (natural) and secondary (induced) salinity. In some locations the separation between natural and induced land salting is relatively easy, but in many other areas the distinction is less clear. The most recent estimate suggests that just over half the mapped salinity is primary in origin. If the integrity of this natural salting is intact, these areas need to be viewed as environmental assets.

The location of primary and secondary salinity occurs on both private and public land. Much of the land salting is associated with the foreshores of the extensive lake and wetland complexes throughout the region. The latest estimates of land salting in the Corangamite CMA region by type and ownership are given *(Table 2.5)*

Type of salinity	Saline sites (number)	Public ownership (hectares)	Private ownership (hectares)	Total salinity (hectares)
Primary	422	2,241	6,942	9,183
Secondary	1,075	1,062	7,022	8,084
Total	1,497	3,303	13,964	17,267

Table 2.5: Number and area of land salting by ownership and type

Saline wetlands

In terms of area, saline wetlands are the most extensive expression of salinity in the Corangamite CMA region. Approximately 72% of the salinity in the region occurs as semi-permanent or permanently saline wetlands *(Figure 2.6)*. Most wetlands receive a considerable volume of groundwater discharge, such that they vary in their salinity range from brackish to hypersaline.

The location of saline wetlands in relation to the primary and secondary land salting is illustrated *(Figure 2.7)*.

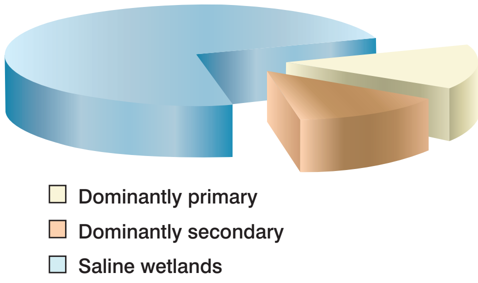


Figure 2.6 Proportion of the salinity types

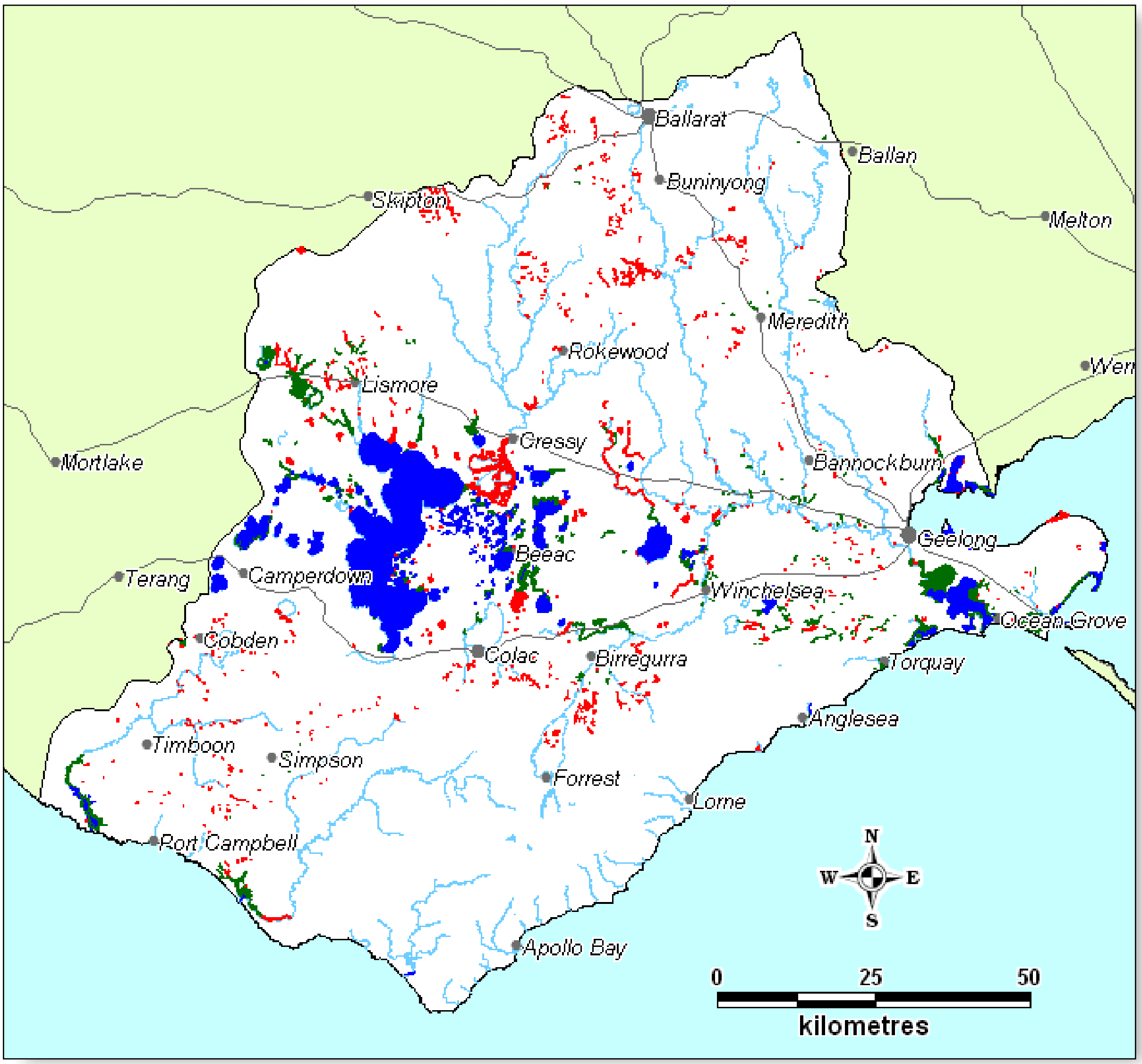


Figure 2.7: Mapped salinity in the Corangamite CMA region

Surface water salinity

Salt is present in all streams and rivers as dissolved mineral salts, sourced from the weathering of rocks within the catchment and the inflows of saline groundwater. While some rivers and streams were naturally quite salty, water quality within the Corangamite CMA region has declined since European settlement (SKM 1996). The current salinity and salt loads for selected streams are given in *Table 2.6*. The flow-weighted salinities of the Barwon, Leigh and Woady Yaloak exceed the Murray Darling Basin Commission benchmark and are generally greater than for streams in northern Victoria.

Waterway and location	Monitoring period From	To	Average Salinity EC μS/cm	Average saltload tonnes per day
Moorabool River West Branch at Lal Lal	Dec '76	Feb '05	421	5
Moorabool River at Batesford	Nov '76	Feb '05	1521	81
Pirron Yallock Creek at Pirron Yallock	Jan '77	Feb '05	1221	35
Birregurra Creek at Ricketts Marsh	Oct '76	Dec '04	10429	294
Woady Yaloak River at Cressy	Nov '76	Feb '05	5265	242
Barwon River at Pollocksford	Nov '76	Feb '05	1991	495

Table 2.6: Salinity of selected waterways in the Corangamite CMA region

Salinity monitoring data is available for 38 gauging stations in the region's waterways, and all show a statistical change in salinity by either becoming more or less saline (Dahlhaus *et al.* 2005b). The most dramatic is the Moorabool River at Batesford where over the period from November 1976 to February 2005, the salinity (measured as Electrical Conductivity or EC) rose by 23.7 $\pm$ 6.0 μS/cm/yr (microSiemens per centimetre per year). Over the same period, the mean salinity value of the river has almost doubled from 1218 μS/cm to 2133 μS/cm EC, and is predicted to reach between 2320 μS/cm and 2404 μS/cm EC by 2012.

The product of the average salinity concentration and average flow results in a considerable tonnage of salt being carried by the Corangamite waterways *(Table 2.6)*. Measured over the past 30 years, an average of 495 tonnes per day (~180,000 tonnes per year) is carried out to sea by the Barwon River.

Groundwater salinity

The salinity of the groundwaters of the Corangamite CMA region varies considerably. The most saline groundwaters occur beneath the hypersaline lakes (e.g. Lake Beeac and Lake Cundare), where values up to 10 times higher than seawater are recorded. By contrast, the groundwaters of the Otway Ranges and the porous volcanic cones around Ballarat have very little salt and are extracted for bottled water.

Groundwater moves slowly through the interconnected spaces in the rock, which results in complicated flow paths and a variable length of time for the water to travel from the recharge zone to the discharge area. Groundwater may take several hundred thousand years, or a matter of days, in its journey from recharge to discharge. For this reason, the salinity of groundwater can vary quite considerably over a short distance, both vertically and horizontally, depending on the complexity of the groundwater flow paths.

Salinity is essentially a groundwater issue, as the discharge of groundwater on land or in rivers and wetlands is the major immediate source of salt at the location. For this reason, monitoring the groundwater levels and salinity is important. A study of the groundwater bores in the Corangamite CMA region found that of the 9,260 bores in the database, 956 have a groundwater-level monitoring record. Approximately 450 salinity monitoring bores were installed during the first decade of salinity management under the initial salinity management plan, *Restoring the Balance*. A 2004 review of these bores found that approximately 20% were now broken and more than half were silted to some degree.

The impact of salinity to the Corangamite CMA region

Salinity threatens the economic, environmental and social assets of the Corangamite CMA region. The Corangamite Regional Catchment Strategy identifies where these salinity threats occur and further comment has been provided to build an overall perspective on the salinity problem.

From an economic perspective, salinity is seen as a threat to water use and land use. The major economic water threat is the increase in salinity in urban water storages that supply significant quantities of water to Geelong and Ballarat, the two major population centres of the Corangamite CMA region. The cost of increasing salinity in water is borne by individual households as well as major industries, especially in Geelong where concerns have been expressed about the quality of the water supplied. As an example, the current salinity of 700 EC (after treatment) at the Lal Lal Reservoir costs urban water users approximately $8.1M per year. By 2010 it is expected that the EC will reach the upper limit of Australian Drinking Water Guidelines, and water users would be facing a cost of approximately $9.2M year, a difference of $1.1 million (Kelliher *et al.* 2006).

Salinity is also having an impact on the productivity of agricultural land. It is estimated there is more than 8,000 ha of land affected by secondary salting, with the majority of this area on private land (Dahlhaus *et al.* 2005b). This land is primarily used for grazing and broadacre cropping, where salinity is reducing potential yields by as much as 90%, costing more than $1 million per annum.

Everyday infrastructure such as buildings, roads, railway lines and utilities including telephone, electricity and gas are currently threatened by salinity. The City of Colac is currently confronted with proposed development of peri-urban areas on the southern fringe of the city being subdivided for urban housing. This area has existing land salting and rising watertables. It is estimated 61km of sealed and unsealed roads are currently salt affected, at an annual cost of approximately $100,000 (Kelliher *et al.* 2006) and this is predicted to rise. Managers of utilities such as telephone, electricity and gas conduits currently adopt preventive salinity measures to protect their assets, but this comes at an increased cost (Nicholson *et al.* 2003).

Salinity threatens the environmental assets of the region, especially the surface waters in wetlands, lakes, rivers and streams. The Barwon River, Lake Corangamite and Moorabool river basins, where the majority of the region's salinity occurs, rate very poor or poor for approximately half of their reaches (DSE 2005b).

Salinity was not directly identified as a priority threat to vegetation in the Regional Catchment Strategy (CCMA 2003a). However, recent assessments indicate more than 6,400 ha of very high and high conservation significance vegetation intersect with mapped salinity (Dahlhaus *et al.* 2005b). In some cases the presence of salinity may be critical to the stability of these vegetation areas, such as halophytic herblands, but in other locations, secondary salting is likely to threaten salt-sensitive vegetation classes.

Salinity was not directly linked to the social assets in the Corangamite Regional Catchment Strategy (CCMA 2003a). Yet it would be fair to assume the social threats identified, such as population pressures and land use change, will be influenced by salinity through poor water quality for urban use, degradation of the recreational values attached to waterways and wetlands and degraded vistas with increasing land salting. Lower productivity from agriculture and possible relocation of industry because of high salinity in water has the potential to reduce employment and economic activity.

The threat of salinity to the Corangamite CMA region in the future

Land salting

In 2001 the National Land and Water Resources Audit (NLWRA) released the Australian Dryland Salinity Assessment 2000. The predictions for Corangamite were dire *(Table 2.7)*; 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 (DNRE) (SKM 2000) and their applicability has been questioned by researchers more familiar with the groundwater flow systems in the Corangamite CMA 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 (Dahlhaus & MacEwan 1997).

A more recent evaluation of the audit predictions by SKM (2005a) included maps of both rising and falling trends in the watertable. Rising groundwater is shown in the Bungaree, Illabarook, Lake Murdeduke, Heytesbury, Ross Plain and Gerangamete regions. Both the reliability diagram *(Figure 2.8 - page 25)* and an inspection of the data used to create the numerical surfaces indicate that the trend shown for the Bungaree, Heytesbury and Gerangamete regions is probably an artefact of the modelling process. However, watertables are slowly rising in locations mentioned above in the Corangamite CMA region. This rise in watertables often does not present as obvious signs of extensive land salting, but has the capacity to affect infrastructure and utility assets. The rise in watertables may also threaten the integrity of native vegetation communities. While no examples of decline of existing native vegetation have been documented, opinion would indicate many of the high-conservation significance vegetation classes would be threatened if confronted by rising saline groundwater (Chris Pitfield, *pers comm*.).

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 2.7: NLWRA predictions for the Corangamite CMA region (SKM 2000).

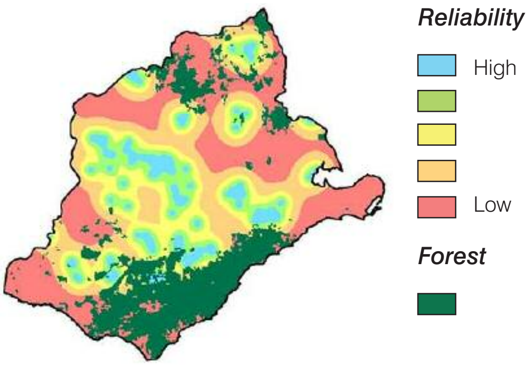
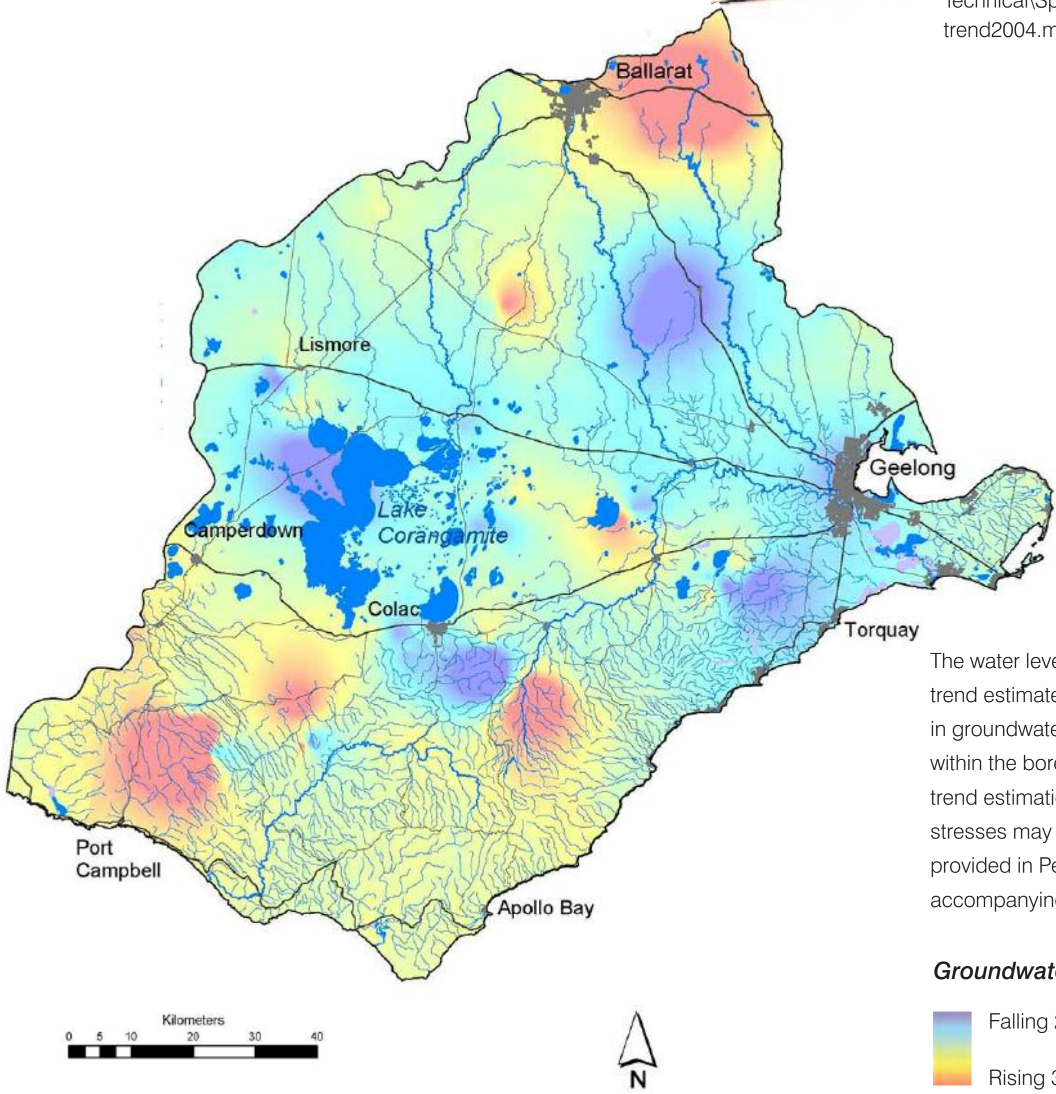


Figure 2.8: Long-term watertable trend (SKM 2005a)

Refer to Sinclair Knight Merz document I:WCMS\Projects\WC02661\Corangamite\Technical\Spatial\ArcMap\trend2004.mxd



The water level trend map was produced from trend estimates based on measured water levels in groundwater bores. While climate dependency within the bore record has been removed prior to trend estimation the impacts of precedent climate stresses may still be present. Further details are provided in Peterson, et:al,2004a and the accompanying SKM project report.

Groundwater Trend

Falling 210mm/yr

Rising 350mm/yr

Benchmarking Watertable and Groundwater Trends
Corangamite Catchment Management Authority Area

LONG TERM WATERTABLE TREND

There is strong evidence land salinisation is expanding and will do so in the future (Auditor General 2001). A summary of recent discharge mapping in the region (Dahlhaus *et al.* 2005b) suggests the area of land salinised is increasing in some locations. This expansion has been variously quantified as 11% based on the remapping of 15% of known land salinity (Gardiner 2001); and 8% at Pittong and 7% at Gerangamete (treated site) based on the discharge monitoring program (Clark & Hekmeijer 2004, *Table 2.8*). The latest 2005 mapping for the municipal salinity management overlays (Miller *et al.*, in prep) records an increase of 49% in land salinity from the previous mapping.

Table 2.8: Summary of discharge monitoring at the six discharge monitoring reference sites

Location	Beeac	Gerangamete agroforestry	Gerangamete control	Moriac	Pittong	Wingeel
Year established	1996	1994	1994	1995	1996	1995
Year reassessed	2000	1999	1999	2000	2000	1999
Change in total salt-affected area	13% decrease	7% increase	25% decrease	7% decrease	8% increase	18% decrease
Change in groundwater levels	~ 1metre lower	0-5 m to 1.5 m lower	stable	~ 0.6 metre lower	Slightly lower	~ 0.6 metre lower

Source: summarised from Clark & Hekmeijer 2004

The results of the monitoring indicate the difficulty in linking cause and effect at an individual site. As an example, at the Gerangamete agroforestry site, recharge control treatment (planting of tree belts) commenced in 1993. Since that time, the area of land affected by salinity has increased by at least 7% and the groundwater tables have dropped $^1/_2$ to $1^1/_2$ metres. During the same period at the control site at Gerangamete, where no treatment has been undertaken, the area of land affected by salinity has decreased 25% and the groundwater levels have remained relatively stable.

Surface water salinity

The length of salinity monitoring records varies for stream gauging stations within the Corangamite CMA region. The EC measurements for most gauges commence from the late 1970s, but several have since ceased monitoring that parameter. Nevertheless, all available EC data were used to determine the salinity trends (Dahlhaus *et al.* 2005b).

The trend analyses obtain stream salinity trends that are independent of fluctuations in flow and season, and hence are indicative of the impacts of saline groundwater inflows caused by catchment salinisation. Although the method corrects for flow and seasonal effects, the analyses do not account for longer-term climate variations, such as a run of wet years or a run of dry years. Obvious outliers, caused be erroneous flow or EC values, were identified by high residual values and were removed from the data set and the trends recalculated.

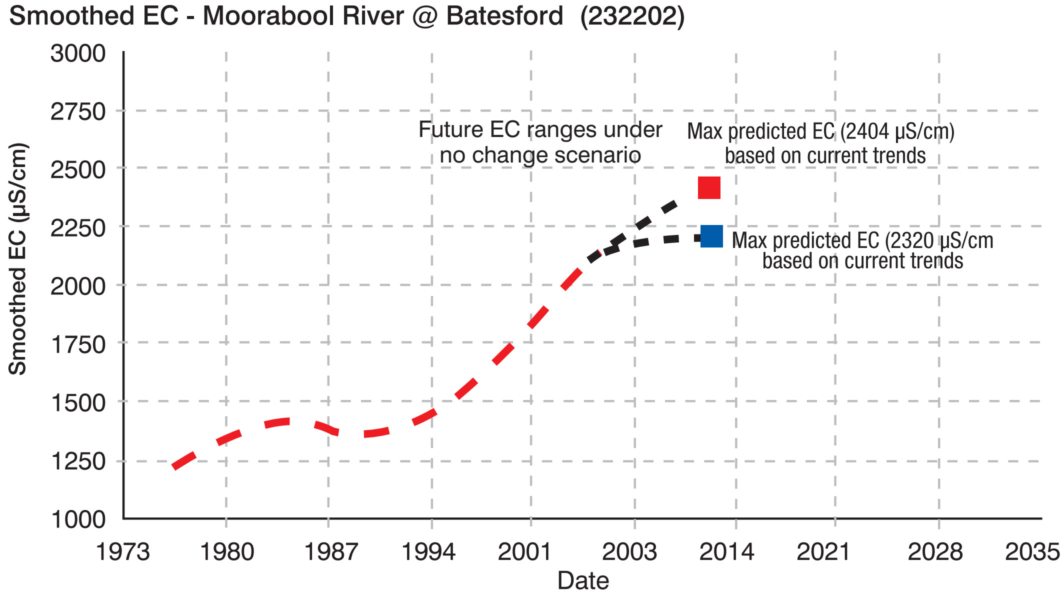
Waterway and location	Monitoring period From	To	Linear trend (EC μS/cm/yr)
Moorabool River West Branch at Lal Lal	Dec '76	Feb '05	Rising 1.0 ± 1.9
Moorabool River at Batesford	Nov '76	Feb '05	Rising 23.7 ± 6.0
Pirron Yallock Creek at Pirron Yallock	Jan '77	Feb '05	Rising 10.3 ± 7.4
Birregurra Creek at Ricketts Marsh	Oct '76	Dec '04	Falling -175.1 ± 112.2
Woady Yaloak River at Cressy	Nov '76	Feb '05	Rising 3.4 ± 23.7
Barwon River at Pollocksford	Nov '76	Feb '05	Falling -31.8 ± 8.3

Table 2.9: Salinity trends of selected waterways in the Corangamite CMA region

An example of the statistical analysis for the Moorabool River at Batesford is shown in *Figure 2.8*, which includes the non-linear trend and the exceedence curve. More data can be found in Background Report 9 (Dahlhaus *et al.* 2005b).

Gauge 232202 - Moorabool River at Batesford

Start date:	November 1976		
End data:	February 2005		
No of samples:	312		
Mean flow:	89 Megalitres/day		
EC:	Mean 1521 µS/cm	Highest 4000 µS/cm	Lowest 340 µS/cm
Mean salt load:	81 tonnes/day		
Linear EC trend:	23.7 ± 6.0 µS/cm/yr		



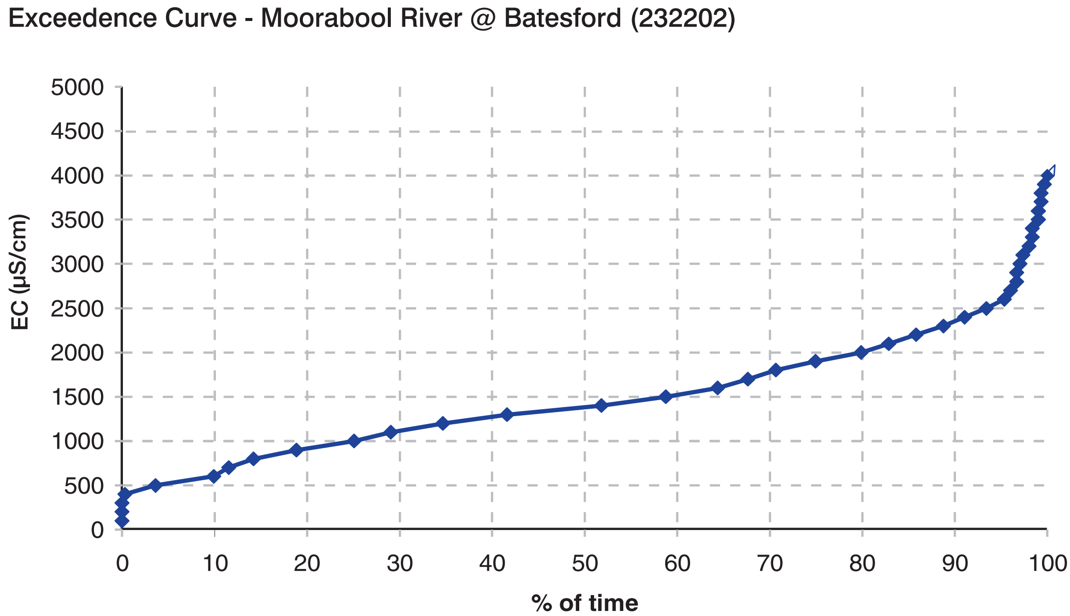


Figure 2.9: Statistical analysis of stream salinity for the Moorabool at Batesford (1976-2005)

Wetland and estuarine salinity

Virtually no monitoring records are available to quantify the trends in wetland and estuarine salinity in the Corangamite CMA region. However, there is evidence that increasing salinity is affecting the integrity of wetland ecosystems such as Lake Corangamite. The potential threat was based on the research by Williams (1995) who recognised that biota has changed from one that is characteristic of lakes in the region of moderate salinity to one that is characteristic of more saline lakes. In particular, *Austrochiltonia subtenuis* (Amphipoda), *Coxiella* (Gastropoda), *Galaxias maculatus* (Pisces) and *Ruppia* (macrophyte) have almost disappeared. The change in the lake ecology has resulted in a dramatic drop in the abundance and numbers of bird species using the lake to the point where its Ramsar listing is now threatened (Williams, 1995).

More recent research detailed strong evidence that the increasing extraction of groundwater from the Warrion Groundwater Management Area (GMA) was responsible for the drying of a number of saline lakes at Red Rock, near Alvie (Adler & Lawrence 2004). The research, based on hydrologic budget calculations, indicated that the salt water previously held in the lakes has now entered the groundwater system, and that salt water from Lake Corangamite was also continuing to contaminate the irrigation resource.

This important research highlights the sensitivity of groundwater-dependent ecosystems and how the lowering of groundwater tables (in this case through extraction for irrigation) can devastate the integrity of saline wetlands. The implications for the SAP are that lowering of saline watertables is not always the most appropriate action to reduce salinity.

Monitoring of wetlands is expected to commence with the recently published Index of Wetland Condition (IWC) as a standard method for assessing wetland condition in Victoria (DSE 2005d). The IWC is a hierarchical index with six "fundamental characteristics" of the wetland, *viz:* wetland catchment, hydrology, water properties, soils, biota and physical form. Each of these fundamental characteristics has "key components" and each of the key components has "measures". Of these salinity (measured as EC) is included.

How does the community perceive salinity compared with other regional threats?

Community perceptions are an important consideration in determining government investment in natural-resource management. Salinity was rated the most important threat to the region's economic assets, above weeds, inadequate strategic management, soil deterioration and land-use change (CCMA 2003a). It is likely that the previous 12 years of salinity investment, which had focused primarily on land salting (Nicholson 2002) would have influenced this response.

The threat of salinity to environmental assets was rated fourth out of the 17 threats considered. More important were reduced flows (which have an impact on salinity concentrations), nutrients and sediments. However, it could be argued the salinity threat to water quality is inextricably linked to reduced water flows, where water is concentrating salinity because of reduced freshwater dilution. Both results indicate salinity is perceived as a major threat to both economic and environmental assets.

2.4 What threat does the salinity pose to the asset?

The threat posed by salinity to the region's assets has been examined through the GSHARP model (Heislers & Brewin 2003). This geographically based model identifies the intersections of a range of salinity hazards such as land salinisation, flow-weighted stream salinities and groundwater rating with the assets listed in *Section 2.1*. Valuation of the assets was described in *Section 2.2*.

Ultimately, the GSHARP project provided:

A **salinity hazard map** for the CCMA region, derived by the addition of:

- Mapped area of land salinised
- Mapped line of salinisation along a watercourse
- Groundwater salinity rating
- Depth to watertable rating
- Flow-weighted stream salinity rating
- Groundwater flow system rating

A **salinity risk**[3] **map**, derived by summing the threat of salinity to the following assets:

- Infrastructure (roads, bridges, railway and towns)
- Utilities (electricity, gas, water, Telstra)
- Agricultural land
- Water reservoirs
- Environment (Public land, Victorian Rare or Threatened (VROT) species, Significant and/or Ramsar wetland)
- Cultural and heritage (Aboriginal, historical, natural)

Details of the data and process are described (Heislers & Brewin 2003).

Immediate salinity threat to assets

The current or immediate-term threat to assets was mapped using a 1 km^2 grid cell, summed according to the ranking of asset intersections with mapped salinity. Ramsar wetlands and water supply reservoirs were ranked on their occurrence within a 'hazardous' GFS. Towns, Public land and Victorian Rare or Threatened Species (VROTS) were ranked on their intersection with shallow watertables (less than or equal to 2 metres below the natural surface).

Interim target areas were selected on the basis of a grouping of cells with high scores in the immediate term *(Figure 2.10)*. These areas were then examined to determine which assets were threatened. Unfortunately, data exchange protocols, confidentiality and copyright issues prevented the original GSHARP data sets to be published, however, the grided (or rasterised) data were supplied and separate maps were generated for each interim target area. Each interim target area was then field-checked to validate that the actual threat to assets existed on ground. The data and results of this process are detailed in Background Report 2 (Dahlhaus 2003a).

Longer-term salinity threat to assets

The longer-term salinity threat to assets used the same data to determine the immediate threat but also included intersection of all assets with shallow watertables less than or equal to 2 metres below the natural surface *(Figure 2.11)*. A further prediction was made using watertables between 2 and 5 metres depth.

Both these predictions confirmed the selection of the interim target areas based on the immediate-term risk.

[3]Under the Australian Standard definition of risk, this map shows the threat of salinity to assets, but not the risk. Risk would require the consequences of the salinity to be considered.

Figure 2.10 Immediate-term threats to assets

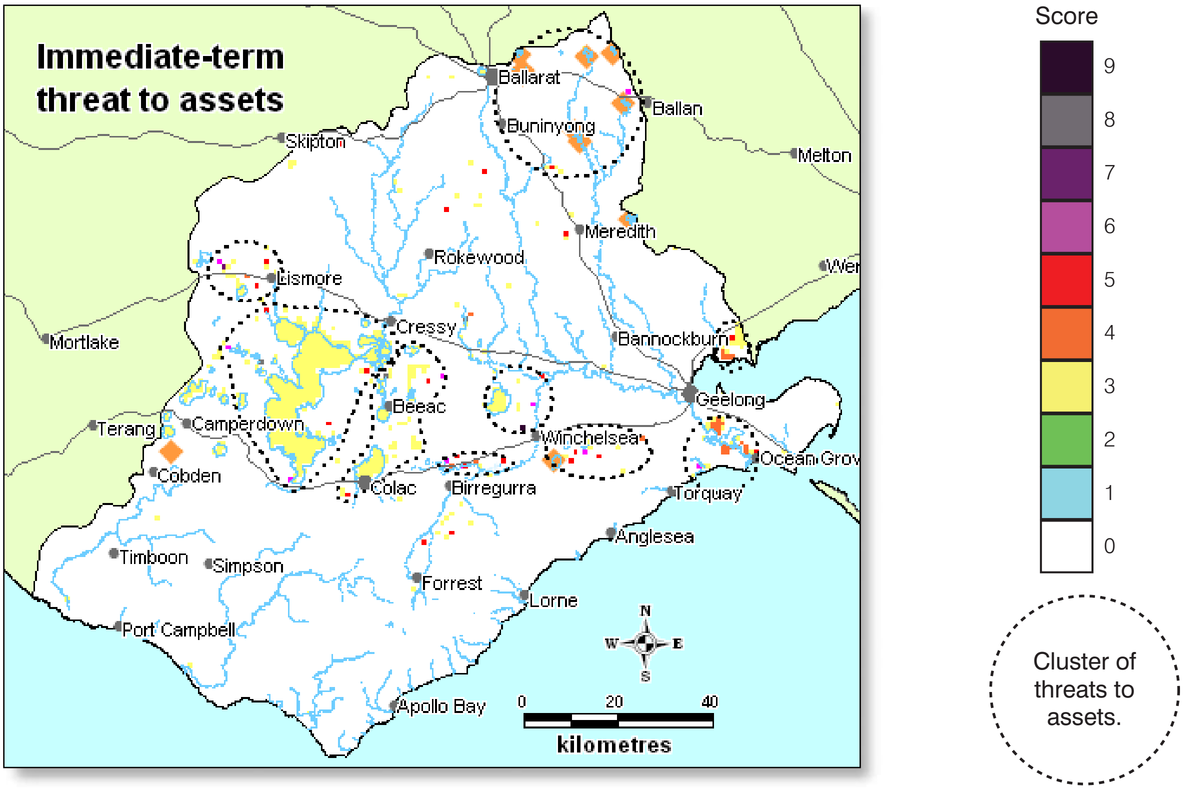
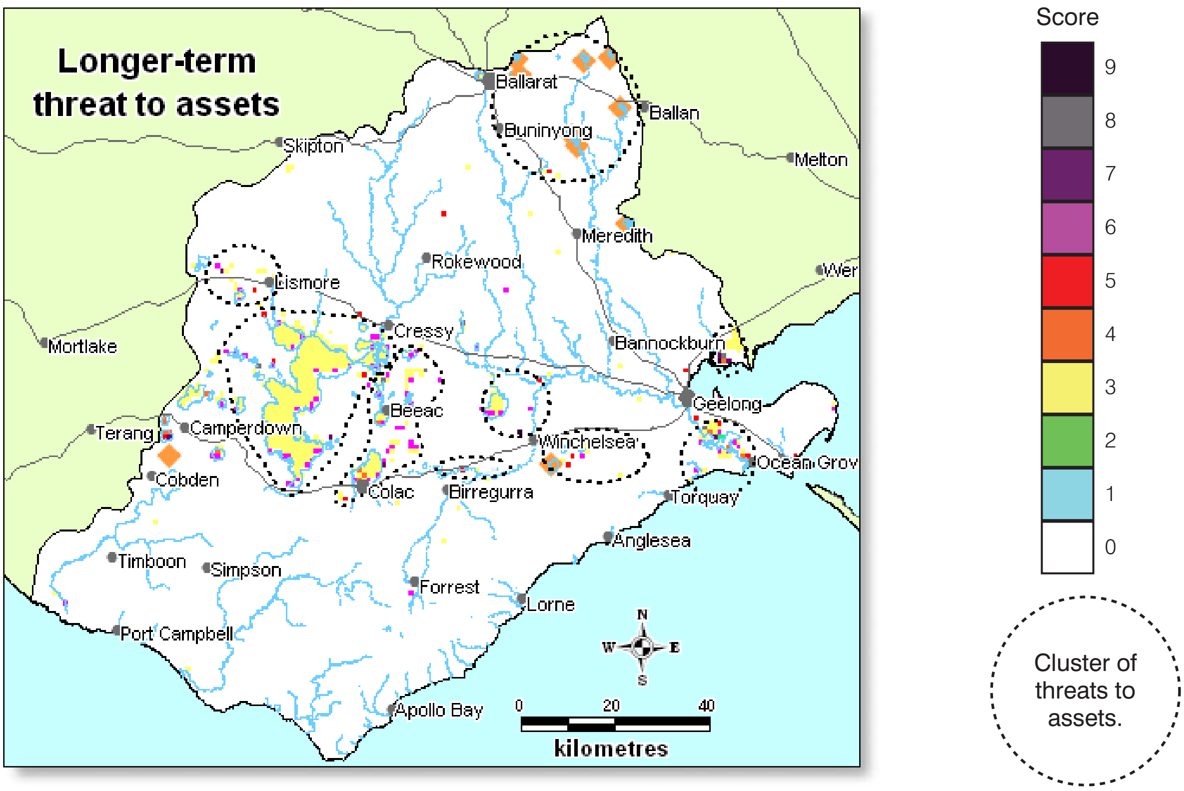


Figure 2.11: Longer-term threats to assets

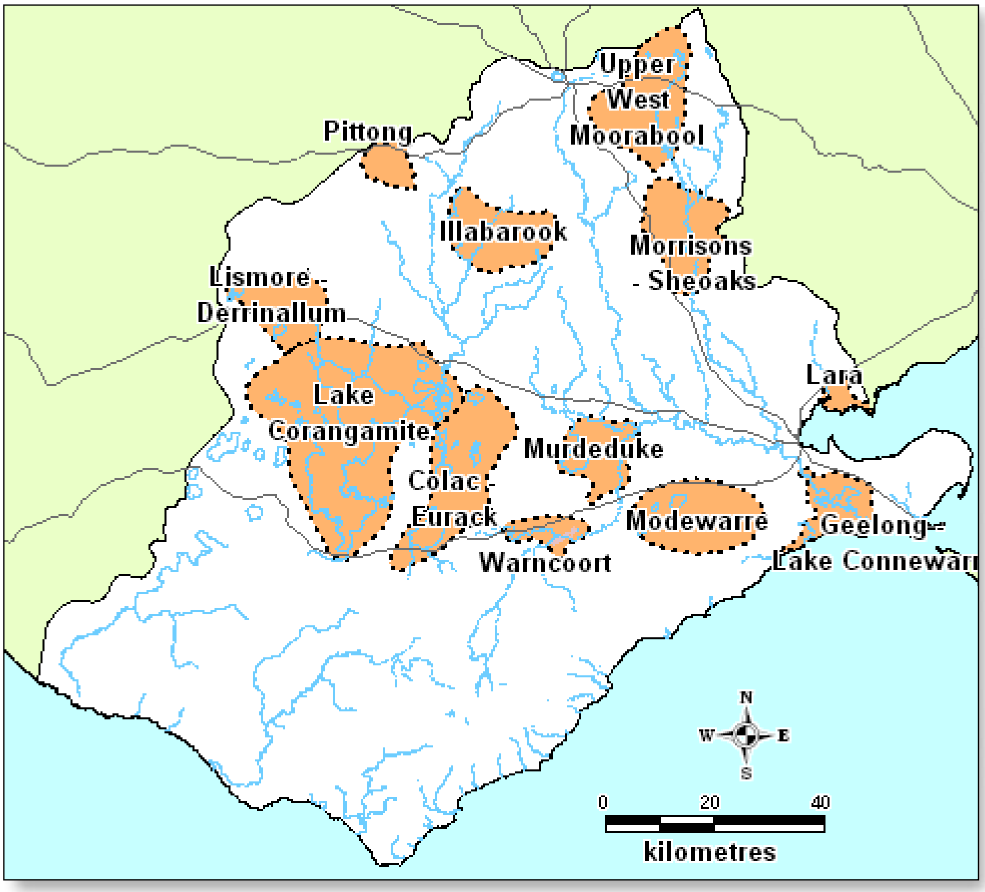


In addition to the interim target areas selected from the GSHARP model *(Figures 2.10 and 2.11)*, three areas were added on the basis of the rising trends in surface-water salinity in the Moorabool and Woady Yaloak rivers. These areas at Morrisons-Sheoaks, Pittong and Illabarook were delineated using the groundwater flow systems, mapped salinity, water quality information and catchment boundaries (Dahlhaus 2003a).

Identification of target areas for salinity management

Twelve target areas are identified as a result of this asset-based approach to salinity investment *(Figure 2.12)*. These twelve areas encompass more than 80% of the primary salting, 87% of the saline wetlands and 63% of the secondary salting in the Corangamite CMA Region *(Table 2.10)*.

Figure 2.12: Salinity Action Plan Target Areas



Target area	Total area (ha)	Primary salinity (ha)	Secondary salinity (ha)	Saline wetlands (ha)
Lake Corangamite	88,894	1,116	2,413	28,883
Morrisons-Sheoaks	22,368	23	40	
Upper West Moorabool	29,045		15	
Colac - Eurack	34,367	1,410	797	4,129
Geelong-Lake Connewarre	12,922	2,307	64	3,104
Illabarook	20,492		366	
Pittong	6,300		378	
Lismore-Derrinallum	16,443	1,466	305	25
Murdeduke	14,959	243	381	2,091
Warncoort	6,826	385	111	13
Modewarre	23,675	270	160	681
Lara	3,418	143	89	949
Total in SAP target areas	**279,709**	**7,363**	**5,120**	**39,874**
Total in CCMA area		**9,182**	**8,084**	**45,731**

Table 2.10: Salinity Action Plan Target Areas

The inclusion of native vegetation assets

Data on the integrity of native vegetation communities was not available at the time of the GSHARP modelling process. However, over the past two years, the mapping of Ecological Vegetation Class (EVC) and bioregions has been completed for the Corangamite CMA region.

In order to include the salinity threats to the integrity of native vegetation communities and develop appropriate SAP management actions, two GIS layers were provided by DSE to the Corangamite CMA. These are Conservation Significance (Potential) (CSP) and EVC – Bioregional Conservation Status (BCS). The CSP rates the spatial extent of native vegetation, its conservation status, patch size, thickness, neighbourhood and connectivity.

The BCS is a combination of Victorian bioregions and the Extant EVC data, or in other words, a rating of the conservation status of the patches of remnant (indigenous) EVC. In some cases the EVC is clearly related to salinity (e.g. the Cane Grass – Lignum Halophytic Herbland in the Geelong – Lake Connewarre target area), whereas others are less certain (eg. Swamp Scrub in the Modewarre target area).

The analysis of threats to native vegetation assets intersected the mapped salinity and the native vegetation communities which were rated as Very High or High CSP *(Table 2.11, Figure 2.12)*.

	Native Vegetation Conservation Significance (Potential)					
	Very High		High		Medium	
	Total area (ha)	Proportion of CSP	Total area (ha)	Proportion of CSP	Total area (ha)	Proportion of CSP
Whole of CCMA region	99,916	100%	149,736	100%	179,546	100%
In mapped saline areas only	5,392	5.4%	4,750	3.2%	92	0.05%

Table 2.11: Intersection of mapped salinity with the CSP of native vegetation

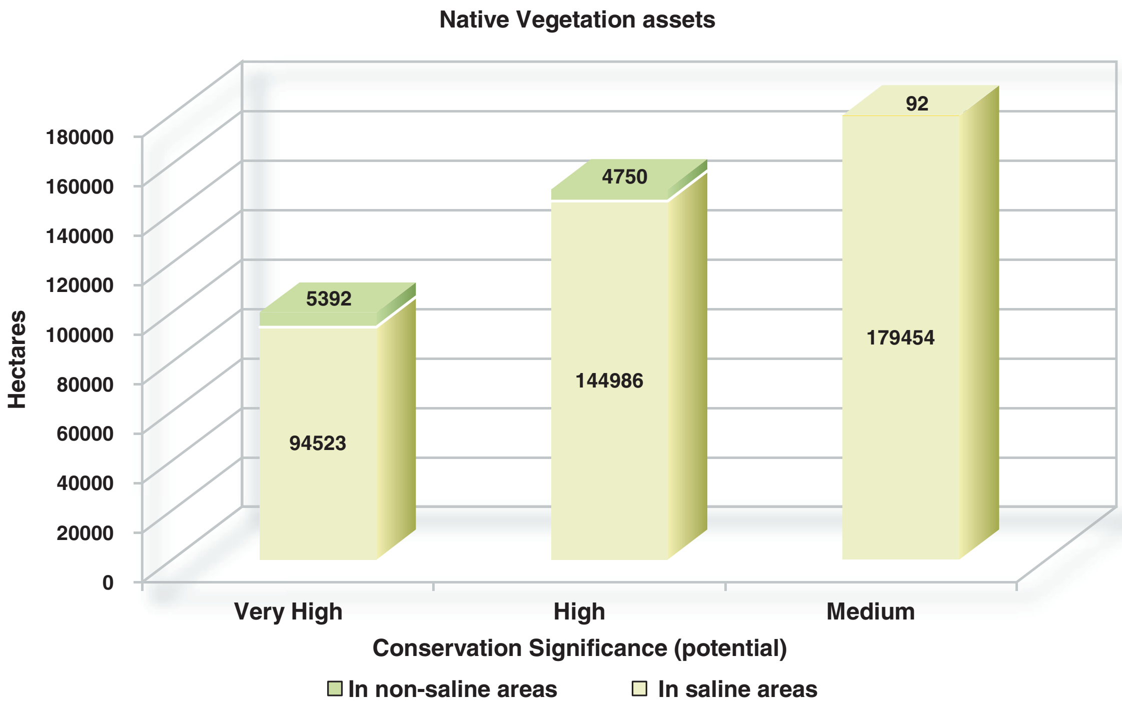


Figure 2.13: Proportion of native vegetation CSP in mapped saline areas

Of the 8.6% of native vegetation with very high and high conservation significance potential which is threatened or potentially threatened by salinity, the 72% is already within the boundaries of the SAP target areas. Within the 28% that remains outside of the SAP target areas, there are six areas where there is a reasonably sized (>50 ha) area of native vegetation with very high or high conservation status threatened by salinity *(Table 2.14)*. These areas were not identified in the original GSHARP analysis (Heislers & Brewin 2003) as areas where multiple assets were threatened by salinity. However, on the basis that high or very high value native vegetation is potentially at risk, these areas have been designated "areas of interest" for further investigation.

As all of these areas are coastal or estuarine areas where primary salinity or saline wetlands have been mapped, it is possible that the very high and high conservation significance potential is related to saline environment EVCs. The threat to these high-value assets requires further investigation and research.

With the addition of the "areas of interest", the SAP will capture 95% of the very high conservation significance potential and 89% of the high conservation significance potential native vegetation potentially threatened by salinity *(Figure 2.14)*.

Areas of interest	Area (ha)	Native Vegetation CSP Very High (ha)	High (ha)
Point Henry	755		46
Point Richards	204		91
St Leonards	134	8	56
Swan Bay - Lake Victoria	2165	396	460
Princetown	2704	479	13
Peterborough	2619	337	115
Total		**1220**	**780**

Table 2.12: Six additional "areas of interest" identified for further investigation

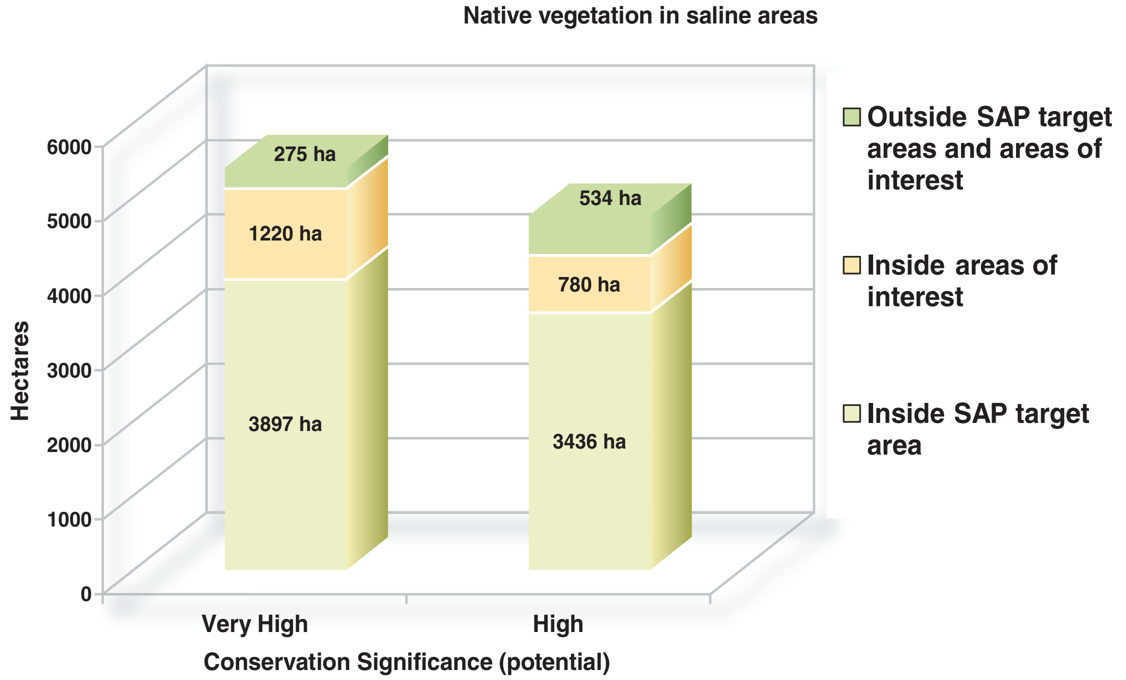


Figure 2.14: Native vegetation potentially threatened by salinity

3. Description of target areas

3.1 Lake Corangamite target area

The Lake Corangamite area is included as a target area on the basis that it enclosed a cluster of high-value assets at risk as identified by the GSHARP model (Heislers & Brewin 2003). The area encloses 88,894 hectares, the majority of which is dominated by Lake Corangamite and adjoining lakes. Many of the saline lakes in the Lake Corangamite target area are internationally listed wetlands, which are ranked as the highest-priority wetlands for protection under both the draft Corangamite Wetland Strategy and the Policy Framework for Wetlands in Victoria (DSE 2003). The target area shares a common boundary with the Colac – Eurack target area on the north-eastern side and the Lismore – Derrinallum target area on the north-western side.

Salinity threats to assets

The primary assets at risk are the 148 saline wetlands which include Lake Corangamite and the connected Lake Gnarpurt Lake Martin and Cundare Pool. Within this target area there are 30 threatened species, seven migratory species, seven marine protected species and the Western District lakes Ramsar site listed on the online database at Environment Australia's website.

Lake Corangamite and adjoining lakes and wetlands are widely recognised in both national and international forums as threatened ecosystems. Lake Martin, Cundare Pool, Lake Gnarpurt and Lake Corangamite have all been listed as Australian wetlands of national and international importance with threatened water regimes (Davis *et al.* 2001), and the Western District lakes have been recognised as important Australian groundwater-dependent ecosystems with a high threat (SKM 2001). Recent research based on hydrologic budget calculations provides strong evidence that the increasing extraction of groundwater from the Warrion Groundwater Management Area (GMA) was responsible for the drying of a number of saline lakes at Red Rock, near Alvie (Adler & Lawrence 2004).

Although Lake Corangamite has been a salt lake for thousands of years, the opening of the Woady Yaloak diversion scheme in 1959 is believed to have significantly and dramatically altered the rate of salt accumulation. This threat was recognised in the initial Corangamite Salinity Management Plan, Restoring the Balance, and is supported by research from Williams (1992, 1995) who recognised that the lake biota has changed with the increase in salinity. The change in the lake ecology has resulted in a dramatic drop in the abundance and numbers of bird species using the lake to the point where its Ramsar listing is now threatened (Williams 1995).

A major study of the Woady Yaloak diversion scheme, completed in 2004, recommends a phased closure of the diversion scheme so that level of the water in the lake is raised to 118 metres AHD by 2009 (GHD 2004).

The investigation predicts that by raising the lake level, a salinity of 50,000 EC_{25} in Lake Corangamite will be exceeded 30% of the time (50,000 EC_{25} salinity is near the tolerance limit of most life living in the lake). However, the study did not consider the impact of the higher water levels in Lake Corangamite and Cundare Pool on the regional groundwater tables and potential impact of salinity of the surrounding assets (i.e. agricultural land, groundwater resources in the Warrion Groundwater Management Area; roads and utilities; and cultural and heritage assets). If the CCMA adopts the recommendations, these impacts would need to be modelled, and a project has been recommended to research the consequences should such a decision be made *(see section 4.6).*

Salinity trends in at least two of the surface water inflows to the lake are also rising. Both the Woady Yaloak River and the Pirron Yaloak Creek shows a rising trend in salinity *(see section 2.3.4.2 for more details).*

There are approximately 100 groundwater monitoring bores in the salinity target area. The water level trends are varied, partly reflecting the response of the aquifers **(local = quicker response; regional = slower response)** and the seasonal and climate influences. The bores with the longest trends generally show reasonably steady or slightly falling water-level trends (Dahlhaus 2003b). However, the modelling by SKM *(Figure 2.7)*, predicts rising watertables in the north-western part of the target area.

Other assets at risk in the area include road infrastructure and some areas of agricultural land. Of the mapped salinity, approximately two-thirds is primary salinity on private land around Lake Martin and the Cundare Pool.

Salinity processes and management options

Four groundwater flow systems occur in the area – Quaternary alluvium and Stony Rises (both local), Pliocene Sands (intermediate) and Volcanic Plains basalt (regional). The vast majority of the saline groundwater is stored in and moves through the regional flow system of the Volcanic Plains basalt (Dahlhaus 2003b). The majority of the saline lakes are groundwater dependent and the geomorphic and historical records suggest that their salinity has been fluctuating in response to climate change for thousands of years (Dahlhaus & Cox 2005).

Lake Corangamite is a terminal lake for both surface and groundwater and many research and investigation projects have examined the hydrological processes. The causes of the rising salinity trends in the Woady Yaloak River and Pirron Yallock Creek are unknown at this stage, and their recent contribution to salt in the lake is unclear. Much of the Woady Yaloak River flow has been diverted from Lake Corangamite via the diversion scheme and the flows in the Pirron Yallock are relatively small and the average salinity (~1220 μS/cm EC) is negligible when compared with the lake (~100,000+ μS/cm EC).

Manipulation of the groundwater inflows to the lake is beyond management by land-use change (due to the regional groundwater system and the very large lake). At its current 'normal' level of 114.7 metres AHD, Lake Corangamite acts as a groundwater sink. Salinity values in the lake have been rising by evaporation of the saline surface water and groundwater inflows. Undoubtedly, the management of salinity in the lake systems is closely linked to the operation of the Woady Yaloak Diversion Scheme. As mentioned previously, the recommendations on the future operation of the Woady Yaloak diversion scheme currently before the CCMA potentially pose additional salinity threats to agricultural land, native vegetation, wetland and groundwater assets which require further research.

The protection of groundwater springs and groundwater inflows to the lakes and wetlands requires management of groundwater consumption, especially in the Warrion Groundwater Management Area (GMA) and the Stony Rises of Pomborneit. Nutrient contamination of the groundwater has been recorded at most springs, with nitrate at McVeans Springs increasing from 0.13 mg/L in 1906 to 16 mg/l in 1994 (Bayne 1998). The protection of smaller wetlands, especially those around Leslie Manor, probably lies with the management of surface water drainage. Anecdotal history suggests these wetlands and lakes to be formerly fresh and once drained became quite saline. Their present value as environmental assets is under review and it is not known if they can be restored, or indeed, if that is desirable.

The protection of infrastructure assets (water, power, telecommunications, roads) is best discussed with the asset managers, but reconstruction, retro-fitting of protective barriers, improving surface and subsurface drainage are possible solutions.

For agricultural assets at risk, discharge management through the productive use and rehabilitation of saline lands is considered the most effective salinity management for the region. Recharge control is not considered feasible at this stage, due to the large regional groundwater system and the complexity of the groundwater interaction with the lakes.

Change Scenario

The draft summary of the major investigation of the Woady Yaloak Diversion Scheme (GHD 2004) recommends implementing changes as follows:

- Continue operating the scheme under the current rules until June 2006;
- Implement Option 4b from July 2006 to June 2009. Option 4b is to close 25% of the Woady Yaloak Diversion Scheme from July 2006 to June 2009 and target a rise in the level of Lake Corangamite to 115.28m. AHD. The diversion channel operates only when the Lake exceeds 115.28m AHD;
- Implement Option 6 in July 2009. Option 6 is to close the Woady 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 salinity outcomes they predict are:

- *For Option 4b* (July 2006 to June 2009): A salinity of 50,000 EC_{25} in Lake Corangamite will be exceeded 55% of the time (50,000 EC_{25} salinity is near the tolerance limit of most life living in the lake), and the average monthly salinity of the Barwon River at Pollocksford = 1,650 EC_{25} (range 1,450 to 2,010 EC_{25}).
- *For Option 6* (post July 2009): A salinity of 50,000 EC_{25} in Lake Corangamite will be exceeded 30% of the time (50,000 EC_{25} salinity is near the tolerance limit of most life living in the lake), and the average monthly salinity of the Barwon River at Pollocksford = 1,590 EC_{25} (range 1,380 to 1,970 EC_{25}).

The GHD study did not consider the impact of the higher water levels in Lake Corangamite and Cundare Pool on the regional groundwater tables and potential impact of salinity of the surrounding assets (i.e. agricultural land, groundwater resources in the Warrion Groundwater Management Area; roads and utilities; and cultural and heritage assets).

A summary of the assets, threats, trends and management options for the Lake Corangamite target area is provided *(Table 3.1)*

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	1116 ha of primary salinity, 994 ha of which is on private land, mostly in the Leslie Manor, Duverney and Foxhow areas. 2413 ha of secondary salinity of which 1755 ha is on private land, mostly in the Cundare, Barpinba and Cressy areas.	Shallow groundwater predicted to rise in north-west sector (SKM 2005a). Proposed raised level of Lake Corangamite may raise watertables and increase area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	Some intersections with VROTS, but species unknown. 372 ha of vegetation with Very High conservation significance and 277 ha with High conservation significance intersects with salt. Largest areas are lower Woady Yaloak River south of Cressy and north of Pirron Yallock. May be halophytic species.	Changes to lake salinity (increase) may change Ramsar status and threaten habitat.	Raise lake level. Protect high-value native vegetation in primary saline areas.	
Cultural and heritage	Archaeological, National Estate	Increasing salinisation of Lake Corangamite recognised as a threat to its Ramsar status.	Changes to lake salinity (increase) may change Ramsar status.	Raise lake level.	
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	~ 1km of pavement break-down on Foxhow Rd near Gnarkeet Chain of Ponds, and along Cundare Rd and Cotties Rd. Electricity, water, telephone all intersect with saline areas, but protected by preventative actions by asset managers at an additional cost.	Increasing salinity threatens roads.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	148 saline wetlands covering 28,883 ha occur within the target area. Lake Corangamite, Lake Gnarpurt, Lake Martin are among the Ramsar and significant wetlands. Increasing salinisation of Lake Corangamite recognised as a threat to its Ramsar status. Salinity in Pirron Yaloak Creek is rising at 10.3 EC/yr. Salinity in the Woady Yaloak River is rising at 3.4 EC/yr, with saltload of 242 tonnes/day.	Groundwater extraction dries out wetlands. Pirron Yallock Creek salinity rises to 1461 EC by 2012.	Changes to Woady Yaloak Diversion Scheme as recommended by GHD study. Improve groundwater management to protect the integrity of wetlands.	Improved road management for saline areas reduces maintenance frequency and costs.

Table 3.1: Summary of Lake Corangamite target area.

3.2 Morrisons – Sheoaks target area

Approximately 22,368 hectares in the Morrisons - Sheoaks region has been selected as a salinity target area on the basis of increasing salinity trends in the Moorabool River and the consequent threat to urban water quality assets. The main off-take pipeline for urban water supply is located at the southern end of the target area. This pipeline supplies approximately 50 megalitres/day or approx 30% of the total water for the City of Geelong (population 185,000).

Salinity threats to assets

The current water quality at the Sheoaks off-take pipeline averages 970 μS/cm EC which creates a major increased salinity burden on the whole urban water supply region, since the water has to be blended with fresher water from other sources to reduce the salinity levels to the urban supply target of 500 μS/cm EC. In addition to the impact for City of Geelong, the increasing salinity in the Moorabool River also impacts on the urban water supplied to smaller towns where the water comes direct from river itself. Over recent years, the salinity of the water supplied to these towns has ranged from 600-1600 μS/cm EC, although it has been consistently above 1000 μS/cm EC which is above the value recommended by the Australian Drinking Water Guidelines (ADWG 1996).

At the upstream end of the target area, the river carries a mean salt load of 28.8 tonnes/day, with no significant change in the salinity over the past 26 years of monitoring (measured at Morrisons, gauging station # 232204). Below the downstream end of the target area (Sheoaks), the salinity trends in the Moorabool River have been significantly increasing over the past 26 years. The linear trend measured at the Batesford gauging station (# 232202) from November 1976 to February 2005 is 23.7 $\pm$ 6.0 μS/cm/yr EC. The non-linear trend (Figure 2.8) shows that the salinity has almost doubled over that period. The average salt load was calculated as 81 tonnes/day (Dahlhaus *et al.* 2005b).

Salinity processes and management options

Based on the modelled salinity trends, and data supplied by the urban water authority, it appears that the salinity increase is partly caused by salt additions from the tributaries which enter the river as it flows through the target area *(Table 3.2)*. Approximately 11 kilometres of salinity has been mapped along the stream banks of these tributaries, and approximately 63 hectares of secondary salinity on the agricultural land in their sub-catchments.

Location (in downstream order)	Maximum	Minimum	Average
Moorabool River at Morrisons	1500 μS/cm EC	350 μS/cm EC	704 μS/cm EC
Tea Tree Creek (tributary)	5200 μS/cm EC	700 μS/cm EC	2595 μS/cm EC
Eclipse Creek (tributary)	4800 μS/cm EC	220 μS/cm EC	2630 μS/cm EC
Sheoaks off-take (Moorabool River)	1600 μS/cm EC	480 μS/cm EC	968 μS/cm EC

Table 3.2: Salinity values sampled progressively downstream in the target area.

Four groundwater flow systems occur in this area:

1. Intermediate and local flow systems through fractured Palaeozoic sedimentary rocks comprising deeply weathered shales and sandstones with sporadic quartz veins
2. Local flow systems in Tertiary gravel deposits, comprising ferruginised and silicretised sands which cap the older rocks
3. Intermediate flow systems in the fractured basaltic rocks of Neogene to Quaternary age
4. Regional and intermediate flows in the "Deep Lead" aquifers, comprising gravel, sand, silt and clay in the beds of buried ancient river valleys.

In the Morrisons – Sheoaks target areas, it is suggested that the saline groundwater discharge occurs at the base of the Tertiary-age sand and gravel overlying the Palaeozoic mudstone and sandstone rocks *(Figure 3.1)*. This model is deduced from observations of the geology, hydrology and salinity occurrences in the landscape, and is yet to be tested and validated by scientific measurements.

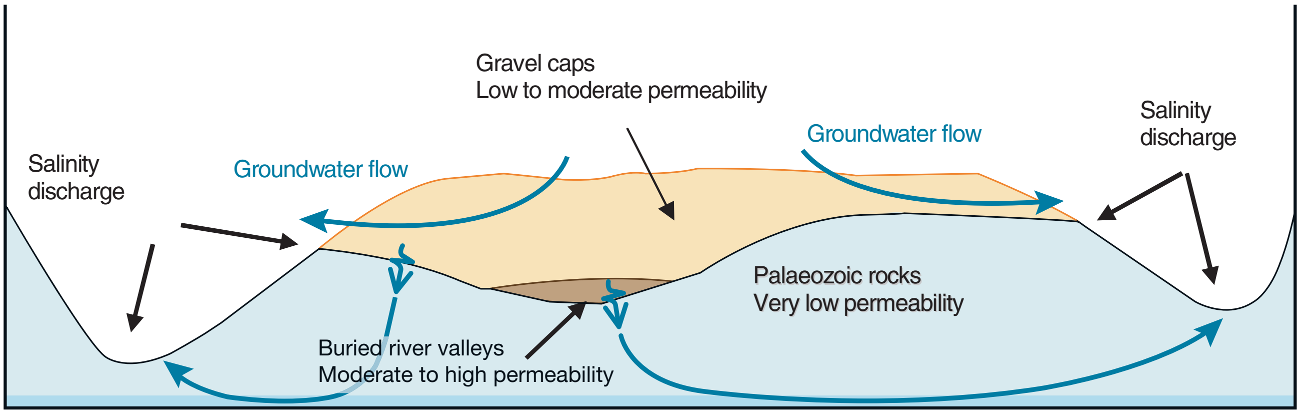


Figure 3.1: Conceptual model of salinity processes at Morrisons – Sheoaks

Establishing tree plantations to control the recharge should provide significant benefits, since the gravel caps are spatially limited and have a low groundwater storage capacity. Scenarios (50-year management) were calculated using *Flowtube*, a one-dimensional finite difference model (Dawes *et al.* 2000). The results showed that eucalypt plantations over the entire slopes in conjunction with revegetating discharge zones provides the most effective control of saline groundwater discharge from the base of the gravel caps. Approximately 6,419 hectares are suited to the establishment of timber plantations, in order to control the recharge (Dahlhaus 2003b).

A recharge mapping study delineated 25 landscape categories using the conceptual model of the hydrogeology and salinity process, and the mapped geology, buffered to include the hydrogeological influence around the boundaries of the units (Dahlhaus 2005). Land degradation and land-use, as determined from aerial photos, were also important decision parameters.

The primary intent of the salinity management works in the Morrisons – Sheoaks target area is to stabilise or reverse the trend of increasing salinity in the Moorabool River. The priority areas for works are:

1. Saline discharge areas – the management of saline discharge aimed at reducing or preventing salt wash-off.
2. Degraded areas – sites where mining or quarrying have occurred provide pathways for rapid recharge. Rehabilitation is aimed at restoring recharge rates to pre-degradation values.
3. High-priority landscapes with few trees – saline discharge occurs at the boundaries and erosion is evident. Re-vegetation is aimed at restoring pre-clearing recharge rates and stabilising erosion.
4. Higher-priority landscapes – re-vegetation is required to restore pre-clearing recharge rates.

Change Scenario

It is conservatively estimated that the groundwater discharge from the gravel caps and the associated salt wash-off from saline discharge areas has contributed 30% to 50% of the increase in salinity to the Moorabool River in the target area in recent years. That is, 10 μS/cm/yr to 15 μS/cm/yr rise in EC. Based on the conceptual model, and the scenarios modelled using estimated hydrogeological parameters for the flow system in the gravel caps (Dahlhaus *et al.* 2002), it is calculated that for every 500 hectares of trees planted on the gravel cap GFS there would be one μS/cm/yr drop in EC at the Sheoaks urban water off-take pipeline over a 20 to 50-year time frame. Depending on the salt wash-off contribution, treating the 63 hectares of saline discharge may reduce the salinity by a further 0.5 μS/cm/yr (Dahlhaus 2003b).

Until further investigations and research are completed, the causes of rising salinity in the Moorabool River remain speculative. Although this initial study suggests that salinity management using trees will reduce the saline discharge over a 20 to 50-year time-frame, in the short-term more immediate actions are needed.

A summary of the assets, threats, trends and management options for the Morrisons - Sheoaks target area is provided *(Table 3.3)*

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	22 ha of primary salinity, 40 ha of secondary salinity mapped on private land, mainly used for grazing in the upper Tea Tree Creek, Eclipse Creek and Aston Creek areas. Some in Coolebarghurk Creek and Deadman Gully.	Area of land salinised slowly increases. Associated sheet, rill, tunnel and gully erosion increases.	Discharge management. Recharge management through establishment of tree blocks on gravel caps.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	2 ha of Very High and 11 ha of High conservation significance native vegetation intersected by saline land.	Area of threat to native vegetation increases.	Discharge management to protect threatened vegetation.	Protect threatened vegetation from salinity threat (not quantified).
Cultural and heritage	Archaeological, National Estate	None identified at risk from salt threats.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	None identified at risk from salt threats.	Potential for road deterioration with increased salinity.	Reduce the potential for expansion of saline discharge through recharge management.	Reduce potential salinity threats to roads.
Water quality	Urban water supply, wetlands, rivers	Rising salinity trends in mid reaches of Moorabool River. Currently 970 EC/yr at Sheoaks off-take (30% of Geelong's water supply) rising at ~15 to 20EC/yr. Increased blending with fresh water needed to improve quality to meet Australian Drinking Water Guidelines. Disquiet by Geelong industry with water quality. Salinity rising in Moorabool River at 23.7 EC/yr at Batesford.	Moorabool River salinity continues to rise by 20 EC/yr. Moorabool water supplies to Geelong, already above Australian Drinking Water Guidelines, continues to increase in salinity.	Reduce saline discharge from springs at base of gravel caps and reduce salt wash-off from discharge sites. More research required.	Treating 500 ha of recharge area will reduce salinity at Sheoaks by 1EC/yr. Treating 63 ha of saline discharge will reduce salinity by 0.5 EC/y.

Table 3.3: Summary of Morrisons - Sheoaks target area.

3.3 Upper West Moorabool target area

The Upper West Moorabool salinity target area encircles approximately 29,000 hectares of the catchment of the Lal Lal urban water supply reservoir. The area has been included on the basis of rising salinity trends in the West Branch of the Moorabool River, measured just above the water supply reservoir. The reservoir supplies the cities of Ballarat and Geelong.

Salinity threats to assets

The single asset identified as threatened by salinity in the Upper West Moorabool area is the urban water supply in the Lal Lal Reservoir, which has been increasing in salinity over the past decade. Discussions with the asset manager (Central Highlands Water) confirm that higher salinity water is a problem for Ballarat industries and domestic users alike. The Australian Drinking Water Guidelines (1996) set a limit of 500 mg/L for Total Dissolved Solids (~800 μS/cm EC). However, many industries, especially those utilising boilers, experience significant rise in maintenance costs as the salinity increases. Most food-processing industries and fabric-manufacturing industries have installed their own water-treatment plants.

At present the water in Lal Lal Reservoir is near 600 μS/cm EC *(Figure 3.2)*. Treatment of the water before it enters the distribution system adds about another 100 μS/cm EC (Geoff Cramer pers. comm.) Extrapolation of the EC trend in the reservoir over the past eight years (400 μS/cm to 600 μS/cm) makes the increasing salinity a very urgent issue, with the water reaching 700 μS/cm in another couple of years (+ ~100 μS/cm after treatment = ~800 μS/cm = Australian Drinking Water Guidelines).

The dramatic rise in salinity within the reservoir is partly due to the run of dry years resulting in increased evaporation and low water levels, which have concentrated the salinity. However, the rise is also reflected in salinity trends in the inflows from the Moorabool River. The linear trend in water salinity measured at the Lal Lal gauging station (232210) is 1.0 ± 1.9 μS/cm/yr between December 1976 and February 2005. The non-linear trend analysis (Figure 3.3) shows a significant rise in the past 10 years. Although the linear trends in the Moorabool River averaged over the past 26 years suggest that the inflows to the reservoir will reach the acceptable drinking water limit of ~800 μS/cm EC in approximately 70 years, the non-linear trends cannot be ignored. It is predicted that without a run of wet years (i.e. three to five years above average rainfall), the salinity in the Lal Lal Reservoir will almost certainly be above the Australian Drinking Water Standard by 2010.

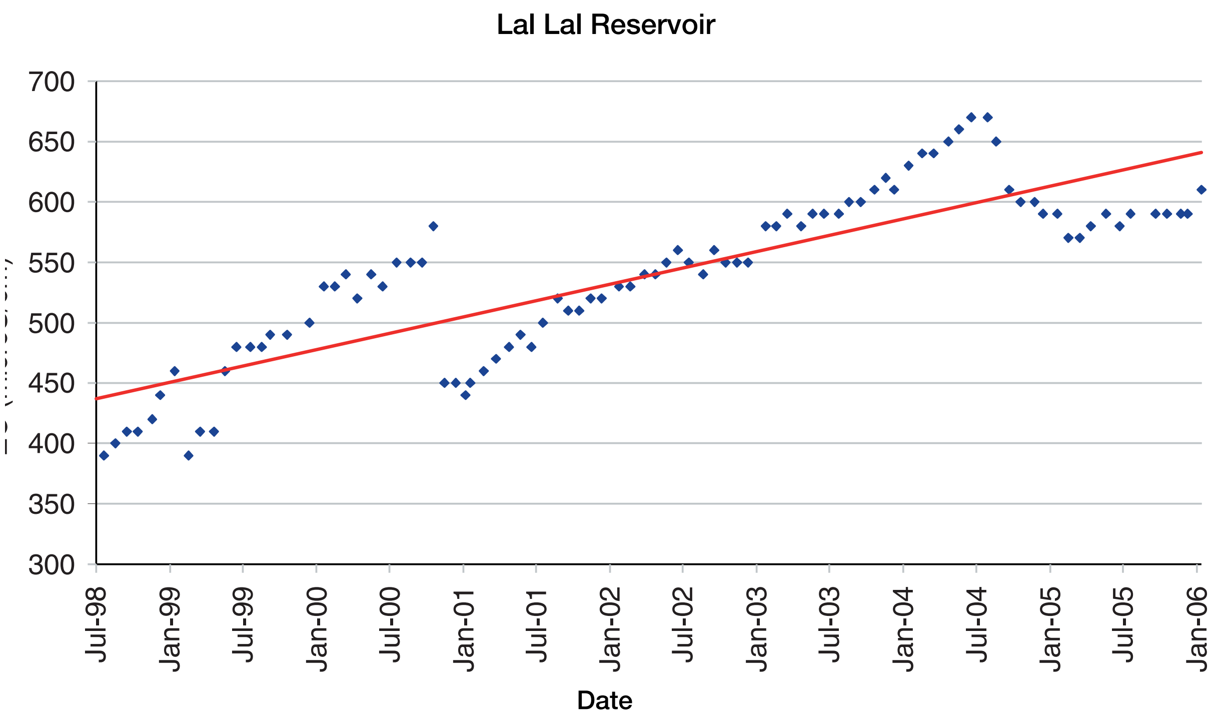


Figure 3.2: Salinity trend in the Lal Lal Reservoir July 1998 to Jan 2006

(Source: Central Highlands Water, 2006

Salinity processes and management options

The Moorabool River is regarded as one of the most stressed rivers in Victoria, with the Index of Stream Condition for the reaches of the West Moorabool River system being in very poor and poor condition (DSE 2005b). The poor condition of the river and the water quality can be related to the diminution of flow as water is harvested and exported to both the Barwon and Lake Corangamite basins. A recent major study concluded that approximately 24,500 megalitres is annually harvested from the West Moorabool catchment, of which, approximately 6,000 megalitres is harvested in farm dams (SKM 2004).

As there has been no salinity mapped in the catchment, it can be speculated that the trend may reflect changes in the ratios of groundwater baseflow and surface run-off contributions to the streams. An increase in the extraction of fresh groundwater for irrigation, an increase in the number of farm dams in the catchment and the recent drought all have the potential to increase salinity in the Lal Lal Reservoir. In particular, groundwater resource management has become an important issue within the catchment and changes in the quality of groundwater baseflow to the Moorabool River would be an inevitable consequence of increasing groundwater consumption.

Limited salinity investigation has been conducted in the Upper West Moorabool target area. A rigorous scientific research program has only recently commenced to establish (scientifically prove) the underlying cause of the rising trend in salinity in the reservoir so that appropriate management actions can be determined. A longer-term investment plan for salinity management in the area would be based on the outcome of the research and investigation program.

Change Scenario

At this stage it is not known what management action is required to slow or reverse the trend. Appropriate salinity management actions can be developed once the scientific research into the cause of the trend is completed (estimated mid-2008).

A summary of the assets, threats, trends and management options for the Upper West Moorabool target area is provided *(Table 3.4)*.

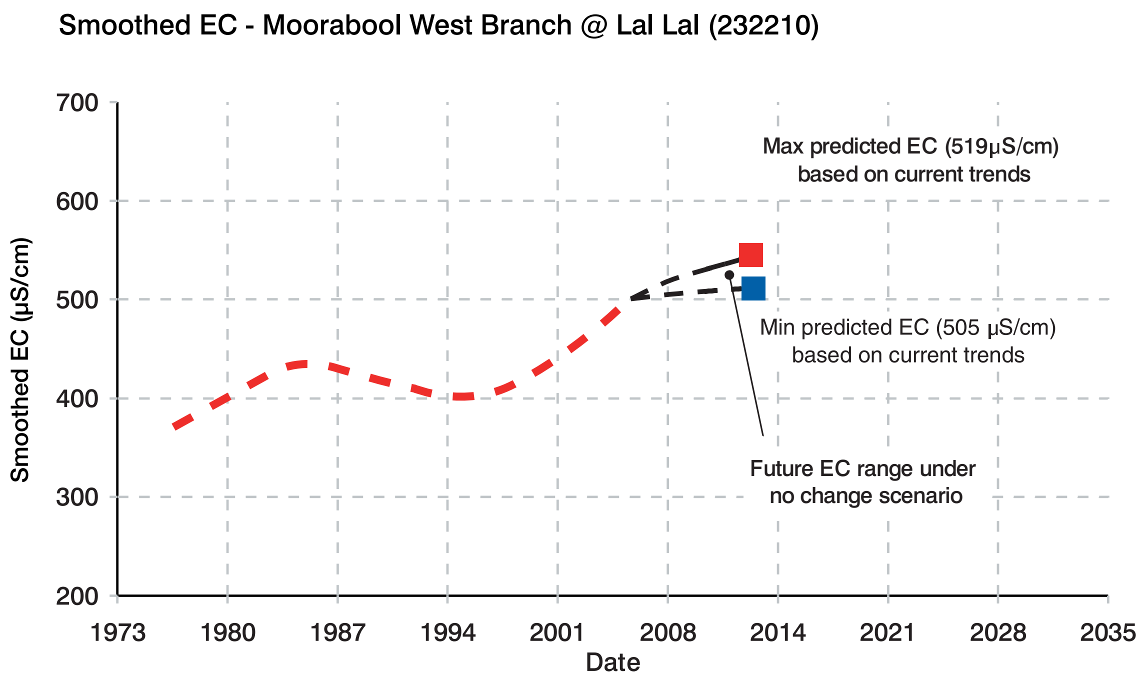


Figure 3.3: Salinity trends in the Lal Lal gauge (1976 – 2005)
(Source: Dahlhaus et al 2005b)

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	15.2 ha of secondary salinity mapped in SAP target area, although more salting of private and public land is known.	Unknown. Shallow fresh watertable predicted to rise significantly by 2050 (SKM, 2005a).	Research required. Possibly discharge management of small saline areas.	Research will identify salinity processes so that management options can be identified.
Biodiversity	Native vegetation, VROTS	One hectare of saline intersections with high conservation significance native vegetation along Black Creek and Woollen Creek.	Unknown.	Very small area. Needs investigation to confirm the nature of the threat.	
Cultural and heritage	Archaeological, National Estate	None identified at risk from salt threats.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Minor patches of salinity intersect with Yendon-Egerton Rd at Black Creek and Geelong-Ballarat railway near Yendon.	Potentially more road threatened if land salinity increases.	Research required. Minor threat to infrastructure.	
Water quality	Urban water supply, wetlands, rivers	Lal Lal Reservoir currently above 500 μS/cm EC; Moorabool River salinity is rising at 1 EC/yr immediately upstream of reservoir.	Ballarat's water supply salinity exceeds Australian Drinking Water Guidelines by 2010.	Causes of rising salinity are unknown at present. Research required.	

Table 3.4: Summary of Upper West Moorabool target area.

3.4 Colac – Eurack target area

The Colac – Eurack target area has been selected on the basis of the cluster of assets at risk as determined by the GSHARP model (Heislers & Brewin, 2003). The area encompasses 34,366 hectares stretching from south of the City of Colac, north to Lake Weering (is adjacent to Lake Corangamite target area). The Colac – Eurack area is dominated by a string of shallow lakes and wetlands from Lake Colac in the south to Lake Weering in the north, many of which have international, national and state significance. Almost two-thirds of the land salinity is primary origin, and the features surrounding the lakes record significant palaeohydrological and palaeoclimate changes. Some lakes, such as Lake Beeac, are regarded as groundwater discharge lake, with hypersaline environments (average salinity ~ 92,000 mg/l) (Coram, Weaver & Lawrence 1998).

Salinity threats to assets

The assets threatened by changes in salinity are dominantly environmental. Within the Colac – Eurack target area, there are 76 saline wetlands which provide habitat for 28 threatened species, eight migratory species, and eight marine protected species. Many of these wetlands are part of the Western District lakes Ramsar site.

The majority of the salinity and threatened assets are located in the area influenced by the Lough Calvert Drainage Scheme. The Upper, Middle and Lower Lough Calvert and Lake Thurrumbong are listed as Australian wetlands of national and international importance with threatened water regimes (Davis *et al.* 2001) and the Western District lakes have been recognised as important Australian groundwater-dependent ecosystems with a high threat (SKM, 2001). The operation of the Lough Calvert Drainage Scheme has recently been reviewed (GHD 2004).

The current conditions suggests that the salinity trend in groundwater discharge lakes such as Lake Beeac and Lake Cundare will remain dependent on climate influences and groundwater extraction lowering watertables. The limited groundwater hydrograph information suggesting steady to slowly falling trends indicates that that these lakes will slowly increase in their frequency of low levels and dry periods which will slowly increase salinity through evaporation. Falling groundwater levels may significantly reduce wetland water levels and dry out groundwater-dependent ecosystems within a 50 to 100-year time frame. However, the threat to the Upper, Middle, and Lower Lough Calvert and Lake Thurrumbong and surrounding ecosystems may result in increasing salinisation of these wetlands as fresh water is diverted by the Lough Calvert drainage scheme.

Figure 3.4: Salinity encroaching into the City of Colac (Salinity is shown by the black polygons)

The most urgent threat is probably to the urban encroachment of the City of Colac into saline areas and the incursion of saline discharge areas into the City of Colac. Although there has been little expansion of the area of land salinity since the mapping was undertaken (1976), the City of Colac is more rapidly expanding into these saline areas. Based on this urban growth, it appears that any further subdivision of the rural-urban zone in these areas would threaten buildings, roads and services.

Among the agricultural land at risk is a significant proportion of public land which appears to be used for grazing and is affected by the secondary expansion of primary salinity *(Figure 3.5)*. The mapped salinity is divided as tabulated below *(Table 3.5)*.

Salinity type	Public land	Private land
Primary	301.3 hectares	1109.1 hectares
Secondary	201.9 hectares	595.3 hectares

Table 3.5: Mapped salinity by type and land ownership

Figure 3.5: Secondary extension of primary salinity wetlands near Beeac.

There are approximately 50 regularly monitored bores in the target area, both for salinity investigation but also as part of the State Observation Bore Network. Groundwater bore hydrographs with longer monitoring records show a steady to slightly declining trend in most of the target area. For this reason, the majority of salinised land regarded as dominantly primary salinity is not expected to significantly expand, except in those places where poor management leads to irreversible loss of vegetation (scalding) and soil degradation.

Salinity processes and management options

The large area to the north of Colac is dominated by the Quaternary groundwater flow system overlying the Stony Rises (both local systems), which both overlie the Volcanic Plains basalt (regional systems) and/or Pliocene Sands (intermediate). Salinity has been a feature of this landscape for millennia, and cycles of salinity have been associated with climate change during the Quaternary, based on the evidence of the lunette formation (Dahlhaus & Cox 2005). Hydrologic change associated with land-use change of the past 200 years may have exacerbated the salinity by causing primary saline areas to spread, although the evidence is largely anecdotal.

Given the diversity of landscapes and groundwater flow systems, salinity management options are varied. Biological control of recharge may be successful in local areas where the Quaternary flow systems are dominant, for example east of Beeac where perennial pastures including the establishment of lucerne has been locally proven (Heislers & Pillai 2000). Attempts at lowering watertables using trees and shrubby vegetation not desirable in areas where sufficient saline groundwater discharge is required to sustain the saline wetland ecologies.

South of Colac the salinity is regarded as secondary, associated with the hydrologic changes associated with land-use change over the past 100 years. One deep bore (# 56055) in the centre of the City of Colac monitors the confined aquifer of the Dilwyn Formation (or equivalent). This bore has positive (artesian) head and shows a rising trend of about 1.2 metres over the past 13 years. Although the aquifer being monitored is 330 metres deep, the overlying confining beds will be saturated to the near surface.

Protecting the urban infrastructure assets south of Colac requires engineering and planning intervention. The construction of surface drains and retro-fitting existing subdivisions in saline areas with improved stormwater management are short-term management requirements. In the longer term, reclaiming land from urban development (avoidance) and salinity mitigation measures as part of future developments are required solutions.

Planning tools, including a Salinity Management Overlay for the Shire Planning Scheme are currently being developed and implemented. The planning tools will include community education, processes for dealing with planning permit applications including the procedural process and specific conditions under which applications would be granted or refused.

In all areas of this region, agricultural assets can be managed through the productive use and rehabilitation of saline land, and saline aquaculture may provide additional opportunities given the number of saline lakes in the region.

Managing salinity to protect the environmental assets is more problematic, since it requires a greater understanding of the nature of the threat (if any) to the primary salinity features and their associated biodiversity value. Many of the wetlands are groundwater-dependent ecosystems (GDEs) and require careful management of groundwater resources and watertables to ensure the integrity of the ecosystems.

A major CSIRO research project has recently commenced to assist in the understanding of GDE management. This project will build on current research which will construct a three-dimensional hydrostratigraphic model to determine groundwater flow paths and their likely response to change and will be a critical tool for scenario modelling.

Change Scenario

The major review of the Lough Calvert drainage scheme recommends no change in the operation of the Lough Calvert scheme for the next three years *(Option L1)*. This recommendation is based on the lack of data due to the scheme not operating for the past seven years because of the dry period (GHD 2004). For this reason the threat to changing salinity due to surface water diversion remains minimal.

The current declining trend in groundwater levels is recognised as a greater threat to the GDEs, with many experiencing an extended dry period over the past few years. The completion of the CSIRO research project will provide guidelines for improved management of groundwater resources and improvement of GDE health. However, until the research has been completed and the research findings implemented into groundwater and GDE management plans, the threat to the integrity of saline wetlands ecosystems is expected to remain unless significant groundwater recharge occurs.

By contrast, there is potential for rising regional groundwater levels associated with changes to the Woady Yaloak Diversion Scheme and higher water levels for Lake Corangamite and Lake Martin. If the recommendations are accepted by the CCMA, there may be a significant impact on GDEs following the 2009 closure of the scheme. These scenarios require research and modelling and may result in setting additional Resource Condition Targets and then Management Action Targets in consultation with the appropriate asset managers.

For agricultural land, management and rehabilitation of saline discharge areas is unlikely to significantly affect the watertables in the immediate or near-term future, due to the extent and slow response of the groundwater flow systems. However, the management of saline discharge areas can slow or reverse degradation of agricultural land and increase productivity by increasing evapotranspiration and facilitating groundwater discharge. Salt export by surface wash-off will be reduced. Until further research is completed these gains cannot be quantified (even hypothetically).

A summary of the assets, threats, trends and management options for the Colac – Eurack target area is provided *(Table 3.6)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, Public land	1410 ha of primary salinity, 1109 ha of which is on private land. Largest tracts are agricultural grazing lands in the Eurack and Lough Calvert areas. 797 ha of secondary salinity, with 595 ha on private land north of Eurack and also north of Irrewarra.	Area of salinised land slowly increases. Proposed raised level of Lake Corangamite may raise watertables and increase area of land salinised *(Refer 3.1.1)*.	Discharge management for primary and secondary sites on public and private lands. Research the impact of raising Lake Corangamite levels.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	1066 ha of native vegetation with Very High and 123 ha with High conservation significance intersects with saline lands. Largest are the saline EVCs in The Sanctuary and Lough Calvert areas. Habitat for 28 threatened species and 8 migratory species threatened by the changing salinity of the wetlands and lakes.	Changes to Lough Calvert Drainage Scheme may affect primary salinity ecology and habitat.	Discharge management to protect threatened high-value native vegetation. Research / investigate EVC sensitivity to salinity.	Research will inform how high-value native vegetation is managed for threats of changing salinity.
Cultural and heritage	Archaeological, National Estate	Some Ramsar sites (saline wetlands) on National Estate register.	Changing salinity may threaten national heritage value.	Research to determine salinity threat.	Research leads to improved management.
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	The City of Colac is encroaching into salinised land with peri-urban areas on the southern fringe of the city being subdivided for urban housing Roads intersect Class 2 saline areas in many areas, especially east of Beeac and south of Colac. Telephone cables and rail line intersect salinity but are protected through preventative actions by asset managers but at an additional cost.	Increasing land salinity increases road deterioration.	Road maintenance education. Implement planning controls for salinity within the City of Colac.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	76 saline wetlands, including Ramsar-listed Lake Beeac, Lake Cundare and Lough Calvert. Lowering watertables is a potential threat to these groundwater-dependent wetlands, such as Upper, Middle and Lower Lough Calvert and Lake Thurrumbong.	Increased groundwater extraction may permanently dry wetlands.	Improve groundwater management for integrity of GDEs. No change to Lough Calvert Diversion Scheme recommended by GHD study.	Groundwater managed to ensure integrity of GDEs.

Table 3.6: Summary of Colac - Eurack target area.

3.5 Geelong – Lake Connewarre target area

The Geelong – Lake Connewarre area encompasses approximately 12,922 hectares, the vast majority of which is mapped saline land and wetlands in the lower Barwon River and estuary. Many saline sites are Ramsar-listed wetlands of international significance and collectively form one of Australia's most significant environmental assets.

Salinity threats to assets

Within the Geelong – Lake Connewarre salinity target area, there 59 saline wetlands which provide habitat for 39 threatened species, 34 migratory species, 58 marine protected species. Collectively, they form part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. These high-value environmental assets are the major ones identified as threatened by salinity in the GSHARP model.

Salinity threats to other assets include agricultural land, infrastructure, utilities and cultural and heritage assets. These areas are close to Geelong which suggests potential for higher risk to infrastructure assets from saline soils, but this has not been specifically identified, suggesting that the intensity of urban and peri-urban development may not be fully captured in the GSHARP data.

Based on the most recent mapped salinity the delineation of salinity is tabulated below *(Table 3.7)*.

Salinity type	Public land	Private land
Primary	1082.7 hectares	1224.6 hectares
Secondary	None mapped	63.8 hectares

Table 3.7: Mapped salinity in the Geelong-Lake Connewarre area

Surprisingly, there are no monitoring bores, either salinity monitoring bores or State Observation Bore Network (SOBN), located in the region, so watertable trends are unknown. Similarly, the salinity trends in the water quality asset of the Lower Barwon River are unknown, as there are no salinity data recorded on the Victorian Water Quality Network (VWQN) database below the Pollocksford gauging station on the Barwon River.

Because the wetlands are very close to sea level and estuarine, the groundwater will be highly saline and at or near the surface. The most credible threats are from added inputs of fresh water from stormwater drainage of nearby urban areas. The encroachment of urbanisation also has the potential to significantly modify the spatial and temporal hydrology by the construction of impervious surfaces (paved areas, roofs, etc.), the addition of irrigated areas (lawns, gardens) and the re-routing of surface water flows (stormwater pipes and drains).

Encroaching infrastructure will also be at risk from shallow saline watertables. Road infrastructure is particularly at risk as the capillary rise will bring salts to the road subgrade.

Interpretation of the areas of primary and secondary salinity suggests that the primary salinity may be spreading, although there is no monitoring information to confirm the increase. The current scenario predicts that the primary salinity areas may spread if the adjoining land is managed inappropriately, or not at all. Because the groundwater will be shallow (<2 metres depth) and highly saline (sea water) the accumulation of salt in the soil has the potential to quickly create scalding and further degradation of agricultural land.

Salinity processes and management options

Salinity management of environmental assets of the lower Barwon is difficult because it represents the ultimate 'end-of-valley' for the Barwon River Basin, which comprises approximately one-third of the Corangamite CMA region. Management of the wetlands has inevitable contradictions. Stormwater contributions from the urban area may dilute the river salinity, whereas the salinity of the tributaries from the north – the Moorabool and the Leigh Rivers – is high and for the Moorabool, the trends are rapidly increasing.

Nevertheless, salinity management of the saline wetlands requires manipulation of water inputs (both surface water and groundwater) to maintain the salinity range required to sustain the integrity of the ecosystems. At present, there are no specified natural ranges of salinity for primary saline wetlands (Rhonda Butcher, pers. comm.). Benchmark monitoring is required to establish the EC ranges and trends.

The agricultural land surrounding these areas typically requires sensitive management systems, which may require use of alternatives to those proposed in previous salinity strategies. For example, use of salt-tolerant pastures such as Tall Wheat Grass would be inappropriate next to Ramsar-listed or significant wetlands, where this pasture grass can become an environmental weed (Graeme Anderson, pers. comm.).

Fresh water input into the Barwon River from the upstream City of Geelong (mostly via the stormwater drainage system) also needs to be monitored to ensure that the ecology of the saline wetlands is not threatened by dilution.

Change Scenario

Management and rehabilitation of primary and secondary saline areas will not lower the watertables, but will slow or reverse degradation of agricultural land and increase environmental values and productivity as appropriate. Until further research is completed these gains cannot be quantified even hypothetically.

Strategic urban planning could assist greatly in ensuring the protection of infrastructure and the environmental values of the target region.

A summary of the assets, threats, trends and management options for the Geelong – Lake Connewarre target area is provided *(Table 3.8)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	2307 ha of primary salinity, 1225 ha of which is on private land, mostly around Breamlea, Lake Connewarre and Reedy Lake. 64 ha of secondary salting on private land, the largest of which are in the Connewarre and Marshall areas.	Area of secondary salinity increases.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	1410 ha of Very High and 2136 ha of High conservation significance native vegetation intersects with salinity. Nearly 1500 ha of Coastal Saltmarsh/Mangrove Shrubland Mosaic EVC (endangered) and 500 ha of Reed Swamp EVC (vulnerable). The saline wetlands provide habitat for 39 threatened species, 34 migratory species, and 58 marine protected species.	Loss of habitat and vegetation through changed wetland and primary salinity.	Research required to formulate appropriate discharge management actions to ensure native vegetation integrity.	Research assists in management of native vegetation to maintain integrity.
Cultural and heritage	Archaeological, National Estate	Ramsar sites on National Estate register. Archaeological sites would be expected.	Unknown. Changed salinity may threaten wetland values.	Research required to benchmark salinity ranges and establish trends.	Research establishes salinity ranges and trends to develop targets.
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Saline intersections with Black Rock – Breamlea Rd and Geelong – Barwon Heads Rd.	Increase in road deterioration due to salinity.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	Lake Connewarre and much of the Lower Barwon Wetland area is Ramsar listed. Tidal barrages and stormwater run-off are threats to these saline wetland assets.	Loss of wetland integrity due to changed hydrology and salinity.	Research required to benchmark salinity ranges and establish trends.	Research establishes salinity ranges and trends to develop targets.

Table 3.8: Summary of Geelong – Lake Connewarre target area.

3.6 Illabarook target area

The Illabarook area has been included in the salinity target areas on the basis of its potential threat to stream water quality of the Woady Yaloak River and possibly Lake Corangamite. The area partly corresponds to the Upper Woady Yaloak – Corindhap Hot Spot of the former salinity management plan, but includes only those tributaries which feed into the Woady Yaloak River. The area encloses 20,492 hectares and runs from Cape Clear in the west to Mt Mercer in the east.

Salinity threats to assets

An analysis of salinity trends at the Cressy Gauge (234201) on the Woady Yaloak River shows a minor rising trend of 3.4 μS/cm/yr EC, which although not statistically significant, is consistent in a number of analyses (Dahlhaus 2003b, Dahlhaus *et al.* 2005b). The mean salt load calculated over the past 29 years is 242 tonnes per day. The Illabarook target area is considered to be a significant contributor of salt to the Woady Yaloak River (Heislers & Pillai 2000, Dahlhaus 2003b), and a current University of Ballarat research project aims to quantify the proportion.

Saline groundwater discharge occurs in the alluvial flats and drainage lines in the area underlain by deeply weathered folded sedimentary rocks, which are overlain by cemented gravel caps. Approximately 366 hectares of secondary salinity has been mapped, nearly all of which occurs on privately owned land.

Despite the paucity of data, scenarios were calculated using Flowtube, based on the best available input information for the area (Dahlhaus 2003b). The current scenario suggests a very slow but continued rise of groundwater levels in the gravel caps and an increase in the discharge areas of less than 10% over 50 years.

Salinity processes and management options

In the Illabarook target area, three salinity processes are recognised, *viz:* saline discharge at the base of the Pliocene sand and gravel overlying the Palaeozoic mudstone and sandstone rocks, saline discharge at the boundary of the Newer Volcanics and the underlying sands or shales, and saline discharge as baseflow into the drainage lines in the Palaeozoic rocks. These models are deduced from observations of the geology, groundwater flow systems, hydrology and salinity occurrences in the landscape and are yet to be tested and validated by scientific measurements.

In the western portion of the Illabarook salinity target area the influence of past mining on the salinity process is believed to be more significant than elsewhere in the Corangamite CMA region. The shallow mine workings in the Pliocene sand and gravel caps and the deeper workings into the buried ancestral rivers have created numerous preferred pathways for infiltrating rainwater to reach the groundwater storage. Mine workings and the associated disturbed ground are often located above the saline discharge in the landscape, and probably contribute more recharge than the adjacent areas.

Recharge control should provide significant benefits, since the gravel caps are spatially limited and have a low groundwater storage capacity. The most immediate effect should be gained by the establishment of wide tree belts on the gravel caps, especially close to the boundaries of the underlying Palaeozoic rocks (i.e. just above the spring lines). A second stage of establishing broadscale plantations on the gravel caps should provide long-term benefits.

A recharge mapping study delineated 17 landscape categories, principally derived using the conceptual model of the hydrogeology and salinity process *(Figure 3.6)*. The mapping also considered the geology, land degradation, past land use (especially mining and quarrying), and current land use as determined from aerial photos (Dahlhaus 2005).

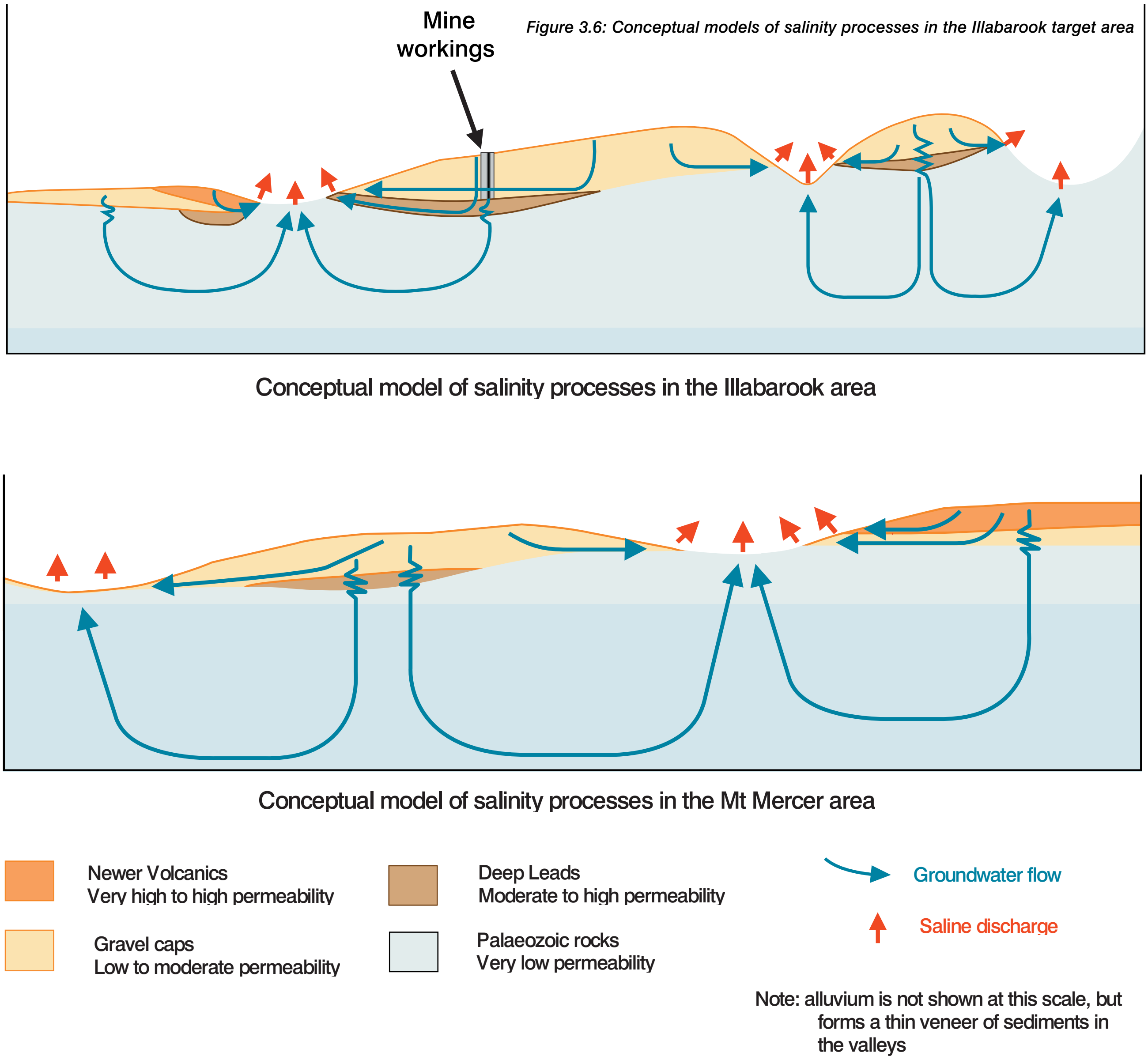


Figure 3.6: Conceptual models of salinity processes in the Illabarook target area

Change Scenario

Until further investigation and research is completed, the causes of rising salinity at the Cressy Gauge remain speculative. However, block planting of trees will reduce the recharge to the gravel caps and this in turn will reduce the volume of highly saline groundwater discharge into the tributaries. In addition, discharge management will reduce the salt wash-off from discharge areas.

The mainly hypothetical Flowtube scenarios were run for 50 years and show that eucalypt plantations over the entire slopes in conjunction with revegetating discharge zones provided the most effective control of groundwater discharge from the gravel caps (Dahlhaus 2003b). The modelling suggests that the combination of recharge and discharge management would reduce the area of saline groundwater discharge by about 50% in 50 years.

A hypothetical outcome is based on the assumption that groundwater discharge from springs around the gravel caps and salt wash-off from discharge areas contributes approximately one-third of the average salt load to the Woady Yaloak River over the past 26 years (i.e. ~ 15,000 tonnes). This suggests that if the entire 11,000 hectares suited to recharge and discharge treatment in the target area was treated, the salinity in the Woady Yaloak River may drop around 700 μS/cm over that time frame, or ~6 μS/cm EC for every 100 hectares treated. If the salt contribution to the Woady Yaloak River from the Illabarook target area was, say, 50%, then the figure would amount to ~11 μS/cm EC drop per 100 hectares treated.

A summary of the assets, threats, trends and management options for the Illabarook target area is provided *(Table 3.9)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	366 ha of secondary salinity, 350Ha of which is grazing and cropping land, in a strip from Cape Clear to Mt Mercer. Secondary salinity is strongly associated with severe gully erosion and sheet erosion in Cape Clear.	More land affected by secondary salinity. Increase in sheet, rill, tunnel and gully erosion associated with salinity.	Discharge management. Recharge control through block planting of trees on gravel caps.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	13 ha of Very High and 47 ha of High conservation significance native vegetation intersects with the salinity. Examples are along Illabarook Creek between Imiries Rd and Chathams Rd and along Moonlight Creek near Parkers Rd.	More native vegetation threatened by secondary salinity.	Discharge management actions to ensure native vegetation integrity.	Protect native vegetation from salinity threats (not quantified).
Cultural and heritage	Archaeological, National Estate	None identified as threatened by salinity.	Unknown. Changed salinity may threaten wetland values.	Research required to benchmark salinity ranges and establish trends.	Research establishes salinity ranges and trends to develop targets.
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Salinity intersections with the Mount Mercer - Dereel Rd and the Illabarook - Moonlight Rd.	Increased road deterioration by increased secondary salinity.	Reduce extent of saline discharge through discharge and recharge works. Road maintenance education provided to Shire.	Less road length threatened by salinity and roads better managed to reduce salinity threat.
Water quality	Wetlands, rivers	Rising salinity trends in Woady Yaloak River recorded at Cressy, currently 5265 EC rising by 3.4 EC/yr.	Increase in salinity of Woady Yaloak River to 5329 EC by 2012, with additional 4 tonnes/day salt load to Lake Corangamite.	Reduce salt wash-off from discharge areas. Reduce saline groundwater discharge at base of gravel caps.	Treating 100 ha of designated recharge and/or discharge will reduce Woady Yaloak River salinity by between 6 and 11EC/yr.

Table 3.9: Summary of Illabarook target area.

3.7 Pittong target area

The Pittong target area has been delineated on the basis of protecting the stream water quality asset of the Woady Yaloak River and possibly Lake Corangamite. The area comprises 6,300 hectares and corresponds to the Upper Woady Yaloak – Pittong Hot Spot in the former salinity strategy.

Salinity threats to assets

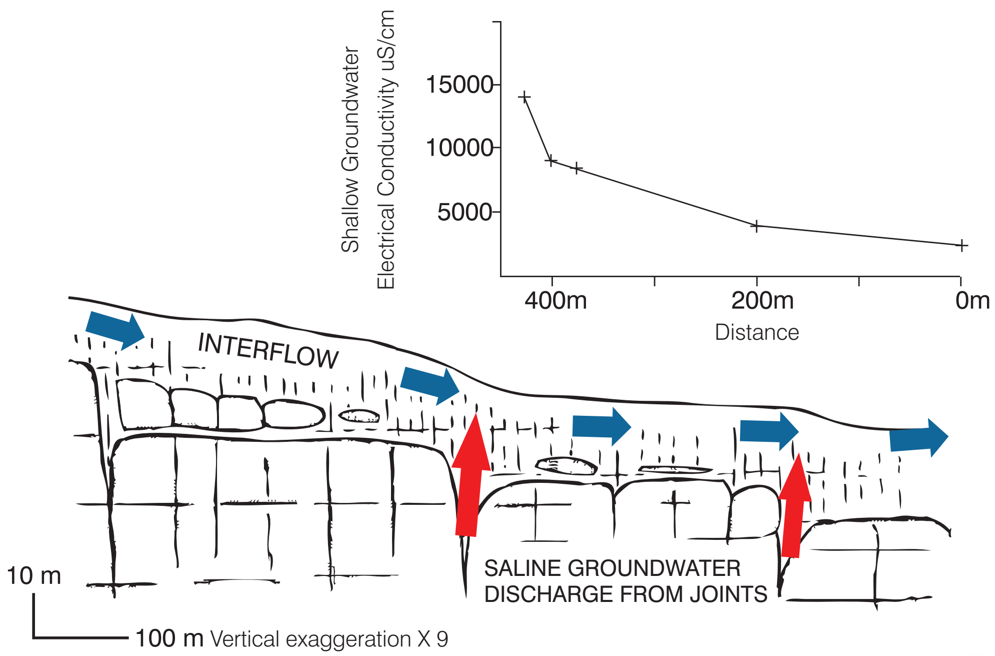
Similar to the Illabarook target area, the Pittong salinity target area is considered to be a significant contributor to the increasing salt trend in the Woady Yaloak River system. The exact magnitude of the contribution is not yet quantified (until the current research is completed). However, the relatively small Pittong target area has the highest proportion of secondary salinity of any of the SAP target areas (6% of the landscape). Secondary salinity has been recognised as a problem in this area since the early 1950s (Cope 1956, 1958) and considerable investment has been made to mitigate the problem. Yet, the area of land salinity is expanding, with the latest monitoring at the state salinity monitoring site showing an 8% increase in the area of land salinised over the period from 1996 to 2000, despite below-average rainfall and falling groundwater levels (Clark & Hekmeijer 2004).

Saline groundwater discharge occurs as springs in the landscape, usually associated with the alluvial flats and drainage lines in the area underlain by deeply weathered granite. In places, the salinity has a serious impact on agricultural production, with 147 ha or 26% of one property and 168 ha or 67% of another classed as saline land. The expansion in secondary salinity increases the area for salt wash-off and increases the salt export to the Woady Yaloak River and Lake Corangamite.

Salinity processes and management options

Over the past decade, a considerable research effort has been made to understand the salinity processes occurring in the area. Although this work is still continuing, a reasonably rigorous conceptual model has emerged that indicates that regional saline groundwater emerges from geological structures (joints, faults, dykes) in the granite as springs and is spread by ephemeral freshwater flows through the regolith *(Figure 3.7)*.

The implications of this model are that control of the saline discharge is outside of the region, but that salinity can be best managed by controlling the ephemeral shallow groundwater flows and soil waterlogging in the valley flats. Recharge control measures should be aimed at using the soil-water on the slopes or diverting it before it reaches the discharge areas and lower parts of the landscape where the saline springs may occur. Perennial pastures are difficult to establish due to the high acidity and aluminium content of the soil. Planting of tree belts to intercept lateral flows should have a reasonably rapid response time and salinity control outcome. The construction of reverse interceptor surface drains to intercept and divert interflow higher in the landscape before it reaches the saline discharge areas should also be considered, subject to the suitability of the soil.



The interflow in the sandy soil horizon picks up small trickles of saline groundwater discharge from springs in the underlying granite and spreads it downslope. (Source: Dahlhaus & MacEwan, 1997)

Figure 3.7: A suggested model of salinity at Pittong.

Establishment of high water-use vegetation in the saline discharge areas to increase the evapotranspiration and reduce the run-off component is equally important as a salinity management strategy. Rehabilitation of saline discharge areas can significantly reduce the saline run-off to streamflow by using the water in the paddock. Reducing the length of time of soil waterlogging by improving surface water run-off is also important to reduce both the spread of saline soil water (and the area of land affected) and the salt wash-off to the Woady Yaloak River.

Change Scenario

Modelling the change scenario is difficult since the soil hydrology parameters are scarce and the research is yet to be completed. A previous estimate, based on the assumption that the Pittong target area contributes roughly 30% of the salt load in the Woady Yaloak River measured at Cressy, indicated that tree belts would reduce the salt load in the river by approximately three tonnes per year for every hectare managed (Dahlhaus 2003b).

Recent salinity management works used geophysics (electromagnetic methods) has enabled the identification of the saline springs in the landscape and enabled the design of the interception tree belts, drains and the targeting of salt-tolerant vegetation. It is anticipated that these works will significantly reduce the area of land salinised and the salt export to the Woady Yaloak River. These gains are yet to be quantified.

A summary of the assets, threats, trends and management options for the Pittong target area is provided *(Table 3.10)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	378 ha of secondary salinity on grazing and cropping land south of Pittong. Increasing at 8% per year.	Area of salinised land increases 8% per year to 600 ha by 2012.	Discharge management. Recharge management using contour planting of trees and drainage.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	23 ha of native vegetation with high conservation significance intersects with saline land.	More native vegetation is threatened by increased salinity.	Discharge management actions to ensure native vegetation integrity.	Protect native vegetation from salinity threats (not quantified).
Cultural and heritage	Archaeological, National Estate	None identified as threatened by salinity.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Several salinity intersections with roads, such as Pittong – Lismore Rd and Francis Lane.	Increased length of road deterioration due to increased salinity.	Reduce extent of saline discharge through discharge and recharge works. Road maintenance education provided to shire.	Less road length threatened by salinity and roads better managed to reduce salinity threat.
Water quality	Wetlands, rivers	Rising salinity trends in Woady Yaloak River recorded at Cressy, currently 5265 EC rising by 3.4 EC/yr.	Woady Yaloak River increases in salinity 3.5EC/yr to 5329 EC by 2012, with additional 4 tonnes/day salt load to Lake Corangamite.	Reduce salt wash-off from discharge areas. Reduce surface water flow through salt springs.	Treating 1 ha will reduce salt loads at Cressy by approximately 3 tonnes/yr.

Table 3.10: Summary of Pittong target area.

3.8 Lismore – Derrinallum target area

The 16,443 hectare Lismore – Derrinallum target area is defined by a cluster of assets at risk in the immediate term as determined by the GSHARP project. The risk is mostly associated with secondary salinity processes along drainage lines and in low-lying areas.

Salinity threats to assets

Assets that had been identified at risk due to salinity were roads, telephone cables, agricultural land and environmental (Lake Tooliorook). In the east of the area and north of Lismore, the salinity occurs along the creek lines of Salt Creek, Haunted Gully, Browns Waterholes and Mundy Gully. In the western section, around Derrinallum township, the broad areas of saline discharge occur in low-lying and poorly drained areas on the volcanic plains. It is likely that some of the secondary salinity has developed from the extensive spread of small areas of primary salinity.

The total area of mapped salinity is 1,796 ha. Primary salting accounted for 1,125 ha the majority of which is on private land (341 ha in public land). There are 305 ha of secondary salting and all of them are on private land. Two wetlands covering an area of 25 ha are saline in nature. Eight kilometres of creek lines have been mapped as saline.

An active gauging station on Browns Waterholes downstream of Lismore has insufficient records at the present to analyse a trend in salinity data. Trends in groundwater levels are varied, with the deeper bore hydrographs generally showing steady to slightly falling trends, whereas the shallower bores generally show seasonal variation with a steady trend. The modelling by SKM (2005a) shows slightly rising watertable trends for the area *(Figure 2.7)*. Although the hydrographs in discharge areas show seasonal fluctuations, the trend of the groundwater levels has remained steady over the past decade or more. The groundwater tables in these areas remain consistently within one metre of the surface.

The current scenario is that the discharge areas will continue to accumulate salt through evapotranspiration and export salt when surface water flows occur. The accumulation of salt in the soil has the potential to create scalding and further degradation of agricultural land. Infrastructure will continue to be affected by the saline discharge.

Salinity processes and management options

The geomorphic setting of the target area is at the transition zone from the Western Uplands to the Western Plains. The three-dimensional spatial distribution and geometry of the geological units is a significant influence on the movement of groundwater and probably controls the discharge locations. This area encircles six groundwater flow systems – Quaternary alluvium, Stony Rises, and Granitic rocks (all local); Pliocene sands and Central Highlands volcanic rocks (both intermediate); and Volcanic Plains basalt (regional).

It is probable that Deep Lead systems (regional) also exist at depth in the area. With such a highly complex conjunction of hydrogeology, salinity management options are also complex and varied.

For the protection of agricultural land assets, biological control of recharge is regarded as an option with low to moderate effectiveness on the granites. However, recharge control is unlikely to be successful in the alluvium (due to the underlying regional basalt system) and the Pliocene sands (due to the overlying recharge through the basalt and stony rises). Consequently, no recharge control treatments are proposed at this time.

Discharge management through the productive use and rehabilitation of saline land is regarded as a feasible option in all landscapes, especially given the scale of the regional and intermediate flow systems. At Lismore, control of drainage line salinisation is dependant on limiting recharge entering the veneer of basalt and Pliocene sand sitting on obscured granite. Achieving this in practical terms is unlikely, so dealing with creek line degradation should have higher priority.

Further research is required to understand the three-dimensional hydrological model for the area to determine groundwater flow paths and their likely response to change. The development of a model would be aimed at establishing scenarios for development of long-term strategies for asset protection from salinity. Similarly, further investigation and research is required before the actual level of risk to Lake Tooliorook (if any) from either increasing or decreasing salinity is known, along with the urgency of the threat.

Change Scenario

Management and rehabilitation of saline discharge areas is unlikely to significantly lower the watertables in the immediate or near-term future, due to the extent and slow response of the groundwater flow systems. However, the management of saline discharge areas can slow or reverse degradation of agricultural land and increase productivity by increasing evapotranspiration and facilitating groundwater discharge. Salt export by surface wash-off will be reduced. Until further research is completed these gains cannot be quantified (even hypothetically).

Research could also assist in targeting specific areas where recharge control may work, especially in the granite flow systems north of Lismore along Browns Waterholes.

A summary of the assets, threats, trends and management options for the Lismore – Derrinallum target area is provided *(Table 3.11)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	1466 ha of primary salinity, 1125 ha of which is on private land (mainly agricultural land), between Lismore and Derrinallum. 305 ha of secondary salinity, nearly all on private land used for agriculture.	Increase in area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	5 ha of Very High and 115 ha of High conservation significance native vegetation intersects with salinity. Mostly along creek lines such as Browns Waterholes and Haunted Gully.	Increased threat to native vegetation due to increased land salinised.	Protect native vegetation through discharge management. Investigation required, as some may be primary saline EVCs.	Native vegetation protected (not quantified).
Cultural and Heritage	Archaeological, National Estate	None identified at threat from salinity.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Telephone cables, water pipeline, rail line (track well elevated) all protected by preventative actions by asset managers but at an additional cost. Salinity intersects with main roads such as Hamilton Highway, Vite Vite Rd, Camperdown Rd, Lower Darlington Rd and Chatsworth Rd.	Increased road deterioration due to increased land salinity.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	Rising salinity trends in Woady Yaloak River recorded at Cressy, currently 5265 EC rising by 3.4 EC/yr.	Woady Yaloak River increases in salinity 3.5EC/yr to 5329 EC by 2012, with additional 4 tonnes/day salt load to Lake Corangamite.	Reduce salt wash-off from discharge areas. Reduce surface water flow through salt springs.	Treating 1 ha will reduce salt loads at Cressy by approximately 3 tonnes/yr.

Table 3.11: Summary of Lismore – Derrinallum target area.

3.9 Murdeduke target area

The Murdeduke area has been targeted because it contains a cluster of assets at risk. The area encloses approximately 14,959 hectares, with threats to assets including infrastructure, agricultural land and the environment.

Salinity threats to assets

Lake Murdeduke is a significant environmental asset (Ramsar listed) identified at threat due to shallow saline watertables and intersections with groundwater flow systems (Heislers & Brewin 2003). However, the nature of the threat is uncertain as the lake is a primary saline feature and the changes to the lake since widespread land-use change are unknown at this stage. Although the lake is fed by the Mia Mia Creek, studies have shown that groundwater throughflow is the dominant influence on the lake salinity. Water balance calculations indicate that climatic influences are the dominant influence on the lake hydrology (Coram 1996). The lake is used for eel farming and recreational fishing.

Other assets at risk include agricultural land, infrastructure and utilities. All of the mapped salinity occurs on privately owned land, and 381 ha are regarded as secondary and 243 ha as primary. Approximately 19km of saline creek lines have been mapped.

There is no data available to establish the salinity trends for the land, water or wetland salinity. The hydrographs of several groundwater bores show a variation in water-level trends depending on the depth and location of the bores. In general, there are no apparent continuously rising watertables, but low amplitude rises and falls over long time periods, as would be expected in a regional system responding to climatic influences.

The current scenario is that saline land areas will continue to accumulate salt through evapotranspiration and export salt when surface water flows occur. Because the groundwater is shallow (<2 metres depth) and highly saline, the accumulation of salt in the soil has the potential to quickly create scalding and further degradation of agricultural land. There is no doubt that infrastructure will continue to be affected by the saline discharge and shallow saline watertables. Road infrastructure is particularly at risk as the capillary rise will bring salts to the road subgrade.

Salinity processes and management options

The groundwater processes of the lake and the flow systems between Lake Murdeduke and Barwon River (east of the lake) have been the subject of various previous research and investigations. The consensus of these studies is that the groundwater flows from the basalt plains into Lake Murdeduke on the western side and flows out of the lake on the eastern side across to the Barwon River. In its passage through the lake, the groundwater removes approximately the same mass of salts as is contributed by the inflowing groundwater, with the result that the salinity should remain relatively constant over time (Coram, 1996).

East of the lake, the groundwater flows follow a broad valley in the pre-basalt topography towards the Barwon River (Gill 1989, Giles 2004). This region is characterised by shallow (<2 metres), highly saline (100000+ μS/cm EC) watertables in the basalts. The groundwater discharges along approximately 8km of the Barwon River, increasing salinities from around 1650 – 2300 μS/cm to 2700 – 3400 μS/cm (SKM 1997).

A local groundwater flow system occurs in the large lunette along the eastern side of Lake Murdeduke. The lunette flow system provides additional recharge to the lake and some discharge along the eastern toe of the dune, resulting in the formation of shallow hypersaline wetlands.

The groundwater flow systems and discharge mapping suggests that much of the land salinity in the area is primary and that the shallow highly saline groundwater and associated discharge have been a feature of the landscape for centuries.

Recharge control in this landscape is considered ineffective, given the vast nature of the regional groundwater system in the volcanic plains. Salinity management for asset protection in this area will require different treatment depending on the asset at risk. Saline discharge on agricultural land is best managed by discharge treatment, which may include surface and sub-surface drainage or the productive use and rehabilitation of saline land. However, the very high salinity of the shallow groundwater may make it difficult to grow productive species. The Quaternary alluvium groundwater flow system overlying the volcanic plains should by highly responsive to the revegetation of discharge areas, which will reduce the spread of land salinity and reduce salt wash-off.

Protection of infrastructure and utility assets may warrant lowering the groundwater table in the immediate vicinity of the asset by continuous pumping, but is unlikely to be cost effective given that the disposal of highly saline groundwater would require the construction of leak-proof evaporation basins. Alternatively relocation or reconstruction of the asset may be required.

Change Scenario

Management and rehabilitation of saline discharge areas is unlikely to lower the watertables in the long term due to the extent and slow response of the groundwater flow systems. However, the management of saline discharge areas can slow or reverse degradation of agricultural land and increase productivity by increasing evapotranspiration and facilitating groundwater discharge. Salt export by surface wash-off will be reduced. Until further research is completed these gains cannot be quantified (even hypothetically).

Improved engineering could significantly extend (perhaps double) the design-life of roads, if the design of road construction and repairs took into account the presence of the shallow saline groundwater.

A summary of the assets, threats, trends and management options for the Murdeduke target area is provided *(Table 3.12)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	243 ha of primary and 381 ha secondary salinity all on private land. Stream-bank salinity along 19 km of waterways (mostly Mia Mia Creek).	Potential for increase in area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	149 ha of Very High and 135 ha of High conservation significance native vegetation intersects with salinity. The largest is south of McIntyres Rd, west of Flemings Rd. Also along Mia Mia Creek, north of Lake Murdeduke.	Potential for increase in area of native vegetation threatened by salinity.	Protect native vegetation through discharge management. Investigation required, as some may be primary saline EVCs.	Native vegetation protected (not quantified).
Cultural and heritage	Archaeological, National Estate	Lake Murdeduke is listed on National Estate register. Archaeological sites would be expected although none identified at risk.	If salinity in Lake Murdeduke changes, it may threaten its natural heritage values.	Investigate historic salinity trends and commence benchmarking values.	Research establishes salinity ranges and trends to develop targets.
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Saline areas intersect with Shelford Rd and Barwon Park Rd. Telephone cables and rail line (track well elevated) intersect salinity but are protected through preventative actions by asset managers but at an additional cost.	Increased road deterioration due to increased land salinity.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	Ramsar-listed Lake Murdeduke receives saline input from Mia Mia Creek and groundwater (throughflow). There is a strong hydraulic connection between Lake Murdeduke and the Barwon River to the east. 20 saline wetlands are mapped in the target area.	Potentially, changed salinity to Lake Murdeduke and groundwater threatens lake integrity and Barwon River.	Reduce salt wash-off from discharge areas. Improve groundwater management for integrity of GDEs.	Research establishes salinity ranges and trends to develop targets.

Table 3.12: Summary of Murdeduke target area.

3.10 Warncoort target area

A relatively small area comprising 6,825 hectares around Warncoort has a cluster of salinity threats to highly-scored assets as determined by the GSHARP model (Heislers & Brewin 2003). The threats are mostly assigned to the development of secondary salinity discharge processes along drainage lines and low-lying areas.

Salinity threats to assets

The saline areas generally lie along the southern edge of the volcanic plain in the valley of the Birregurra Creek. The salinity values of the creek are very high, generally 10,000 μS/cm EC, but have been recorded up to 40,000 μS/cm EC. It has been reported (Dennis 2002) that the Birregurra Creek was formerly a shallow meandering watercourse with substantial, vegetated flood plains. The creek was previously used for stock watering; however, with the increase in salinity this is no longer possible. However, the hydrogeological conditions imply that the creek must have been receiving saline groundwater discharge for the past centuries.

A 130 ha low-lying area on the volcanic plains is the largest area of saline agricultural land mapped, and is regarded as dominantly primary in origin. The main assets at risk are infrastructure assets – road, rail, power lines, and phone cables. A small area of public land adjoining the creek is saline. Of the mapped salinity, 379 ha of dominantly primary and 111 ha of dominantly secondary salinity have been mapped on private land and six ha of primary salinity on public land.

Insufficient data is available to establish trends in land salinity or groundwater levels. Only two credible groundwater bore hydrographs could be found for the area; however, both have insufficient data on the bore records for interpretation of trends. As there is insufficient monitoring information to determine if the area of land is affected by salinity has increased, the current scenario assumes that the discharge areas will continue to accumulate salt through evapotranspiration and export salt when surface water flows occur. The accumulation of salt in the soil has the potential to create scalding and further degradation of agricultural land. Infrastructure will continue to be affected by the saline discharge.

Trend analysis of the salinity recorded at the gauging station on Birregurra Creek (233211) shows a falling linear trend of –175 μS/cm/yr over the past 29 years. The mean salt load for the same period was 294 tonnes per day, which is more than three times that of the Moorabool River and higher than the Woady Yaloak River (Dahlhaus *et al.* 2005b). This falling trend is predicted to continue, with an unknown impact on the creek ecosystem, but an improved water quality of the Barwon River.

Salinity processes and management options

This area occurs at the complex junction of several groundwater flow systems – the Volcanic Plains basalt (regional), the Pliocene Sands (intermediate), the Gerangamete Marls (local) and the Quaternary alluvium (local). Despite the high-value assets and the location of two dozen bores in the area, the salinity processes are not well understood. The detail in the bore information is lacking and the geology at depth can only be speculated. The interaction of the groundwater flow systems and their contribution to the salinity process will be clarified once the current CSIRO research project is completed.

Based on the response of the groundwater flow systems, biological control of recharge is generally considered to have a low benefit as a salinity management option. The artesian influence of the Dilwyn Formation aquifer as measured at Colac and Barwon Downs is likely to influence the salinity processes at Warncoort. Confidence in the recharge control option may increase once the hydrogeological model for the area is developed to allow scenario modelling of salinity impact and threats to assets. Strategies for asset protection could then be developed.

For high-value assets, such as power lines, roads or Telstra cables, continuous groundwater pumping could be used to lower the water table in the immediate vicinity, but may not be cost-effective and requires acceptable disposal options. Relocation, restoration or retrofitting of protective barriers may be more appropriate.

For agricultural land assets, discharge management by the productive use and/or rehabilitation of saline land would provide more effective benefits in the short term. This can be achieved through the subtle land classing and fencing of saline lands to restrict stock using the areas and allow the establishment of appropriate plants (productive or biodiversity as required). Strategic grazing management such that it does not impact negatively on the current biodiversity value (if any) is also required. This action requires “in paddock assessment” of each saline area and individual planning for each property.

Change Scenario

Management and rehabilitation of saline discharge areas is unlikely to significantly lower the watertables in the immediate or near-term future due to the extent and slow response of the groundwater flow systems. However, the management of saline discharge areas can slow or reverse degradation of agricultural land and increase productivity by increasing evapotranspiration and facilitating groundwater discharge. Salt export by surface wash-off will be reduced. Until further research is completed these gains cannot be quantified (even hypothetically).

A summary of the assets, threats, trends and management options for the Warncoort target area is provided *(Table 3.13)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	385 ha of primary salinity, of which 379 ha is on private land, mostly along Birregurra Creek and a low-lying area along Mooleric Rd. 111 ha of secondary salinity on private land, mostly along drainage lines. Large area along Salt Creek Lane.	Increase in area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	41 ha of Very High and 142 ha of High conservation significance native vegetation intersects with saline land. Most occurrences are associated with drainage lines such as Birregurra Creek.	Increase in area of native vegetation threatened by salinity.	Protect native vegetation through discharge management. Investigation required, as some may be primary saline EVCs.	Native vegetation protected (not quantified).
Cultural and heritage	Archaeological, National Estate	None identified as threatened by salinity.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Bitumen pavement breakdown, low-voltage timber electricity poles in discharge areas. Telephone cables, gas and rail line (track well elevated) intersect Class 2 salinity but are protected through preventative actions by asset managers but at an additional cost.	Increased road deterioration due to increased land salinity.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	One saline wetland (along Birregurra Creek) is mapped. Salinity in Birregurra Creek is falling at 175 EC/yr, but mean salinity is 10,429 EC and highest recorded is 44,900 EC. Mean salt load is 294 tonnes/day into Barwon River.	Salinity of Birregurra Creek continues to decline to 8110 EC by 2012. Changes to Lough Calvert Drainage Scheme may impact on salinity of Birregurra Creek.	Reduce salt wash-off from discharge areas. No change to Lough Calvert Drainage Scheme as recommended in GHD study.	Salinity trend of Birregurra Creek does not increase.

Table 3.13: Summary of Warncoort target area.

3.11 Modewarre target area

The Modewarre area has been established as a salinity priority area in the initial salinity strategy, where it was known as the Moriac Hot Spot. The renewed target area comprises approximately 23,675 ha south east of Winchelsea in the upper catchment of the Thompson Creek where the GSHARP model identified threats to high-score assets in the immediate term (Heislers & Brewin 2003).

Salinity threats to assets

The assets in the Modewarre area are generally affected by secondary salinity, with discharge occurring at a range of sites across the landscape, intersecting numerous roads and affecting some agricultural land. The Wurdiboluc Reservoir, an urban water supply reservoir for the City of Geelong, is located high in the landscape and is unlikely to be threatened by saline discharge. Lake Modewarre is an important recreational lake and Gherang and Brown Swamps are of high environmental value. Lake Modewarre is reported as brackish, but it is unknown if the asset is at risk, as the salinity trend for the lake has not been established.

All of the mapped salinity (with the exception of one ha) occurs on private land. Approximately 270 ha are dominantly primary in origin and 160 ha are dominantly secondary. Approximately 54km of salinity is mapped along creek lines.

About 30 groundwater monitoring bores have been constructed in the Modewarre target area in prior research and investigation programs. The water level hydrographs for these bores show uniformly steady to slightly falling trends during the monitoring period. Groundwater is generally within three metres of the surface in the lower landscapes and may be up to 7,000 mg/L dissolved salts. The groundwater bore hydrographs do not show significant trends and there appears to be little or no threat in the immediate or near-term future of rising groundwater levels.

The land salinity in the area was mapped by DPI in 2005, recording a 20% increase in salinity than previously mapped. It is assumed that this detailed mapping has recorded salinity that has emerged over the past 10 to 20 years, although a proportion of the new sites may have been previously present, but missed by previous mapping. The secondary salinity may continue to slowly extend in area as the evapotranspiration accumulates salts in the soil and the land becomes degraded. If no change to land management is made, the accumulated salts will eventually kill the vegetation, creating scalds and erosion. Salt washing from the surface will add to the salt load of Thompson Creek.

There is no doubt that infrastructure will continue to be affected by the saline discharge and shallow saline watertables. Road infrastructure is particularly at risk as the capillary rise will bring salts to the road subgrade.

Salinity processes and management options

The geology and hydrogeology of the area is quite complex. The salinity is associated with three groundwater flow systems – the Quaternary alluvium (local), the Pliocene Sands (intermediate) and the Volcanic Plains basalt (regional). The salinity in the thin Quaternary alluvium is almost certainly associated with discharge from the more extensive underlying intermediate and regional systems. Based on the exposures and bore intersections of the various rock types, it is speculated that a variety of regional, intermediate and local processes contribute to the salinity.

In these landscapes the majority of recharge to the sands occurs from leakage through the overlying basalt plains to the north. Recharge control is generally considered ineffective because of its inability to sufficiently reduce the watertables within a human time-frame. Effectively, it would require lowering the watertable across thousands of hectares of the Volcanic Plains and Pliocene sands. Towards the south some of the saline discharge is probably associated with groundwater moving up from deeper aquifers along the Bambra Fault, especially where the transmissive Dilwyn Formation aquifer is faulted against the poorly transmissive marl (Dahlhaus 2003b).

At present there is insufficient knowledge and understanding (or indeed proof) of the sources and flow paths of the saline groundwater to a specific discharge area for the practical implementation of recharge control or interception tree belts. In the short term, discharge management techniques, such as surface and sub-surface drainage and/or productive uses and rehabilitation of saline land, are considered more appropriate salinity management options. As more knowledge is gained about the distribution and geometry of the aquifers, some parts of the landscape may be delineated for recharge control or interception of lateral flows, if local systems in the Pliocene sands are recognised.

Change Scenario

Management and rehabilitation of saline discharge areas is unlikely to lower the watertables in the long term due to the extent and slow response of the groundwater flow systems. However, the management of saline discharge areas can slow or reverse degradation of agricultural land and increase productivity by increasing evapotranspiration and reducing groundwater levels. Salt export by surface wash-off will be reduced. Until further research is completed these gains cannot be quantified (even hypothetically).

Improved engineering could significantly extend (at least double) the design-life of roads, if the design of road construction and repairs took into account the presence of the shallow saline groundwater.

A summary of the assets, threats, trends and management options for the Modewarre target area is provided *(Table 3.14)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	270 ha primary and 160 ha secondary salinity all (bar one ha) on private land east of Winchelsea (around Moriac). Land use varies from agricultural production to lifestyle properties.	Increase in area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	Reduce salt wash-off (not yet quantified). Reduced trend in loss of agricultural land to salinity (not quantified).
Biodiversity	Native vegetation, VROTS	58 ha of Very High and 106 ha of High conservation significance native vegetation intersects with land salinity. Most occurrences are associated with drainage lines and low lying areas, especially around Paraparap. The Yarra Pigmy Perch in Upper Thompson Creek may be threatened by salinity.	Increase in area of native vegetation threatened by salinity.	Protect native vegetation through discharge management. Investigation required, as some may be primary saline EVCs.	Native vegetation protected (not quantified).
Cultural and heritage	Archaeological, National Estate	None identified as threatened by salinity.			
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	13 road intersections with salinity, mostly around Paraparap (eg. Giddings Rd, Flaxbournes Rd.), Moriac and Modewarre (Cape Otway Rd).	Increased road deterioration due to increased land salinity.	Road maintenance education.	Improved road management for saline areas reduces maintenance frequency and costs.
Water quality	Wetlands, rivers	4 saline wetlands mapped. Lake Modewarre salinity may be affecting eel populations. Thompson Creek is believed to be increasing in salinity, but data not available to calculate trends.	Lake Modewarre threatened by changed salinity. Salinity of Thompson Creek continues to increase.	Reduce salt wash-off from discharge areas. Improve groundwater management for integrity of GDEs.	Groundwater managed to ensure integrity of GDEs.

Table 3.14: Summary of Modewarre target area.

3.12 Lara target area

The Lara area is a new target area for salinity management, selected on the basis of the concentration of threatened assets identified in the outcomes of the GSHARP model (Heislers & Brewin 2003). The area encloses approximately 3,418 ha south of the township of Lara and adjacent to Avalon Airport.

Salinity threats to assets

The Lara target area encloses 18 saline wetlands (~950 ha), including the salt evaporation ponds used for the commercial production of salt. These wetlands are originally of primary (estuarine) origins and modified to suit the commercial operations. The coastal and estuarine saltland/wetland systems to the south are Ramsar-listed wetlands of international significance and collectively form one of Australia's most significant environmental assets. Within the Lara salinity target area, there are 28 threatened species, 25 migratory species, 22 marine protected species and the Port Phillip (Western Shoreline) and Bellarine Peninsula Ramsar sites.

Little to no agricultural land threatened at present, the only issues being with management of grazed saline land adjoining environmental areas. Adjacent high-value infrastructure assets include Avalon airport, the township of Lara and the Melbourne – Geelong Highway.

The area includes 79 ha of mapped salinity on public land and 153 ha of mapped salinity on private land. Only one bore with a hydrograph record is located in the area. The watertable is approximately 5.5 metres deep and the monitoring shows a slight downward trend in the watertable levels over the past decade. This indicates little or no threat to assets from encroaching secondary salinity in the near term. However, given the high value of the assets in the region, continued monitoring of the watertable should be a priority.

Because the saline areas and wetlands are very close to sea level and managed for salt harvesting, the groundwater will be highly saline and at or near the surface. The likely threats in the current scenario will be from added inputs of fresh water from stormwater drainage of nearby industrial and urban infrastructure, particularly the Avalon Airport. The encroachment of industrial and urban infrastructure also has the potential to significantly modify the spatial and temporal hydrology by the construction of impervious surfaces (paved areas, roofs, etc.), the addition of irrigated areas (lawns, gardens) and the re-routing of surface water flows (stormwater pipes and drains). Encroaching infrastructure may be at risk from shallow saline watertables and road and airport runway/taxiway infrastructure is particularly at risk as the capillary rise will bring salts to the paving subgrade.

Salinity processes and management options

Very little is known about the salinity processes at Lara as no previous investigations have been sourced. The vast majority of the salinity is interpreted as primary mostly associated with coastal and estuarine wetlands. There may be some encroachment of secondary salinity associated with the raised watertables in the commercial salt harvesting operation.

Further research is required to determine the nature of the salinity threat and appropriate actions for managing the salinity threat in the target area. Baseline monitoring is required to establish trends for the area of land salinised, the range of salinity of the wetlands and the depth to watertable trends.

Change Scenario

Until further research is completed the required salinity management is unknown, however strategic urban planning could assist greatly in ensuring the protection of infrastructure and the environmental values of the target region.

A summary of the assets, threats, trends and management options for the Lara target area is provided *(Table 3.15)*.

Primary Asset	Secondary Assets	Description of threat	Trends/Scenarios	Management options	Managed scenario
Land	Agricultural land, public land	143 ha of primary salinity, 79 ha of which is on private land, mostly along Hovells Creek and along the coast between Point Lillias and Point Wilson. 89 ha of secondary salinity, with 74 ha on private land, mostly bordering Cheetham Salt evaporation ponds.	Increase in area of land salinised.	Appropriate discharge management for primary and secondary sites on public and private lands.	No net gain in secondary salinity, or net loss of primary salinity.
Biodiversity	Native vegetation, VROTS	151 ha of Very High and 88 ha of High conservation significance native vegetation intersects with salinity. Much of this is associated with the Ramsar-listed wetlands around Point Lillias. 28 threatened species, 25 migratory species, 22 marine protected species are associated with the saline wetlands.	Increase in area of native vegetation threatened by increasing or decreasing salinity. Changed water quality to wetland and coastal salinity sites threatens ecosystem integrity.	Protect native vegetation through discharge management. Investigation required, as some may be primary saline EVCs.	Native vegetation protected (not quantified).
Cultural and heritage	Archaeological, National Estate	Point Wilson / Avalon coastal area is listed on National Estate register.	Potentially, changes in salinity could alter natural heritage values.	Investigate historic salinity trends and commence benchmarking values.	Research establishes salinity ranges and trends to develop targets.
Infrastructure and utilities	Roads, rail, towns, electricity, gas, water, telephone	Minor road intersections only, salinity expanding along the western edge of Avalon airport precinct.	Increased road deterioration due to increased land salinity.	Appropriate discharge management for primary and secondary sites on public and private lands.	Threat to road infrastructure diminishes.
Water quality	Wetlands, rivers	18 saline wetlands are mapped in target area, including Ramsar-listed sites. Saline lakes used as evaporation basins by Cheetham Salt for commercial salt production.	Changes to wetland and estuarine salinity threatens aquatic ecosystem integrity.	Reduce salt wash-off from discharge areas. Improve groundwater management for integrity of GDEs. Improve management of fresh water run-off into primary saline wetlands.	Research establishes salinity ranges and trends to develop targets.

Table 3.15: Summary of Lara target area.

4. The Corangamite Salinity Action Plan

4.1 Planning and investment process

Development of the SAP for Corangamite followed a seven-step process, discussed and endorsed by the Corangamite CMA. The first step was to use an asset-based approach to identify target locations (as described in section 2). The subsequent steps in the process are represented diagrammatically *(Figure 4.1)*.

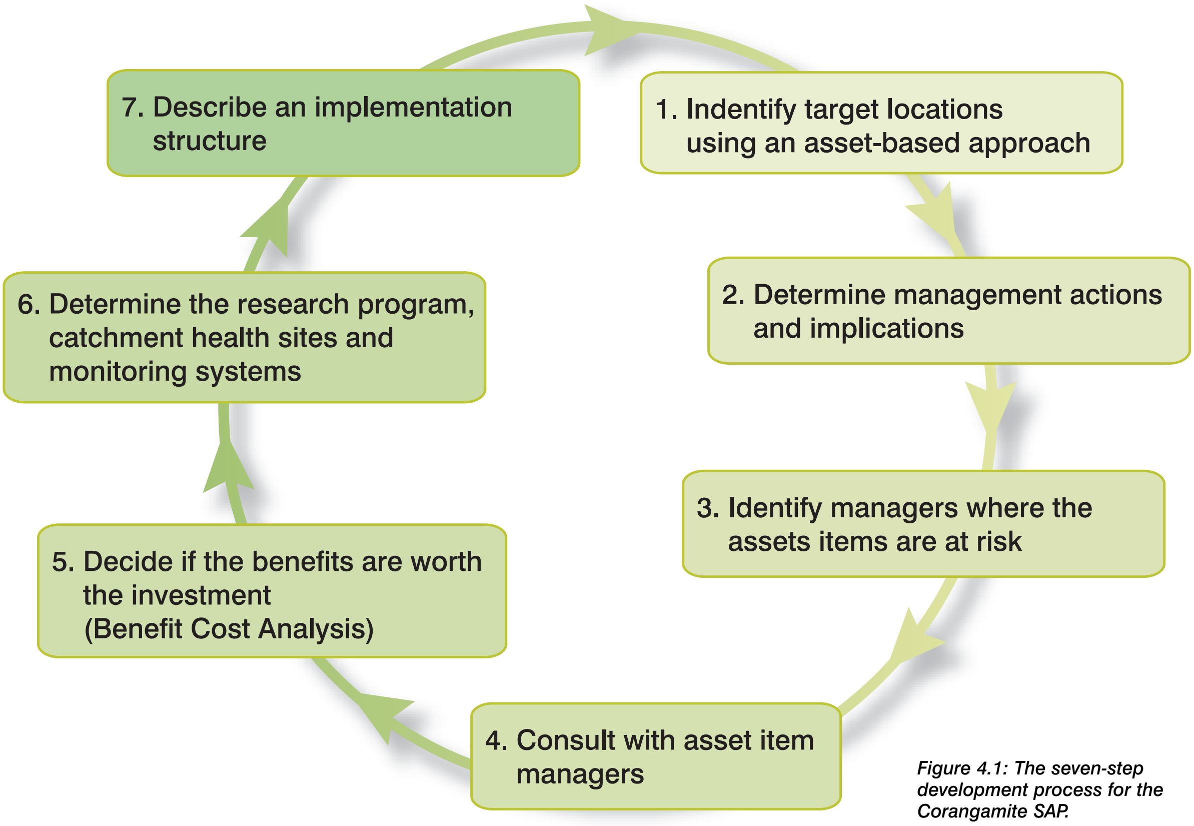


Figure 4.1: The seven-step development process for the Corangamite SAP.

Within each step of the process, appropriate tools, models and/or frameworks were used. The seven-step planning and investment process was designed to provide an approach that can be revisited as new knowledge and information becomes available, thus creating a 'living' plan.

4.2 Appropriate management actions and their implications

The description of the salinity processes occurring in each target location provided a sound basis for exploring appropriate salinity management actions (refer to section 3). To refine the management actions further, three additional approaches were used. The first was to model the changes to salinity under different treatment scenarios. This was primarily undertaken using Flowtube, a one-dimensional finite difference model that allows change in recharge and discharge under various treatments to be modelled (Dawes *et al.* 2000).

The second was to use site-specific research results from university and departmental activities. This applied to work conducted at the Pittong (MacEwan & Dahlhaus 1996), Illabarook (Church 2004), Lake Murdeduke (Giles 2004), Lake Corangamite (Dickinson 1995) and Colac-Eurack (Blackam 1999) target areas.

The third is to use evidence provided by experienced salinity extension officers who had first-hand exposure to the effects of a range of management options. Their insights are documented in the review of Restoring the Balance (Nicholson 2002) and Background Report 4 (Nicholson *et al.* 2003).

The management actions suggested focused either on engineering, planning or biological solutions.

Engineering treatment options

Five engineering options were considered. Two of these options were deemed appropriate when used in combination with other biological treatments. These are described below.

Modifications to road foundations

The premature failure of roads in the region is real, with an estimated 61km of sealed and unsealed roads currently salt affected. Consultation with asset managers has revealed they either do not currently recognise the cause of the road failure as being caused by salinity and/or they are unfamiliar with the appropriate treatment of the road foundation to minimise the damage in the future (Nicholson *et al.* 2003).

There are engineering solutions that could be adopted to modify the design and construction of road foundations and repairs. Given maintenance of road assets are the responsibility of either VicRoads or local municipalities, the appropriate action in the salinity plan is to increase the recognition and design approaches of these asset managers.

Surface and subsurface drainage in built areas

The asset-based salinity risk analysis identified the urban development south-west of Colac in the Colac – Eurack target location as directly threatened by rising groundwater. Engineering solutions are available to protect these assets, however the benefit cost of such actions is yet to be determined. Nevertheless, they are a potential treatment to remove the salinity threat to these assets.

This type of treatment is expensive and requires extensive planning to ensure success. The appropriate action in this salinity plan is to work closely with local government to explore future works.

Manipulation of water flows in waterways

It has already been acknowledged that manipulation of water flows by either increasing or decreasing volumes is potentially a solution to changing trends in water salinity.

Alteration to water flows needs to be considered in the Lake Corangamite, Colac – Eurack and indirectly the Warncoort target locations where the Woady Yaloak diversion scheme and the Lough Calvert drainage scheme have changed natural water flows. The current water flow arrangements have impact on important regional assets such as Lake Corangamite, wetlands through Eurack and the Birregurra Creek (Dahlhaus 2003b).

A major study of the operation of the Woady Yaloak diversion scheme has been completed (GHD 2004). The recommendations of this study are currently under consideration by the Corangamite CMA but if adopted are likely to lead to increased flows into Lake Corangamite from the Woady Yaloak River, reducing salinity levels in the lake while maintaining an acceptable impact on salinity in the Barwon River.

Water volumes are also an issue in the Upper Moorabool and Morrisons-Sheoaks target locations of the Moorabool River (Dahlhaus 2003b).

Increasing trends in salinity in both the urban water storage at Lal Lal and the mid reaches of the Moorabool River, which is used as a conduit for Geelong's drinking water, could be addressed by improving flows in the River.

Recent work (SKM 2004) has short-listed 10 options for improving flows in the Moorabool River. These are currently under consideration by the Corangamite Catchment Management Authority, however it is anticipated more investigations will be required before any specific options are considered. The Salinity Action Plan should contribute to these deliberations by identifying where the salt inflows are occurring in the upper reaches of the Moorabool River.

Shallow surface drains to intercept lateral flow of perched groundwater

This treatment involves the use of shallow interceptor drains located at appropriate locations on the recharge areas. This treatment was found to only be applicable in the Pittong target area where the soils have a strongly developed sandy gravel horizon (termed the A_2 horizon) at about 20 cm depth. Below this horizon, tight clays impede the vertical infiltration of water. Following rainfall, fresh water moves laterally through this sandy horizon and is contaminated with salt as it passes through saline discharge from springs in the local granite bedrock (in some cases within one metre of the surface). This localised geology results in saline discharge being spread downslope from the saline discharge points and along the broad valley floors. Intercepting the fresh water using shallow surface drains can re-direct the fresh water safely into existing waterways or dams *(Figure 4.2)*. The treatment is site specific and would need to be adopted on a case by case basis.

Most of the benefit derived from this management action is to reduce salinity further down the catchment and in waterways, rather than to the land owner. If anything, shallow surface drains across a paddock are likely to be more of a nuisance than a benefit.

Discharge management to prevent waterlogging and fresh water contamination

Saline areas are often waterlogged for substantial periods of the year. They are often flat, with little relief to allow surface water to drain away. This results in the water table remaining at the soil surface for longer periods of time, creating a hostile environment for most vegetation. This commonly results in only the unproductive halophytic plants like spiny rush surviving and makes it virtually impossible to establish more productive salt-tolerant species.

The prevention of waterlogging is a critical component of successful discharge management in the Corangamite CMA Region. Unfortunately, the current response by outsiders and investors is that the prevention of waterlogging equates to the draining of saline areas. It does not.

The treatment involves the diversion of fresh surface water away from the saline areas through banks and shallow, wide bed channels. The diversions and channels are arranged across contours on minor grades for safe water carriage.

There are now numerous examples in the region where the prevention of waterlogging has allowed salt-tolerant vegetation to be successfully established. As a result, a vegetative cover has been created, preventing salt accumulation over the drier summer months. This in turn reduces the amount of salt on the soil surface that gets washed off in the following winter. Monitoring at some treated sites has shown a significant reduction in salt accumulation at the soil surface (0 to 10 cm), a drop in the watertable and an increase in the productivity of the land (John Carr, pers comm.). The effect on salt loads has not been precisely quantified, however the measured reduction in surface salt would imply a reduction in salt loads leaving the site.

The Morrisons-Sheoaks, Pittong, Illabarook and Murdeduke target locations suit this treatment option.

Vegetative cover can also be enhanced by the prevention of waterlogging, without the need to introduce new plants. This applies to areas that are only marginally saline but are expanding because of the waterlogged conditions.
The Pittong area is the only target location where these conditions occur.

Planning options

Planning can be an effective tool to prevent constructing infrastructure assets in areas of current or future salinity. It is also valuable to adopt protective measure if the works need to be constructed in a specific location which is salt affected. Local Government is a key player in local planning and its decisions greatly influence the risk that built assets are exposed to.

The asset-based approach used in the SAP has identified one significant example where urban development is occurring in close proximity to saline discharge. However, to take preventive action, it is logical to equip local government planners with the information to alert them to any potential salinity risk in the planning phase. Salinity management overlays, used as part of the municipal planning scheme, are appropriate tools to achieve this outcome.

The development of salinity management overlays (SMO) is expensive. It is recommended salinity investment is made to develop SMO in the following priority order:

1. Development of SMOs where salinity already occurs and development is currently occurring. This is the Colac – Eurack target location.
2. Development of SMOs where Local Government has identified as corridors for future growth.
3. Development of SMOs in other areas where salinity currently exists or is predicted to appear in the future.

Biological treatment options

Revegetation has been a commonly recommended treatment option for salinity control since the advent of coordinated salinity action (Salinity Bureau 1988). Its acceptance is based on the need to replace vegetation lost since European settlement. While this logic still holds, an increased understanding of groundwater processes allows a more targeted use of revegetation and an innovative arrangement of these plantings.

The vegetation options can be considered in two parts. The first is the establishment of vegetation in recharge (non-saline) areas, with the aim of using fresh soil water before it causes watertables to rise. The second is to use vegetation that can tolerate salinity planted on discharge areas, thereby providing a cover to reduce the concentration of salt on the soil surface.

Recharge treatment options – high-density tree planting

This option relies on replacing vegetation of similar water use to what was existing pre clearing. To achieve this high-density planting (greater than 1000 stems per hectare) is recommended, effectively creating a changed enterprise use for the land. If local indigenous trees are used, this is likely to be greater than the density of mature trees removed at clearing but is intended to maximise water use in the shortest possible time. The type of tree established, while important, is secondary to the primary objective of maximising water use. Thinning of the initial planting could occur without jeopardising the effectiveness of the treatment but complete removal (harvesting) would require replanting to maintain the salinity benefit.

Large areas of the Corangamite CMA Region have had trees removed since European settlement and it could be argued there would be benefits from re-instating this type of vegetation. However, in the SAP investment is only recommended in target locations where localised groundwater flow systems exists and the treatment is likely to deliver a demonstrable change in salinity discharge within decades. This currently limits this treatment option to the Morrisons – Sheoaks and Illabarook target locations.

Public and private benefits are derived from this option. The public received the salinity benefit from reductions in groundwater, however the individual on whose land the trees are located can obtain benefits through thinning and subsequent harvest. Therefore a public / private co-contribution to establishment would be appropriate.

Recharge treatment options – Tree interception belts

In target locations where relatively fresh soil water moves laterally through the A_2 horizon, or ephemeral perched groundwater water is forced close to the surface by underlying impermeable bedrock, narrow belts of trees planted at strategic locations can be effectively used to intercept this fresh subsurface water. This option works on the same principal as shallow surface drains (refer to 4.2.1.4), but uses tree roots to intercept the lateral flow of water and transpiration to remove the trapped water. This option would create various width belts of indigenous and/or commercial forestry trees (3 to 5 rows) located periodically throughout the landscape in an alley farming arrangement. Tree belts may range from 50 to 300 metres apart *(Figure 4.2)*.

Pittong is the only target location suitable for this type of treatment.

Virtually all of the benefit derived from this management action is for public good, with only minor benefits to the landholder (shelter). It is not anticipated the timber value of the plantations would be of any significance and may create inconvenience to other farm operations (eg moving livestock). Majority public investment is appropriate.

Recharge treatment options – Tree planting adjoining or near saline discharge

This option involves the establishment of high-density trees (indigenous or forestry) in areas where watertables are likely to be within reach of tree roots. Belts of trees may be five to 10 rows wide. The watertable in these locations is not highly saline and interception reduces the amount of water reaching the discharge area. Trees are established above the discharge area.

This treatment is applicable to the Morrisons – Sheoaks, Pittong and Illabarook target areas.

The benefit from this option is shared between the public (reduced salt wash-off) but also by the landholder who may obtain some improvement (and productive benefit) from the less saline discharge area.

Discharge treatment options – Protection and management of discharge to allow natural vegetation recovery

This management treatment involves land class fencing to divide saline land from non-saline areas, thus providing the opportunity to control grazing. Experience from the previous salinity implementation in the region (Nicholson *et al.* 1992) shows the control of grazing is often enough to allow natural vegetation to recover and/or re-establish. This treatment usually involves periodical grazing and weed control and is most applicable to areas of primary salting.

Recent consultation with extension staff has indicated the adoption of this treatment option would be enhanced if tree planting would be offered in conjunction with fencing (Nicholson 2005). While the tree planting would not provide any direct salinity benefits, it is likely to provide other benefits (shelter, habitat for birds) and would increase adoption. The tree planting and fencing option has also been included as a management option.

The benefit from this option is unlikely to be through increased production, but through increased enhancement of the biodiversity value.

This treatment is appropriate for six of the 12 target locations in the Corangamite CMA Region.

Summary of management options for target locations

Engineering and biological treatments described above can be used individually or in combination to achieve salinity control. A summary of the various management options for each target location is listed *(Table 4.1)*.

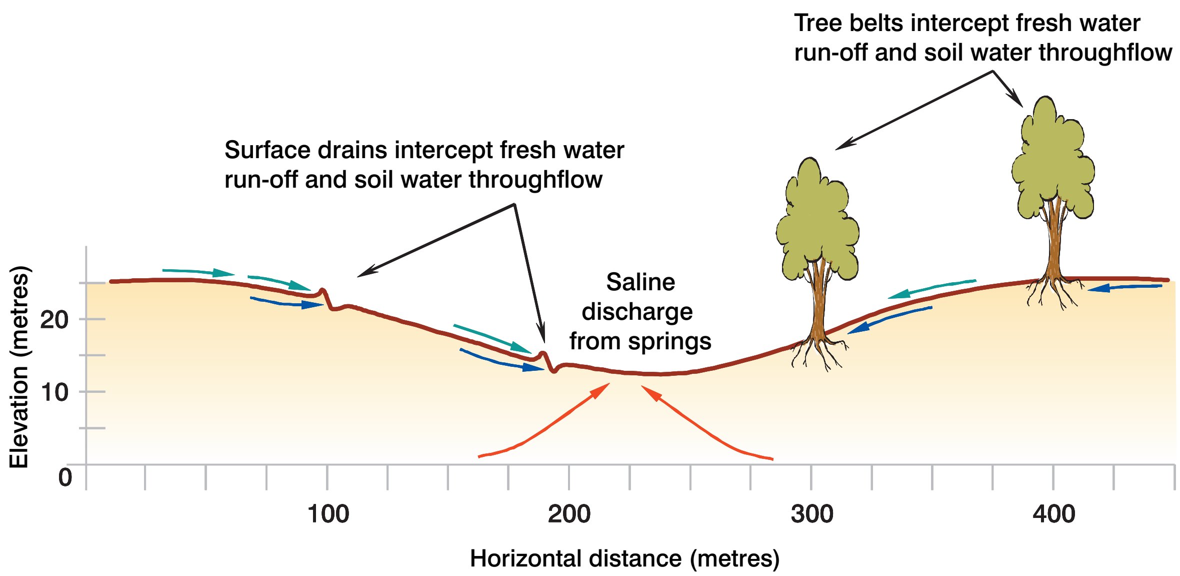


Figure 4.2: Surface water and soil water interception using shallow drains and tree interception belts.

Target location	Recharge management action				Discharge management actions				
	1. High density tree planting.	2. Tree planting interception belts	3. Shallow surface drains to intercept lateral flow of perched groundwater	4. Tree planting adjoining or near saline discharge	5a. Protection & management of discharge areas to allow natural vegetation recovery (fencing only)	5b. Protection & management of discharge areas to allow natural vegetation recovery (with trees)	6. Protection & management of discharge areas with establishment of additional vegetation	7. Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover	8. Water logging control
Lake Corangamite					✘	✘	✘		
Morrisons – SheOaks	✘			✘				✘	
Colac Eurack					✘	✘	✘		
Geelong – Lake Connewarre					✘	✘	✘		
Pittong		✘	✘	✘				✘	✘
Illabarook	✘			✘				✘	
Lismore – Derrinallum					✘	✘	✘		
Warncoort							✘		
Murdeduke							✘		
Modewarre					✘	✘	✘		
Lara					✘	✘	✘		
Upper west Moorabool	**No on-ground targets set until current studies are completed**								

Table 4.1: Management options applicable to each target location.

4.3 Identification of asset managers who need to adopt the management actions

The Corangamite CMA is responsible for salinity management in the region, however most of the management actions need to be implemented by managers to assets that are beyond the direct influence of the authority. Successfully engaging these asset managers and enrolling them to the cause of adopting proposed salinity management options is critical.

The asset-based approach to select the target locations *(Section 2.4)* allowed specific asset items to be identified. Detailed examination of the salinity processes enabled discussion about the cause of the problem and for appropriate treatment options to be identified *(Section 4.2)*. It also enabled specific asset managers to be identified in each location.

Asset managers chosen for consultation were:

- Corangamite, Colac Otway and Surf Coast shires.
- City of Greater Geelong.
- Vicroads (major roads).
- Vic Track (railways).
- Powercor (electricity).
- Telstra (telecommunications).
- Gas transmission companies
- Central Highlands Water.
- Barwon Water.
- Landholders.
- Parks Victoria.
- Crown Land (Department of Sustainability and Environment).
- Modewarre catchment and lake committees.

4.4 Asset manager consultations

Asset manager engagement was based on a highly targeted consultation approach, with one-to-one or group discussions conducted with parties whose assets were directly affected by salinity or whose participation is required to implement proposed salinity treatment options.

Discussions were based on a semi-structured interview process using the program logic approach developed by the Corangamite Salinity Team in the mid 1990s (Nicholson *et al.* 2003). The program logic allowed the attitude and capacity of the asset manager to be summarised, along with the suitability of the technology and where to locate the treatments in the landscape. A summary of these findings is presented in Background Report 4 (Nicholson *et al.* 2003).

The consultation was designed to engage the asset managers, create ownership of the problem and the solutions, and to minimise the likelihood of stakeholder burnout, given the recent Regional Catchment Strategy development and other project demands created through the projects funded by the National Action Plan on Salinity and Water Quality. The results from the targeted approach provided a wealth of highly valuable information that allows intervention to be customised to each target location. The general response from the various asset managers is provided.

The main asset manager consultation for the SAP was conducted in 2003. Since then salinity management actions have been undertaken using the draft SAP as a guide in seven of the 12 target locations. This has enabled the considerations from the first consultation to be tested and allowed additional insights to be gained (Nicholson 2005). It has added to the understanding regarding implementation.

Infrastructure managers

The main infrastructure classes considered were roads, railways and towns. The intersection of these asset classes with the salinity hazard identified 61km of sealed and unsealed roads and several sections of railway line. The City of Colac was the only urban area identified at risk, as a result of salinity encroachment on the south-west city limits.

Infrastructure managers were generally aware of the threat posed to their assets by salinity and in most cases had adopted treatments to protect their asset. Salinity threats are sometimes taken into account and designed for in the original construction phase. The noticeable exception was the managers of municipal roads, where there was limited recognition of the impact salinity was having in asset deterioration and/or a limited appreciation of the treatments that could be used to minimise long-term salinity impacts. This particularly applied to road maintenance crews who are assigned the task of patching crumbling road surfaces. As a consequence, an ongoing maintenance program was adopted which treated the symptoms of salinity, but rarely addressed the underlying causes of salinity and the associated groundwater issues.

Despite this, most assets have been designed to accommodate the salinity threat, although all infrastructure managers said they would find accurate saline discharge mapping a very useful tool for the future development and maintenance of their assets. They were pleased to be considered in the consultation process.

Colac Otway Shire recognised that it has a salinity 'problem' at the urban development / saline land interface. Although it is not currently perceived as an urgent issue, it acknowledges it is not fully equipped with the procedures, skills, time and funds to deal with the implications of the expanding salinity. Colac Otway Shire indicated it could deal with the salinity only if it was supported with the tools and capacity to properly respond to the issue. A salinity management overlay was seen as a useful starting point, but further resources would be needed for implementation and ongoing infrastructure management.

Utility managers

Electricity, gas, water and telephone cables were the asset classes investigated. Numerous examples of salinity intersecting with these utilities was identified through the asset-based approach and later confirmed by physical site inspections (Dahlhaus 2003a). However, the intersection of a utility with salinity did not necessarily infer salinity damage to those assets. When consulted, each of the utility managers had their own strategies for protecting their asset against salt.

Agricultural land managers

Overall there was support for the various conceptual groundwater models used to describe why salinity occurred in a location and therefore why the suggested treatment options were being canvassed. Many anecdotal stories of recharge and discharge treatment confirmed the theoretical salinity processes described. However, salinity was inadequately represented on the maps and highlighted the need to accurately determine where salinity is occurring before treatment is applied in any target area.

Acceptance of the treatment options varied between sites. In the three target areas where recharge control was suggested, there was some degree of scepticism about the efficacy and scale of the treatment. Treatments were either seen as unproven, such as tree belts or shallow surface drainage in the Pittong area, or the quantity required to achieve control, if implemented, would dramatically alter the current land use. Both issues were a dis-incentive to adoption and have limited initial uptake, especially in the Illabarook target area where commercial tree planting by farmers has been discouraged by timber companies because of the shallow soils and marginal rainfall.

In the Morrisons – Sheoaks target area, where rainfall is higher and many commercial plantations already exist nearby, the commercial interest in further large-scale planting is high. It is reported tensions have already arisen between individual land managers and timber companies. Individual landholders hold concern timber companies are purchasing grazing land to establish softwood and hardwood plantations and further encouragement through the Salinity Action Plan will only accelerate the wide-scale planting. This fear has partly been confirmed during recent implementation where one timber company was responsible for more than 90 % of recharge planting in the target area.

The consultants preparing this SAP adopted the principal that if high-density tree planting for recharge control was needed on specific areas of the landscape, it was imperative the managers of that land be encouraged to adopt the preferred practices, irrespective of ownership arrangements or existing business structures. This was simply because the primary objective of the SAP is to achieve an environmental outcome, namely salinity reduction in the Moorabool River and for Geelong's urban water supply. Who owns the land on which the treatment needs to be adopted, either now or in the future, is secondary. However, the SAP also accepts implementation of this principal must be done with sensitivity towards local community feeling. The current tension appears to have arisen from confusion about the level of incentive provided and communication with neighbouring landholders rather than the intention of achieving salinity reduction.

There was widespread surprise that deep-rooted perennial pastures were not included as a recharge treatment option as the explanation for exclusion of this option did not reconcile with local experience. Research is currently under way to further investigate the role of perennial pastures as a recharge control option.

The proposed treatment of discharge control was well received. Many landholders had wanted to tackle the salinity directly but were unable to obtain the necessary financial and technical support in the past. Treatment of these areas is costly and without help, landholders take on a significant financial risk, especially as the likely financial returns are small compared with the required investment. In some instances this has been complicated by the recognised need of the asset manager to address waterlogging issues whilst institutional arrangements have actively discouraged water management on discharge areas. This tension needs to be resolved to provide asset managers with the community support to proceed. Examples of successful discharge revegetation have been established in the past two years, confirming the validity of the treatment options.

Land managers who own or adjoin areas of primary salinity support the land class fencing option. Adoption would be increased if tree planting was also supported part of the land class fencing.

Urban water resource managers

Rising salinity was a recognised as a concern to Barwon Water and some of its customers. They recognise an urgent need to investigate the causes of the rising trends in salinity and apply the appropriate treatments. Barwon Water is currently supporting revegetation projects within the Sheoaks – Moorabool sub-catchment via the Moorabool River Gorge Recovery Program. However, further investigation has indicated a significant and potentially serious threat to the quality of water supplied through the entire Moorabool system. The reasons for the apparent rise in salinity in this supply are unclear and in some cases speculative.

Environmental managers

Seven of the 12 target locations contained Ramsar and/or significant wetlands. Importantly, these environmental assets featured salinity as a natural and integral component of the environmental system. The ‘health’ of these wetlands and lakes was difficult to ascertain given the complex interactions with groundwater and climatic influences.

The most prominent threat appears to be in the Corangamite area, which contains Lake Corangamite, Lake Martin and Lake Gnarpurt. The future management of Lake Corangamite is under review (GHD 2004), however if the preferred options are adopted and the lake level rises, significant areas of primary salting are likely to be periodically inundated.

Other areas of concern were the Geelong – Lake Connewarre area and the complex series of lakes in the Colac – Eurack area. Consultation with the asset managers in these locations was made more difficult because of the shared management responsibility. The partners sharing the asset varied from location to location, often with day-to-day management responsibility being devolved to other organisations and, in one instance, private business (Cheetham Salt). Parks Victoria, the Department of Sustainability and Environment and several other management committees all recognised the need to apply ‘sympathetic’ management to these natural assets. This complexity was made more difficult with landholders on private land being recommended actions through the draft SAP that were in sharp contrast to either the way adjacent public land was currently being managed or in relation to the management arrangements they had with various public entities. These conflicting management arrangements need to be urgently addressed.

Analysis of asset manager needs

Despite the variability in response from different asset managers, some common threads can be drawn together which can inform any future intervention strategy. This was compiled using the program logic as a framework. This resulted in the responses from each asset manger being assessed for:

- The **capacity** of the asset managers within each area to undertake the task.
- The **attitude** (or motivation) of asset managers to want to address the salinity issue.
- The availability of **technologies** and **techniques** to treat salinity.
- The ability for asset managers to **target** where salinity treatment actions needed to occur.

A summary of this assessment has been made for each target location *(Table 4.2)*. A five-level scale has been adopted; low, low – moderate, moderate, moderate – high and high. Low represents an inability of the asset manager in the area to currently meet this need and, by inference, where intervention is required. Conversely, a high rating implies a very strong degree of confidence by the asset manager that this aspect of the salinity treatment is adequately addressed. There should be no need to provide additional resources or intervention, other than what is already occurring. However, changing circumstances such as the re-allocation of resources (for whatever reason) could easily change the current ratings.

The ratings are interpretations by the authors based on responses from the initial meetings and in some instances follow-up discussion with the asset managers.

Table 4.2: Summary of asset manager's response to proposed salinity treatment options, grouped by program logic

Target location	Asset manager	Type of treatment option proposed	TARGETTED ACTION (Ability to locate where the treatment is required in the landscape)	TECHNOLOGY (Evidence the proposed treatment option will manage salinity threat)	ATTUTUDE (Asset managers attitude to adopting the suggested treatment)	CAPACITY (Existing capacity of the asset managers to adopt the proposed treatment)
Upper Moorabool	Water Authorities	Unknown.	**Low** (research required)	**Low** (research required)	**Moderate** (recognised need to address the issue)	**Low** (may involve other parties support to implement
Morrisons – Sheoaks	Water Authorities	Engineering – investigation of pipeline.	**High** (link Lal Lal to Sheoaks directly)	**High** (deliver water to Sheoaks at Lal Lal levels)	**Low** (effects on Moorabool River flows, community awareness low)	**Moderate-High** (if cost benefit proven)
	Landholders	High density tree planting on recharge areas (treatment 1).	**Moderate** (ground truthing required)	**Moderate** (needs verification but opportunity exists)	**Low – Moderate** (salinity awareness low – new target area)	**Low** (financial, co-ordination and contractor incentive required)
		Tree planting adjoining or near saline discharge areas for watertable reduction / drawdown (treatment 4).	**Moderate** (ground truthing required)	**Moderate** (Few local examples available)	**Moderate** (Few local examples available)	**Low** (co-ordination, labour support and 75% financial incentive required)
		Protection and management of discharge areas including waterlogging control. (treatment 7).	**High**	**Moderate** (reduce salt wash from exposed sites)	**Moderate** (some landholders aware, others need encouraging)	**Low** (co-ordination, technical support and 75% financial incentive required)
Pittong	Landholders	Tree planting interception belts on recharge areas (treatment 2). Shallow surface drains to intercept lateral flows of perched watertables (treatment 3).	**Moderate** (design assistance required)	**Moderate**	**Low** (participatory trialling required)	**Moderate** (50% financial incentive, and co-ordination required)
		Protection and management of discharge areas including waterlogging control. (treatments 4, 7 & 8).	**High**	**High** (local examples available)	**High** (all landholders keen to address the issue)	**Low** (co-ordination, technical advice and 75% financial incentive required)
Illabarook	Landholders	Tree planting adjoining or near saline discharge areas for watertable reduction / drawdown (treatment 4).	**Moderate** (ground truthing required)	**Moderate – High** (local examples available)	**High**	**Low** (co-ordination, labour support and 75% financial incentive required)
		High density tree planting on recharge areas (treatment 1).	**Moderate** (ground truthing required)	**Low – Moderate** (few obvious local examples available)	**Low** (until proven to achieve commercial return equivalent to existing enterprises)	**Low** (commercialisation of trees required)

Table 4.2: Summary of asset manager's response to proposed salinity treatment options, grouped by program logic

Target location	Asset manager	Type of treatment option proposed	TARGETTED ACTION (Ability to locate where the treatment is required in the landscape)	TECHNOLOGY (Evidence the proposed treatment option will manage salinity threat)	ATTUTUDE (Asset managers attitude to adopting the suggested treatment)	CAPACITY (Existing capacity of the asset managers to adopt the proposed treatment)
Illabarook (cont)	Landholders	Protection and management of discharge areas, including waterlogging control (treatment 7).	**High**	**Moderate – High** (local examples available)	**Moderate** (many keen to address the issue)	**Low** (co-ordination, technical advice and 75% financial incentive required)
Lismore – Derrinallum	Shire	Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
	Landholders	Protection and management of discharge areas. (treatments 5a, 5b & 6).	**High**	**Moderate** (current treatments only marginally better than the status quo)	**Low – Moderate** (unconvinced of the return for the investment)	**Moderate** (co-ordination, technical advice and 50% financial incentive required)
	Telstra	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Parks Victoria	Unknown.	**Low** (research required)	**Low** (research required)	**Low** (unsure if a salinity threat exists)	**Low** (but may change when actions are determined)
Lake Corangamite	Consultation held over pending outcome of current reviews					
Colac - Eurack	Parks Victoria/DSE Crown Land	Protection and management of saline land and reserves.	**Moderate** (updated public/crown land mapping required)	**Moderate** (for reserve land but no influence on surrounding lands)	**High** (understand the importance of these reserves)	**Low** (under resourced to effectively manage all areas)
	Landholders	Protection and management of discharge areas. (treatments 5a, 5b, & 6).	**High**	**Moderate** (current treatments only marginally better than the status quo)	**Low – Moderate** (unconvinced of the return for the investment)	**Low – Moderate** (co-ordination, technical advice and 50% financial incentive required)
		Salinity planning overlay to prevent urban/rural subdivisions.	**High**	**High**	**Low** (would limit subdivision and resale values)	**Low** (would be financially damaging)
	Telstra	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Shire	Salinity planning overlay to prevent urban subdivisions.	**High**	**High**	**Moderate** (some need recognised)	**Low** (Lack knowledge and finances to create the necessary overlays and planning procedures)

Table 4.2: Summary of asset manager's response to proposed salinity treatment options, grouped by program logic

Target location	Asset manager	Type of treatment option proposed	TARGETTED ACTION (Ability to locate where the treatment is required in the landscape)	TECHNOLOGY (Evidence the proposed treatment option will manage salinity threat)	ATTUTUDE (Asset managers attitude to adopting the suggested treatment)	CAPACITY (Existing capacity of the asset managers to adopt the proposed treatment)
Colac - Eurack (cont)	Shire	Engineering solutions to prevent watertable encroachment.	**Low – Moderate** (investigation required)	**Moderate** (theoretically possible)	**Low** (potentially high cost for the rate payers protected)	**Low** (Need financial support to make it cost effective)
		Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
Warncoort	Shire	Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
	Landholders	Protection and management of discharge areas. (treatment 6).	**High**	**Moderate** (current treatments only marginally better than the status quo)	**Low – Moderate** (unconvinced of the return for the investment)	**Moderate** (co-ordination, technical advice and 50% financial incentive required)
	VicRoads	Appropriate road design.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Telstra	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Powercor	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Rail	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
	Gas	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**
Murdeduke	Shire	Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
	Landholders	Protection and management of discharge areas including waterlogging control (treatments 6 & 7).	**High**	**Moderate** wider range of treatments sought)	**Low – Moderate** (some landholder keen, others require encouraging)	**Low – Moderate** (co-ordination, technical advice and 75% financial incentive required)
	Telstra	Equipment protection.	**Moderate** (would value updated discharge maps)	**High**	**High**	**High**

Table 4.2: Summary of asset manager's response to proposed salinity treatment options, grouped by program logic

Target location	Asset manager	Type of treatment option proposed	TARGETTED ACTION (Ability to locate where the treatment is required in the landscape)	TECHNOLOGY (Evidence the proposed treatment option will manage salinity threat)	ATTUTUDE (Asset managers attitude to adopting the suggested treatment)	CAPACITY (Existing capacity of the asset managers to adopt the proposed treatment)
Murdeduke (cont)	Parks Victoria	Improved management of natural saline systems and adjoining lands.	**Moderate – High** (RAMSAR management plan identifies sources of external threats. Saline land categories need mapping)	**Moderate** (wider range of management regimes sought for public and private land).	**High** (understand the importance of the wetland)	**Low** (External threats beyond asset manager's control. co-ordination, technical advice and financial support required)
Modewarre	Shire	Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
	Landholders	Protection and management of discharge areas. (treatments 5a, 5b, & 6).	**High**	**Moderate - High** (local examples exist of well managed saline sites)	**Moderate** (many have done work, some still need encouraging)	**Low – Moderate** (co-ordination, technical advice and 75% financial incentive required)
	Parks Victoria / Lake Modewarre management	Unknown.	**Low** (additional research required)	**Low** (additional research required)	**High** (keen group with a management plan)	**Low – Moderate** (limited resources to implement management plan)
Geelong – Lake Connewarre	Parks Victoria	Improved management of natural saline systems and adjoining lands.	**Moderate – High** (RAMSAR management plan identifies sources of external threats. Saline land categories need mapping)	**Moderate** (wider range of management regimes sought for public and private land).	**High** (understand the importance of the wetland)	**Low** (External threats beyond asset manager's control. co-ordination, technical advice and financial support required)
	Landholders	Protection and management of discharge areas (treatments 5a, 5b & 6).	**High**	**Moderate** (wider range of treatments sought)	**Moderate** (evidence of keen landholders if support is provided)	**Low – Moderate** co-ordination, technical advice, time and 75% financial incentive required)
	Shire	Appropriate road design.	**Moderate** (Updated salinity discharge maps required)	**High** (Engineering technology exists)	**Low – Moderate** (unaware of the appropriate treatment)	**Low** (New skills required)
Lara	Cheetham Salt / Parks Vic	Protection and management of discharge areas. (treatments 5a, 5b).	**High**	**High**	**High** (attitudes can vary)	**High**
	Parks Victoria	Improved management of natural saline systems and adjoining lands.	**Moderate – High** (RAMSAR management plan identifies sources of external threats. Saline land categories need mapping)	**Moderate** (wider range of management regimes sought for public and private land).	**High** (understand the importance of the wetland)	**Low** (External threats beyond asset manager's control. co-ordination, technical advice and financial support required)
	VicRoads	Appropriate road design.	**High**	**High**	**High**	**High**

Wider stakeholder consultation

A draft Corangamite SAP was released in July 2003 to key stakeholders, other interested parties and the wider community. A total of 163 comments were received, with the majority of those comments coming from various groups within the DSE and the DPI. An additional Background Report (no. 7) has been prepared to respond to each comment (Dahlhaus & Nicholson 2005). More than 95 % of the comments related to clarity, difficulty in finding the relevant material in background reports and the need to update data set based on more recent information. This has been done.

There were four significant issues raised by more than one respondent that requires some discussion:

Target location selection process

The initial selection of target areas was based on a process developed by the Centre for Land Protection Research (now PIRVic). Identification used a framework that contained three components. The first was to disaggregate the landscapes of the region into similar groundwater systems (Dahlhaus *et al.*, 2002b), the second was assessment of salinity risk based on the intersection of the salinity hazard with regional assets (Heislers & Brewin, 2003) and the third was a stream water quality assessment (Dahlhaus 2003b). A final check was introduced to 'ground truth' the asset salinity hazard intersections (Dahlhaus 2003a). It was clearly recognised the availability of accurate or comprehensive data sets limited the selection process. The most critical deficiencies have been identified and are currently being addressed or are listed in the high-priority research needs *(Section 4.6)*.

The target locations formed the basis for the remainder of the development process, namely the consultation approach, management action targets and benefit cost analysis. This selection approach preceded the asset-based approach currently being encouraged for investment in natural resource management. Some comments suggested the selection process should be revisited, but given the resources required to redo the selection process, this is not feasible.

Attempts have been made to rework the selection process using the asset-based approach recommended by the DSE *(see Section 2)*. Although deficiencies still exist, the work completed so far does provide a platform to undertake a more comprehensive asset-based approach at the completion of this salinity action plan in 2008.

The consultation process

Criticism was levelled at the targeted consultation approach adopted in the development of the salinity action plan. However there were three strong reasons for taking this direction.

Firstly, the adoption of appropriate salinity management requires acceptance and direct action by the person or authority who owns or manages the asset under threat or whose actions are contributing to the salinity hazard. The logic behind the asset-based approach supports this position. Unless these parties are engaged successfully, the desired salinity management will not be achieved.

Secondly, there was a need to create ownership of the problem and the solutions (the treatments). A direct approach was adopted where the reasons for the salinity problem could be discussed, possible treatments examined and an implementation program formulated that best suited the needs of those particular asset managers in that specific area. This targeted approach recognised that each area was likely to have different needs. It also gave the ability for the asset manager to be recognised for the work that has been undertaken in the past decade and for this new plan to acknowledge and respect this activity.

Finally the consultancy team was fully aware of the considerable pressure that had already been placed on stakeholders from the Regional Catchment Strategy review and renewal process as well as the multitude on foundation projects under way as part of the National Action Plan. There was a real risk that further wide community consultation in the early stages of plan development would encounter stakeholder burnout. A further risk was the possible perception that the series of consultancies initiated by the Corangamite CMA consultancy was uncoordinated and repetitive. This was to be avoided where possible.

A preliminary draft was prepared in July 2003 and presented to the CMA which then sought wider stakeholder and community comment.

Incorporation of biodiversity values

The selection process used to identify target locations did not include ecological vegetation classes (EVC) and the VROT and AROT information did not specify what flora or fauna was at a particular location. The EVC data was not readily available to the Centre for Land Protection Research when the GSHARP modelling was being completed. This deficiency was identified and noted at the time.

Subsequent availability of EVC and native vegetation conservation significance potential maps has allowed this data to be included in considerations for each target area. However, because the initial selection process has not been re-run *(for reasons outlined in 4.4.7.1)*, it has not resulted in new target locations being identified, although areas of interest have been identified *(refer to Section 2.4.4)*. The biodiversity values will be fully included when the asset-based approach is completed again in 2008.

Resource condition targets.

Following the implementation of the draft SAP in 2003, several research and investigation projects have been completed. The knowledge gained through the completion of these projects has provided greater capability to set pragmatic and achievable resource condition targets for the target locations.

Resource condition targets have been reset *(Section 6)*.

4.5 Adoption of proposed management actions

Discussions with asset managers at each target location allowed rates of adoption to be explored for the appropriate management options. Incentives, methods of support, preferred delivery agents, potential co-investors and next steps were all discussed (Nicholson *et al.* 2003) and are important to note because if not delivered in this way, the rate of adoption may not occur. Further consultation with those involved with implementation and feedback from asset managers (Nicholson 2005) has enhanced understanding of the adoption constraints. These insights are summarised in *Table 4.3.*

Some of the proposed treatment options for salinity are occurring even without the existence of a salinity program. This needs to be acknowledged when assessing the likely influence of future salinity intervention.

The quantities of works to be adopted in each targeted area are based on asset manager response and include all possible treatments *(Table 4.4)*. However, after the benefit cost analysis is completed, some listed treatments may not be recommended as management action targets *(see Section 5)*. Nevertheless, these figures should form the basis for developing management action targets. It should be noted the numbers presented are the difference between the intervention and non-intervention (do nothing) scenarios.

Table 4.3: Next actions and recommended delivery agent / partners (based on consultation in 2003, revised in 2005)

Target location	Next actions	Asset manager's suggested delivery agent	Immediate co-investment parties
Lake Corangamite	Commence Lake Corangamite, Gnarpurt, Martin and Cundare pool research.	University post-graduate projects.	Research – Natural Heritage Trust and national action plan, universities.
	Commence limited discharge management program above 118 AHD.	DPI in conjunction with local groups.	NHT, NAP.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Morrisons – Sheoaks	Commence investigation of possible cause of rising salinity trend and possible treatment actions.	Central Highlands Water in conjunction with appropriate consultants or research organisations.	Water quality – Barwon Water, CCMA waterways program.
	Integrated farm planning and salinity technical support program.	Moorabool River Gorge Recovery Program (MRGRP) partnership between landcare, Barwon Water, Moorabool Shire, CCMA & DPI. Technical support by DPI.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land.
	Commence saline discharge area revegetation program.		
	Commence tree planting work on areas immediately above discharge sites.		
	Commence saline spring protection and management.		
	Commence methods of making commercial forestry more attractive on recharge areas.	MRGRP with Agency Farm Forestry support.	Forestry – DPI Farm Forestry Cost share programs, forestry companies, greenhouse investors.
	Monitor existing recharge planting for efficacy.	MRGRP in conjunction with university and hydrogeology monitoring and DPI.	NHT, NAP.
	Implement rabbit control program.	MRGRP in partnership with DPI.	Pest control – DPI.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water Boards, Parks Victoria, DPI.
Upper Moorabool	Commence investigation of possible cause of rising salinity trend and possible treatment actions.	Central Highlands Water in conjunction with appropriate consultants or research organisations.	Water quality – Central Highlands Water, Barwon Water, Corangamite CMA Waterways program, Southern Rural Water.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Colac Eurack	Training for municipal road engineers and crews.	Colac Otway Shire in partnership with qualified consultant.	Colac Otway Shire.
	Create salinity overlay and procedural processes.		
	Investigate the engineering options to protect urban infrastructure from rising watertables.		
	Commence limited discharge management program.	Renewed Partnership Program required to include landcare, DPI, CCMA and Parks Vic.	Parks Victoria.
	Conduct PAR trials to examine increasing profitability from marginally saline land.		Revegetation – Natural Heritage Trust and National action plan. Industry program on productive use of saline land.

Target location	Next actions	Asset manager's suggested delivery agent	Immediate co-investment parties
Colac Eurack	Commence Lake Colac, Lough Calvert and Beeac research.	University post-graduate projects.	Research - Natural Heritage Trust and national action plan, universities, CCMA wetlands program.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water Boards, Parks Victoria, DPI.
Geelong – Lake Connewarre	Training for municipal road engineers and crews.	Engineering consultants.	City of Greater Geelong.
	Support lake and riparian revegetation programs. Develop wetland network/partnership program for target area.	Joint works programs delivered locally as partnership between Parks Victoria, City of Greater Geelong, DPI, CCMA, Bellarine Landcare, Greening Connewarre, and Field and Game. Technical support via agency, where appropriate.	Parks Victoria. City of Greater Geelong environment unit and stormwater management.
	Conduct PAR trials to broaden landuse options for saline land using natural species. Integrated farm planning and salinity technical support program.	Joint works programs delivered locally as partnership between Parks Victoria, City of Greater Geelong, DPI, CCMA, Bellarine Landcare, Greening Connewarre, and Field and Game. Technical support via agency, where appropriate.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land. Wetland management – Parks Victoria, CCMA waterways and wetlands programs.
	Implement rabbit control program.	Joint program in partnership with DPI.	Pest control – DPI.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water Boards, Parks Victoria, DPI.
Pittong	Commence discharge management program, including technical advice on surface water management.	Woady Yaloak Catchment Group (WYCG), through the neighbourhood group process but with technical advice on drainage and water management.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land.
	Conduct PAR[4] trials on suggested recharge control treatments.	WYCG in conjunction with university and hydrogeology monitoring.	NHT, NAP.
	Implement rabbit control program.	WYCG in partnership with DPI.	Pest control – DPI.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water Boards, Parks Victoria, DPI.
Illabarook	Commence tree planting work on areas immediately above discharge sites.	Woady Yaloak Catchment Group (WYCG), through the neighbourhood group process.	Revegetation – Natural Heritage Trust and National action plan.
	Commence discharge management program, including technical advice on surface water management.	WYCG, through the neighbourhood group process but with technical advice on drainage and water management.	Industry program on productive use of saline land.
	Demonstration of potential success with commercial forestry.	DPI with commercial forestry interest and landholder representatives.	Forestry – DPI Farm Forestry cost share programs, forestry companies, greenhouse sink investors (govt).
	Implement rabbit control program.	WYCG in partnership with DPI.	Pest control – DPI.
	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.

[4] Participatory Action Research

Target location	Next actions	Asset manager's suggested delivery agent	Immediate co-investment parties
Lismore – Derrinallum	Training for municipal road engineers and crews.	Engineering consultants.	Corangamite Shire.
	Commence Lake Toolirook research.	University post-graduate projects.	Research – Natural Heritage Trust and national action plan, universities.
	Commence limited discharge management program.	Lismore Land Protection Group (LLPG), with technical advice from DPI.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land.
	Conduct PAR trials to examine increasing profitability from marginally saline land.	Lismore Land Protection Group in partnership with industry groups.	
	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Warncoort	Training for municipal road engineers and crews.	Engineering consultants.	
	Facilitate erosion control and drainage rules discussions.	Birregurra Creek Land Protection Group (BCLPG) and CCMA, in partnership with drainage scheme operators.	CCMA waterways program.
	Commence limited discharge management program.	BCLPG.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land.
	Commence resource condition monitoring	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Murdeduke	Training for municipal road engineers and crews.	Engineering consultants.	
	Support lake and riparian revegetation programs.	Renewed partnership program required between Barwon Valley Landcare Group (BVLG), Parks Vic, Greening Aust, DPI, Surf Coast Shire, CCMA and Leigh catchments.	Wetland management – Parks Victoria, CCMA waterways and wetlands programs.
	Commence limited discharge management program.	Renewed partnership program required between Barwon Valley Landcare Group (BVLG), Parks Vic, Greening Aust, DPI, Surf Coast Shire, CCMA and Leigh catchments.	Revegetation – CCMA waterways program, Natural Heritage Trust and National action plan.
	Conduct PAR trials to broaden landuse options for saline land.		
	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Modewarre	Training for municipal road engineers and crews.	Engineering consultants.	
	Implement revegetation programs and improved land management of local lakes, wetlands and riparian areas.	Renewed partnership program required to include Thompson Ck Catchment Project, Lake Modewarre Committee, Surf Coast Shire, DPI, CCMA and Parks Vic.	Revegetation – Natural Heritage Trust and national action plan. Industry program on productive use of saline land.
	Continue discharge site protection projects.		
	Commence Lake Modewarre, Gherang and Browns Swamp research.	University post-graduate projects.	Wetland management – Parks Victoria, CCMA waterways and wetlands programs.

Target location	Next actions	Asset manager's suggested delivery agent	Immediate co-investment parties
Modewarre	Commence resource condition monitoring.	To be determined.	Monitoring – Water boards, Parks Victoria, DPI.
Lara	Commence limited discharge management program.	Parks Vic, City of Greater Geelong, DPI, CCMA, Avalon Landcare.	Wetland management – Parks Victoria, CCMA waterways and wetlands programs, Cheetham Salt.
	Support cooperative saline land /wetland protection programs.	Joint works programs delivered locally as partnership project between above groups.	
	Commence resource condition monitoring.	To be determined.	Monitoring – Parks Victoria, DPI.

Table 4.3: Next actions and recommended delivery agent / partners (based on consultation in 2003, revised in 2005)

Target location	Recharge treatments (ha / yr)				Discharge treatments (ha / yr)				
	1. High density tree planting	2. Tree planting interception belts	3. Shallow surface drains to intercept lateral flow of perched groundwater	4. Tree planting adjoining or near saline discharge	5a. Protection & management of discharge areas to allow natural vegetation recovery (fencing only)	5b. Protection & management of discharge areas to allow natural vegetation recovery (with trees)	6. Protection & management of discharge areas with establishment of additional vegetation	7. Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover	8. Water logging control
Lake Corangamite					27 (private)	27 (private)	44 (private)		
Morrisons – SheOaks	220[5] 82[6]			5				5	
Colac Eurack					9 (public) 22 (private)	44 (private)	6 (public) 26 (private)		
Geelong – Lake Connewarre					33 (public) 37 (private)	37 (private)	4 (private)		
Pittong		189	194	22				44	145
Illabarook	18 (public) 17 (private)[6] 173 (private)[8]			7				26	
Lismore – Derrinallum					7 (public) 23 (private)		16 (private)		
Warncoort						38			
Murdeduke							29 (public/private)	13 (public/private)	
Modewarre					24 (public/private)		16 (public/private)		
Lara					14 (public)				
Upper west Moorabool	**No on-ground targets set until current studies are completed**								

Table 4.4: Annual works targets by treatment type and location (difference between the intervention and non-intervention scenarios).

5 Based on a once off payment, primarily design for private forestry companies

6 Based on an annual payment, intended for private landholders.

7 Based on once off payment at establishment

8 Based on an annual payment

4.6 Research

Throughout the development of the SAP a number of research and investigation projects were identified. In general, the research is required to improve the asset-based approach to targeting investment (i.e. improved assessment of both the threats and assets), understand the salinity processes, improve treatment options and quantifying the effects of the treatment. Many of these knowledge gaps were identified during the asset manager consultation and stakeholder feedback stages of the project. The research program is tabulated *(Table 4.5).*

Research has already commenced for some of the listed projects and is pending for other projects. The list is not intended to exclude new or innovative research and investigation. However, it is anticipated the output of any new research should assist in improving the success of salinity intervention. It is anticipated that new research projects will be included in the annual research prospectus developed under the Corangamite Research, Development and Investigation Strategy currently being developed.

A more comprehensive discussion of the research needs is provided in Background Reports 6 and 9 (Dahlhaus, *et al.*, 2003, 2005b), including the scale of the projects and suggested options for research delivery. In some instances university post-graduate research would be the most appropriate approach, in other cases commissioned research may be needed (e.g. CSIRO, CRCs, state research institutions, private consultants). The research program has been included in the economic analysis.

Research project	Year											
	2004		2005		2006		2007		2008		2009	
Research reasons for rising salt trends in Moorabool River.					Commenced	Commenced	Pending	Pending	Pending	Pending		
Disaggregate groundwater flow systems for the volcanic plains.				Commenced	Commenced							
Research the impact of raising the level of Lake Corangamite on the land salinity in the surrounding area.						Pending	Pending					
Research groundwater dependent saline ecosystems for improved groundwater and salinity management.					Commenced	Commenced	Pending	Pending				
Research the threat of salinity on vegetation of high conservation significance in "areas of interest" and SAP target areas.							Pending	Pending				
Test Gravel Cap hypothesis for salinity in Morrisons – Sheoaks and Illabarook target areas.						Commenced	Commenced	Pending	Pending			
Research on-site and off-site impacts of salinity treatment to date (both recharge and discharge).	Commenced	Commenced				Pending	Pending	Pending	Pending			
Research role of deep rooted perennial pastures and other options.		Commenced	Commenced	Commenced	Commenced	Pending	Pending					
Investigate and expand the treatment options for discharge management.								Pending	Pending	Pending	Pending	
Investigate and improve the cost-benefit assumptions.										Pending	Pending	
Review the asset – threat model for selecting priority areas for salinity management, including the layers and their values and weightings.										Pending	Pending	
Improve salinity process models, especially in relation to the cause and effect.						Lower priority	Lower priority	Lower priority	Lower priority			
Improve knowledge of all groundwater flow systems.						Lower priority	Lower priority	Lower priority	Lower priority			
Research the reasons for the historical trends for land and water salinity.						Lower priority	Lower priority	Lower priority	Lower priority			
Investigate salinity impact of raised bed cropping and legume cropping.						Lower priority	Lower priority	Lower priority	Lower priority			
Improve parameters for numerical hydrology and land-use models.						Lower priority	Lower priority	Lower priority	Lower priority			
Research improved methods for valuing of non-market benefits.						Lower priority	Lower priority	Lower priority	Lower priority			

Commenced *Pending* *Lower priority research (co-investment opportunities)*

Table 4.5: Research projects

5. Benefit – cost analysis and priority setting

The benefit-cost analysis assesses the difference between the 'No-Plan' scenario and the 'With-Plan' scenario. The 'No-Plan' scenario represents the 'base' case, modelling the 'added' costs of degradation over time if no new initiatives are introduced to manage the problems. The 'No-Plan' scenario incorporates any natural resource management efforts underway and recognises the likely impacts of any salinity control strategies already implemented or planned for that area.

A 'No-Plan' scenario differs from a 'Do-Nothing' scenario, which would be the case where no salinity management strategies already planned for are implemented over the planning horizon. As it is likely that at least some minor control works would be implemented over this time, using the 'Do-Nothing' scenario as the 'base' case would overestimate the benefits from introducing the SAP.

A 'With-Plan' scenario represents the 'alternative' case, modelling the benefits and costs of implementing a range of solutions for either addressing the current salinity problems or preventing them from becoming as severe in future years as indicated in the 'No-Plan' scenario.

The benefit-cost analysis used in the Corangamite SAP models the difference between the 'No-Plan' and the 'With-Plan' scenarios.

A number of investment criteria are available to evaluate a project based on economic merit. This Benefit-Cost Analysis considers the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) of implementing the salinity management actions and programs outlined in this plan.

The NPV is the difference between the discounted values at a required discount rate of future benefits and costs associated with the project. A positive NPV indicates that there is a greater value being generated than resources consumed and therefore, based on pure economics, the project should be undertaken. If the NPV is negative, the project is not economically viable.

The BCR is equal to the present value of benefits divided by the present value of costs. A project is normally considered desirable if the BCR is greater than one, however where significant non-market benefits occur as a result of intervention, such as improved water quality or wetland health, a figure less than one can be acceptable. As described in earlier sections, salinity in the Corangamite CMA Region is primarily about water quality and primary saline assets. Therefore, consideration of the BCR and NPV results needs to be viewed with caution.

The Discount Rate can be thought of as the rate of exchange between value today and value in the future. As required by government guidelines, 4% and 8% discount rates were used in this benefit-cost analysis.

The 4% discount rate refers to the return the government expects from its investment in natural resource management activities, while the 8% discount rate reflects the assumed financial return a private landholder would expect from an investment. The lifespan on all project activities and impacts is assumed to be 30-years.

The benefit-cost model is presented in three parts:

1. **Target area analysis,** which examines the costs and benefits for the 12 target locations.
2. **Whole catchment analysis,** identifies the costs of the research and investigation, monitoring and program support aspects of the SAP.
3. **Catchment-wide analysis.** This is the result of combining the target area analysis and the whole catchment analysis.

5.1 Information sources

The information used to assess the benefits and costs of saline land and water management in the Corangamite Catchment has been derived from the following sources:

- Local knowledge and experience of the consultancy team.
- Experience from DPI staff involved in earlier sanity implementation.
- Asset mangers and stakeholders interviewed during the consultation process.
- Published and unpublished material, including information obtained from the Corangamite CMA, the two water authorities operating in the area (Barwon Water and Central Highlands Water), DPI, DSE, ABS and ABARE.
- Published reports, including a Murray Darling Basin Commission (MDBC) report regarding salinity damage cost functions for urban water (Wilson & Laurie 2002), and the National Land and Water Resources Audit (NLWRA): audit and dryland salinity reports, citing road degradation costs due to high watertables (URS 2002).

5.2 Assumptions

The following assumptions were used to develop the benefit-costs analysis.

Treatment costs in target locations

Eight treatment options were explored for recharge control and saline land management in the 12 target locations. The rationale behind using these treatments is described in Section 4.2 of this report. A summary of these costs is provided *(Table 5.1a, 5.1b)*.

Costs were also assigned to the training of municipal road engineers and crews to reduce premature road failure due to salinity. This was a once-off cost of $35,000. The training was applicable to eight target locations and four municipalities.

Treatment		Assumed treatment costs ($/ha)
Recharge control	High-density tree planting.	Three variations were considered: 1) $1,100, for private forestry companies. 2) $1,650 for private landholders, as a once-off payment. 3) $270/ha/yr for private landholders as an annual payment (based on average gross margin and stocking rate).
	Tree planting interception belts.	$465
	Shallow surface drains to intercept lateral flow of perched groundwater.	$150
	Tree planting adjoining or near saline discharge.	$3,300

Table 5.1a: Summary of costs for recharge control

Treatment		Assumed treatment costs[9] ($/ha)
Discharge management	Protection and management of discharge areas to allow natural vegetation recovery (fencing only). Protection and management of discharge areas to allow natural vegetation recovery (with trees).	$315 $3,300
	Protection and management of discharge areas with establishment of additional vegetation.	$600
	Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover.	$200
	Waterlogging control only.	$200

Table 5.1b: Summary of costs for discharge management

Benefits in target locations

The benefits derived from the implementation of the SAP are partly tangible (they have a market value) and partly intangible (non-market value). Most of the environmental and social outcomes provided by improved salinity management are not traded in commercial markets and the values of these outcomes are difficult to estimate. These can only be presented descriptively in this analysis.

The benefits from recharge and discharge treatment occur to the land, water and infrastructure assets. The key benefits are listed.

Land benefits from treatment

The market benefits to the land from recharge and discharge treatments are predominantly increasing agricultural production through grazing or timber. The values of these benefits are described *(Table 5.2a, 5.2b)*.The non-market benefits to land include potential improvements in biodiversity as a result of revegetation (flora and fauna), the protection and enhancement of naturally saline land assets and the reduction in salt accumulation on the soil surface, which in turn reduces salt wash-off.

	Treatment	Assumed land treatment benefits ($/ha)
Recharge control	High-density tree planting.	Calculated as: 30% pulpwood, harvested every 12 years @ $3,600 to 4,500[10]. 70% sawlogs, thinned at 12 and 20 years, clear felled at 30 years @ $7,080 to $8,850.
	Tree planting interception belts.	No market benefits.
	Shallow surface drains to intercept lateral flow of perched groundwater.	No market benefits.
	Tree planting adjoining or near saline discharge.	No market benefits.

Table 5.2a: Summary of market benefits to land assets from recharge control

[9] for all discharge treatments a cost for weed control was incorporated. The level of this cost differed by area, being dependent upon the percentage of spiny rush. In areas where rabbits were believed to be a problem, an extra $50/ha was included for any area treated to help in the control of rabbits.
[10] It was assumed yield at Morrisons – Sheoaks would be 75% of highly productive forestry plantations and only 60% productive at Illabarook.

	Treatment	Assumed treatment costs[9] ($/ha)
Discharge management	Protection and management of discharge areas to allow natural vegetation recovery (fencing only). Protection and management of discharge areas to allow natural vegetation recovery (with trees).	Calculated as 20% of production from non saline land x gross margin of $22.50/DSE[11].
	Protection and management of discharge areas with establishment of additional vegetation.	Calculated as 50% of production from non-saline land x gross margin of $22.50/DSE.
	Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover.	Calculated as 75% of production from non-saline land x gross margin of $22.50/DSE.
	Waterlogging control only.	Calculated as 30% of production from non-saline land x gross margin of $22.50/DSE.

Table 5.2b: Summary of market benefits to land assets from discharge management

[11] DSE means Dry Sheep Equivalent (refer Appendix B for definition). Stocking rates vary in each target area. Refer to Background Report 5 for target location details.

Water benefits from treatment

Urban water users (households, industry and commerce) are the only market benefits identified from recharge and discharge treatments and these are only assigned to the water removed from the Morrisons – Sheoaks target location.

Saline damage cost functions from Wilson & Ivey (2002) were used in the calculation. The following assumptions were adopted:

- A benefit of $0.38 per EC (µS/cm) reduction for each household in Geelong.
- A benefit of $2.80 per EC (µS/cm) reduction for every ML of water used by industry.
- Water from the Morrison – Sheoaks off-take is supplied to 16,274 households in Geelong.
- 4,160 ML water from the Morrison – Sheoaks off-take is used by industry and commerce in Geelong.

The non-market benefits to the water asset include improvements in ecological heath of waterways and wetlands in the region as well as enhancement of riparian zones.

Infrastructure and utility benefits from treatment

Consultation with VicRoads, National Rail, Powercor, Telstra and Gasnet Australia suggested these asset managers were currently managing the salinity threat through their existing design and construction programs. Therefore no benefits (or costs) were assigned to these assets.

Infrastructure benefits were only assigned to roads under the management of local government. Mapping would indicate 19.6km of sealed roads and 16.7km of gravel roads are currently failing prematurely because of salinity. The proposed treatment (training program with local government) is assumed to reduce the need for road repair by 50%. The benefits have been assigned as $600 perkm per year for sealed roads (excluding highways), and $400 perkm per year for gravel roads.

There were no non-market benefits assigned to infrastructure and utilities. Further details of the cost and benefit assumptions used in the benefit-cost model are detailed in Background Report 5 (Kelliher *et al.* 2006).

Costs for whole catchment activity

The whole catchment analysis includes the costs of the research and investigation, monitoring and program support. The annual costs have been assigned as:

Extension

• Education and extension	$100,000 per person
• Management and support	$120,000 per person

Research

• Research topics	$100,000 per program
• Technical consultancy	$ 40,000 per contract
• Post-graduate research	$ 20,000 per scholarship

Monitoring

• New gauging station	$ 50,000 per base
• New bore	$ 10,000 per bore
• Characterisation of site	$ 5,000 per site
• Ongoing monitoring	$ 30,000 per year

Other assumptions

Additional assumptions used in the analysis include:

- Analysis is over a 30-year period.
- Adoption rates are taken from *Table 4.4* in Section 4.5 for a 10-year period. They are assigned to treatment on primary and secondary salting sites and for public and private land. Details on how the adoption rates were derived are discussed in Background Report 4 (Nicholson *et al.* 2003) and Background Report 8 (Nicholson 2005).
- The benefits derived from the various treatments are:
  - Recharge planting begins to generate benefits after five years.
  - Saline discharge treatment begins to generate benefits after one year.

5.3 Benefit cost analysis

The benefit-cost model is presented in three parts;

- Target area analysis,
- Whole catchment analysis,
- Catchment-wide analysis.

Target area analysis

Each target area of the Corangamite Catchment is unique in the extent of the salinity problem, the mix of actions proposed and the projected level of adoption.

The tangible costs and benefits for the 12 target locations are listed *(Table 5.3 and Table 5.4)*. The benefits-cost ratios and net present value are also presented, along with the descriptions of the non-market benefits *(Table 5.5)*. It could be argued some of the non-market benefits listed in *Table 5.5* do have a market value. However, defining these in monetary terms was beyond the scope of this analysis.

Target location	Market costs @ 4%			Market costs @ 8%		
	Recharge costs	Discharge costs	TOTAL	Recharge costs	Discharge costs	TOTAL
Upper West Moorabool	No on-ground works defined			No on-ground works defined		
Morrisons – Sheoaks	$6,405,444	$33,941	$6,439,385	$4,300,212	$27,039	$4,327,251
Pittong	$1,631,437	$513,470	$2,144,907	$1,299,687	$418,311	$1,717,998
Illabarook	$8,290,127 (annual payment)	$169,837 (annual payment)	$8,459,964 (annual payment)	$5,165,867 (annual payment)	$135,301 (annual payment)	$5,301,169 (annual payment)
	$485,024 (once-off)	$169,837 (once-off)	$654,861 (once-off)	$358,148 (once-off)	$135,301 (once-off)	$493,450 (once-off)
Lismore – Derrinallum		$152,379	$152,379		$121,985	$121,985
Lake Corangamite		$938,446	$938,446		$747,615	$747,615
Colac – Eurack		$1,328,739	$1,328,739		$1,059,134	$1,059,134
Warncoort		$784,861	$784,861		$625,853	$625,853
Murdeduke		$188,289	$188,289		$150,593	$150,593
Modewarre		$113,386	$113,386		$90,921	$90,921
Geelong – Lake Connewarre		$1,109,073	$1,109,073		$884,137	$884,137
Lara		$10,493	$10,493		$8,360	$8,360

Table 5.3: Market costs for on-ground works in each target location (discounted @ 4% and 8%)

Target location	Market costs @ 4%				Market costs @ 8%			
	Agriculture & forestry	Infrastructure & roads	Urban water	TOTAL	Agriculture & forestry	Infrastructure & roads	Urban water	TOTAL
Upper West Moorabool	No on-ground works defined			$0	No on-ground works defined			$0
Morrisons – Sheoaks	$15,518,422		$583,229	$16,101,651	$7,155,880		$287,254	$7,443,134
Pittong	$2,425,880			$2,425,880	$1,329,452			$1,329,452
Illabarook	$7,731,753			$7,731,753	$3,617,624			$3,617,624
	$640,896			$640,896	$351,229			$351,229
Lismore – Derrinallum	$607,145	$2,561		$609,705	$345,287	$1,605		$346,892
Lake Corangamite	$862,300			$862,300	$540,599			$540,599
Colac – Eurack	$1,049,818	$7,067		$1,056,885	$621,468	$4,431		$625,898
Warncoort	$292,647	$3,077		$295,724	$183,468	$1,929		$185,397
Murdeduke	$610,196	$1,643		$611,840	$368,601	$1,030		$369,631
Modewarre	$311,827	$3,994		$315,882	$179,267	$2,504		$181,772
Geelong – Lake Connewarre	$411,005	$13,366		$424,372	$251,559	$8,380		$259,938
Lara				$0				$0

Table 5.4: Market benefits for on-ground works in each target location (discounted @ 4% and 8%)

Target location	Market benefits	BCR (@ 4%)	NPV (@ 4%)	Non-market benefits
Upper West Moorabool	• None calculated until research is completed.	0	$0	• Potential in-stream effects of reduced salinity. • Environmental benefits from treatment options (when identified).
Morrisons – Sheoaks	• Reclamation of saline land for agriculture. • Forestry production. • Lower salinity in urban water.	2.50	$9,662,266	• In-stream effects of reduced salinity. • Biodiversity benefits from tree belts around discharge areas. • Aesthetic benefits from more trees in the landscape.
Pittong	• Reclamation of saline land for agriculture.	1.13	$280,973	• In-stream effects of reduced salinity in the Woady Yaloak River. • Biodiversity benefits from tree belts. • Aesthetic benefits from more trees in the landscape. • Potential to impact on the water quality of Lake Corangamite.
Illabarook	• Reclamation of saline land for agriculture. • Forestry production.	0.91 (annual payment) 0.98 (once off payment)	-$728,211 -$13,965	• In-stream effects of reduced salinity in the Woady Yaloak River. • Biodiversity benefits from tree belts around discharge areas. • Aesthetic benefits from more trees in the landscape. • Potential to impact on the water quality of Lake Corangamite.
Lismore – Derrinallum	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	4.00	$457,326	• Possible environmentally important refugia site for nearby Ramsar-listed wetlands and lakes. • Reduced saline wash-off to Lake Corangamite.
Lake Corangamite	• Reclamation of saline land for agriculture.	0.92	-$76,146	• Potential to protect internationally recognised lakes and wetlands identified to be very seriously threatened. • Protection of high conservation significance saline sites.
Colac – Eurack	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	0.80	-$271,853	• Potential to protect internationally recognised lakes and wetlands identified to be very seriously threatened. • Protection of high conservation significance saline sites.
Warncoort	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	0.38	-$489,137	• Potential to protect the ecology of the Birregurra Creek.
Murdeduke	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	3.25	$423,551	• Potential to protect an internationally recognised lake identified to be at risk. • Enhanced biodiversity values of discharge treatment options on primary salting (public and private land).

Table 5.5: Market and non market benefits for the 12 target locations

Target location	Market benefits	BCR (@ 4%)	NPV (@ 4%)	Non-market benefits
Modewarre	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	2.79	$202,435	• Potential to protect nationally important lakes and recreational lake. • Enhanced biodiversity values of discharge treatment options on primary salting (public and private land).
Geelong – Lake Connewarre	• Reclamation of saline land for agriculture. • Reduction in premature breakdown of roads.	0.38	-$684,701	• Potential to protect an internationally recognised wetlands and estuary which forms one of Australia's most significant environmental assets. • Enhanced biodiversity values of discharge treatment options on primary salting (public and private land).
Lara	• None.	0	-$10,493	• Potential to aid in the protection of an internationally recognised wetlands and estuary which forms one of Australia's most significant environmental assets.

Table 5.5: Market and non market benefits for the 12 target locations

The results show a BCR greater than one for six of the target locations. This is primarily due to the significant returns from forestry investment and the positive benefits from reclaiming saline land for agricultural production. The target locations with a BCR less than one have important non-market benefits.

Consultation with land managers in the Illabarook area indicated the adoption of high-density tree planting on recharge areas would be greatly accelerated if the proposed once-off payment be replaced with an annual payment of $270/ha/yr. Benefit-cost analysis suggests this investment would have a negative NPV of $728,000 @ 4% and $1.68 million @ 8%. Given most of the benefits from this scale of planting are private, there is limited justification to invest public monies to this extent to achieve this outcome. The alternative of a once-off payment, while reducing the rate of adoption, provides a NPV close to one. Therefore the annual payment incentive at Illabarook has been excluded from further analysis.

Whole-catchment analysis

The whole of catchment analysis identifies the costs of the research and investigation, monitoring and program support aspects of the SAP. These activities cannot be assigned to a specific target location as they are conducted over many target locations or outside the 12 target locations. Assigning market benefits to this work is difficult, preventing meaningful BCR or NPVs to be developed. They are listed as costs only *(Table 5.6)*.

Discount rates	NPV Costs ($)
4%	$9,978,924
8%	$7,718,915

Table 5.6: Net present value of costs associated with whole of catchment activities

Catchment-wide analysis

The catchment-wide analysis combines the target area analysis and the whole-catchment analysis *(Table 5.7)*.

Discount rates	NPV Costs ($)	BCR
4%	$498,668	0.98
8%	$6,312,268	0.65

Table 5.7: Net present value and benefit-cost ratio for catchment-wide activity

The results show a catchment-wide benefit cost ratio slightly less than one. This is not surprising given the many salinity costs are directed at protecting or enhancing assets which have not been assigned a market value.

Sensitivity analysis

The values of future costs and benefits of the NPV and BCR are based on forecasts of the future and cannot be know with certainty. While they are, or should be the 'most likely' values, it is important to test the key variables used to determine the sensitivity of the economic indicators.

Where the outcomes are shown to be sensitive to changes in a variable, the appropriateness and impact of the variable should be checked, along with whether any changes to the design of the program or underlying assumption are warranted.

The impacts of changing key variables outlined *(Table 5.8)*, with additional discussion provided in Background Report 5 (Kelliher *et al.* 2006).

Key variable	Original BCR	Overall BCR sensitivity to changing values
Farm gross margin per DSE – testing ± 20%.	0.98	0.94 to 1.01
The cost of salinity to urban water users – testing values used in alternate reports	0.98	0.96
The salinity reductions estimates for the Moorabool River – testing ± 10%	0.98	No change
The forestry return reduction factor – testing ±- 5% & 10%	0.98	0.94 to 1.02

Table 5.8: Sensitivity analysis

Changing these key variables had minor impact on the overall benefit-cost ratio. The most significant change was altering the returns from private forestry. Conservative returns were used in the initial analysis (75% of potential yield in Morrisons – Sheoaks and 60% of potential yield in Illabarook), however changes to these returns only altered the BCR by 0.04.

5.4 Priority Setting

Setting priorities for salinity management is complex due to the many competing interests. In the case of the Corangamite CMA, the non-market benefits such as Ramsar-listed wetlands and lakes, stream ecology and significant vegetation classes are the dominant assets under threat from salinity. The assets that have market value, such as urban water supplies, agricultural lands, infrastructure and utilities, while also under threat from salinity, need to be closely examined in conjunction with the non-market assets.

To set priorities for the target areas that require the most immediate action and funding under the SAP, a three-step approach was used, *viz:*

Step 1. Rank the target areas based on the Benefit-Cost Analysis

Step 2. Rank the target areas based on non-market and unquantifiable criteria

Step 3. Combine the two rankings to provide overall priorities

Rankings based on benefit-cost analysis

Ten of the 12 target locations were ranked based on the Benefit-Cost Analysis *(Table 5.9)*.

Rank	Target locations	BCR (4%)
1	Lismore – Derrinallum	4.00
2	Murdeduke	3.25
3	Modewarre	2.79
4	Morrisons – Sheoaks	2.50
5	Pittong	1.13
6	Illabarook	0.98
7	Lake Corangamite	0.92
8	Colac – Eurack	0.80
9	Geelong – Lake Connewarre	0.38
10	Warncoort	0.38
	Upper West Moorabool	No BCR
	Lara	No BCR

Table 5.9: Target areas ranked by Benefit-Cost Ratio

Rankings based on non-market and unquantifiable criteria

Ranking the target areas based on the non-market benefits is less straightforward than that for ranking based on benefit-cost analysis. For this reason the project team developed six criteria to evaluate the target areas. These are:

1. Do we have an international or national obligation to protect and manage the assets in this target area?
2. Is there evidence of the situation getting worse?
3. Are there off-site impacts associated with this target area?
4. How urgent is the threat?
5. What is the hydrogeological response time?
6. Is it possible to replace the assets in this target area if they are degraded?

Using these criteria, the target areas are ranked *(Table 5.10)*.

Rank	Target Area	International or national obligation	Proven worsening situation	Off-site impacts	Urgency of threat	Hydrogeological response	Replaceable assets
1	Lake Corangamite	Yes	Yes		High	Slow – medium	Totally irreplaceable
2	Morrisons – Sheoaks	No	Yes	Threat to urban water supply of Geelong, Meredith and Bannockburn	High	Fast	Replaceable but expensive
3	Upper West Moorabool	No	Yes	Threat to urban water supply of Ballarat and Geelong	High	Fast	Replaceable but expensive
4	Colac – Eurack	Yes	Yes	Threat to urban areas of Colac	High	Slow – medium	Replaceable buildings, irreplaceable wetlands
5	Geelong – Lake Connewarre	Yes	Possibly		Medium	Slow	Totally irreplaceable
6	Pittong	No	Yes	Impact on Lake Corangamite and downstream water users	Medium	Fast	
7	Illabarook	No	Yes	Impact on Lake Corangamite and downstream water users	Medium	Medium	
8	Lismore – Derrinallum	No	Yes			Slow – medium	
9	Modewarre	No	Unsure	Impact on Breamlea wetlands	Medium	Slow – medium	
10	Murdeduke	Yes	Unsure	Impact on Barwon River salinity		Slow	Irreplaceable
11	Warncoort	No	Unsure		Low		
12	Lara	Yes	Unsure			Slow	Irreplaceable

Table 5.10: Target areas ranked by non-market and unquantifiable criteria

Overall Ranking

Combining the two rankings gives an overall ranking *(Table 5.11).*

Rank	Market ranking	Non-market ranking	Overall ranking
1	Lismore – Derrinallum	Lake Corangamite	Lake Corangamite
2	Murdeduke	Morrisons – Sheoaks	Morrisons – Sheoaks
3	Modewarre	Upper West Moorabool	Upper West Moorabool
4	Morrisons – Sheoaks	Colac – Eurack	Colac – Eurack
5	Pittong	Geelong – Lake Connewarre	Geelong – Lake Connewarre
6	Illabarook	Pittong	Lismore – Derrinallum
7	Lake Corangamite	Illabarook	Illabarook
8	Colac – Eurack	Lismore – Derrinallum	Pittong
9	Geelong – Lake Connewarre	Modewarre	Murdeduke
10	Warncoort	Murdeduke	Modewarre
11		Warncoort	Warncoort
12		Lara	Lara

Table 5.11: Target areas' overall ranking

5.5 Cost-Sharing Arrangements

Salinity management is a challenge for rural and regional communities, industry and government. Maintaining and enhancing a partnership approach is very important to successful salinity management. Implementing the SAP will require joint action between the community and government as it produces benefits to both private individuals and the broader community as a whole.

The details of public investment in key work components and cost sharing needs to be developed considering the outcomes of activities and the government's guidelines for cost sharing for natural resource management. In cases where the wider community gains most of the benefits, the government will assume greater responsibility for funding contribution towards the implementation of salinity control strategies.

The Victorian Government in consultation with various relevant authorities has adopted a set of principles for state-wide investment by the community and government in natural resource management. At a regional level these principles have been adopted by CMAs as the basis for making Regional Catchment Strategy cost-sharing decisions.

Principles

A number of principles underpin the development of cost-sharing arrangements for on-ground works.

Duty of care. All natural resource users and managers have a duty of care to ensure that they do not damage the natural resource base. The users should be responsible for making good any damage incurred as a result of their actions.

Beneficiary pays. This requires landholders to pay the resource degradation costs associated with agricultural production. Communities are to contribute to resource management activities by landholders that give rise to public benefits.

Government contributes for public benefits. Government contributes primarily for activities that produce public benefits. Users, both existing and future, are expected to pay for activities that provide benefit (government may agree to contribute to land and water management activities that produce private benefits where cumulative uptake of these activities provides significant public benefit or where there is market failure).

Economic viability. Activities must be technically sound and the benefits must justify the cost.

State-wide policy and monitoring. Government will meet the cost of state-wide activities, including planning, monitoring and assessment, research and investigations where they are crucial to sustainable resource management.

Beneficiaries of investment

The beneficiaries of the SAP vary in each target area due to the complexity of benefits. A summary of the main benefits from recharge and discharge activities are listed *(Table 5.12)*.

Target Areas	Benefits from on-ground works			
	From Recharge Control		From Discharge Control	
	Private	Public	Private	Public
Upper West Moorabool	N/A	N/A	N/A	N/A
Morrisons – Sheoaks	Large forestry benefits.	Reduced salinity in urban water supplies. Reduced salting in Moorabool River.	Small agricultural production gain.	Reduced salinity in urban water supplies Reduced salting in Moorabool River.
Pittong	None, likely impost on agricultural activities.	Reduced salting in the Woady Yaloak River.	Moderate agricultural production gain.	Major reduction in salt in the Woady Yaloak River.
Illabarook	Minor forestry benefits.	Reduced salting in the Woady Yaloak River.	Small agricultural production gain.	Reduced salting in the Woady Yaloak River.
Lismore – Derrinallum	N/A	N/A	Small agricultural production gain.	Reduced salt wash-off. Reduced premature road failure.
Lake Corangamite	N/A	N/A	Moderate agricultural production gain.	Reduced salt wash-off to Lake Corangamite. Protection of primary saline assets.
Colac – Eurack	N/A	N/A	Moderate agricultural production gain.	Reduced salt wash-off to Lake Beeac and Lough Calvert. Reduced premature road failure. Protection of primary saline assets.
Warncoort	N/A	N/A	Minor agricultural production gain.	Reduced premature road failure. Protection of primary saline assets.
Murdeduke	N/A	N/A	Minor agricultural production gain.	Reduced salt wash-off to Lake Mudeduke. Reduced premature road failure. Protection of primary saline assets.
Modewarre	N/A	N/A	Minor agricultural production gain.	Reduced salt wash-off to Lake Modewarre. Reduced premature road failure. Protection of primary saline assets.
Geelong – Lake Connewarre	N/A	N/A	Minor agricultural production gain.	Reduced salt wash-off to Lake Connewarre. Reduced premature road failure. Protection of primary saline assets.
Lara	N/A	N/A	N/A	Protection of primary saline assets.

Table 5.12: Summary of public and private benefits from on ground works

While there are variations in the public and private benefit in each target location, it is suggested a cost-sharing arrangement of 75% public investment and 25% private investment be adopted for simplicity and pragmatism. Asset managers supported these cost-sharing arrangements during the consultation phase *(Background Report 4)*. However, it is recommended those responsible for implementation adjust the cost sharing in areas where anomalies may occur. For example, in the Pittong target location the proposed recharge treatments (alleys of trees and contour drains) confer virtually no benefits to the farmer and are more likely to be a hindrance to current farming practices. Yet the farmers are expected to pay 25% of the costs of implementation. In contrast, the majority of the market benefits from the forestry option in the Morrisons – Sheoaks target location reside with private beneficiaries (farmers and timber companies). Again, they are only being asked to pay for 25% of the implementation cost. In these specific cases, cost sharing should be re-examined to align with cost-sharing principles.

5.6 Funding requirements for the first three years of the SAP

Funding for the first three years is required for support programs, research and investigation projects, monitoring programs, public on-ground works and the public's share of private on-ground works *(Table 5.13)*. The full analysis is shown in Appendix C.

Programs	Total for first 3 years
Supporting Programs	
Education and extension program	$2,430,000
Management and support	$360,000
Training program for roads	$29,400
Total for support programs	**$2,819,400**
Research and Investigation	
Research funding	$768,332
Technical consultancy	$140,000
Post-graduate person – research	$160,000
Total for support programs	**$1,068,332**
Monitoring	
Gauging stations installed	$50,000
Bores installed	$0
Sites maintained and replaced	$86,250
Sites monitored	$90,000
Total for monitoring programs	**$226,250**
Works	
Recharge	$1,558,758
Discharge	$1,569,343
Total for works programs	$3,128,101
Total program costs	**$7,242,083**

Table 5.13: Public funding required for years 1 to 3 of the SAP

6. Targets and monitoring

The National Framework for Natural Resource Management Standards and Targets (NRM Ministerial Council, 2003a) provides the principles and requirements for targets which are used to guide the investment in regional salinity management. The framework outlines a minimum set of matters for which regional targets are required, with guidelines and protocols for target setting, monitoring and reporting. The document states the desired national natural resource outcomes and specifies the minimum set of matters for which the CCMA must set regional targets *(Table 6.1)*.

The targets set by the CCMA (in line with the national framework) are considered by the Commonwealth and State as part of the accreditation process prior to investment by governments in the SAP. The targets relate to an absolute improvement in resource condition, or a decrease in the rate of degradation, and are usually expressed as numbers or percentage changes. The targets are categorised into three levels: aspirational targets, achievable resource condition targets (RCTs), and management action targets (MATs).

National Outcomes *The national outcomes are aspirational statements about desired national natural resource outcomes*	*Matters for which Regional Targets must be set* **Resource Condition Matters for Targets**
1. The impact of salinity on land and water resources is minimised, avoided or reduced.	1. Land salinity.
2. Biodiversity and the extent, diversity and condition of native ecosystems are maintained or rehabilitated.	2. Soil condition.
3. Populations of significant species and ecological communities are maintained or rehabilitated.	3. Native vegetation communities' integrity.
4. Ecosystem services and functions are maintained or rehabilitated.	4. Inland aquatic ecosystems integrity (rivers and other wetlands).
5. Surface and groundwater quality is maintained or enhanced.	5. Estuarine, coastal and marine habitats' integrity.
6. The impact of threatening processes on locations and systems which are critical for conservation of biodiversity, agricultural production, towns, infrastructure and cultural and social values, is avoided or minimised.	6. Nutrients in aquatic environments.
7. Surface water and groundwater is securely allocated for sustainable production purposes and to support human uses and the environment, within the sustainable capacity of the water resource.	7. Turbidity / suspended particulate matter in aquatic environments.
8. Sustainable production systems are developed and management practices are in place which maintain or rehabilitate biodiversity and ecosystem services, maintain or enhance resource quality, maintain productive capacity and prevent and manage degradation.	8. Surface water salinity in freshwater aquatic environments.
	9. Significant native species and ecological communities.
	10. Ecologically significant invasive species.
	Management Action Matters for Targets
	1. Critical assets identified and protected.
	2. Water allocation plans developed and implemented.
	3. Improved land and water management practices adopted.

Table 6.1: National Outcomes and Minimum Set of Regional Targets

6.1 Aspirational target

An aspirational target is a long-term vision or goal about the desired condition of the natural resource in the 50+ year time frame. These targets should align with the national outcomes listed in *Table 6.1* and set the context for the resource condition targets and management action targets.

The aspirational target for the Corangamite SAP was set by the CCMA Sustainable Agriculture and Land Management Implementation Committee (SALMIC), members of the CCMA Board and other invited stakeholders at a workshop held in Colac on May 29th 2003. The workshop participants agreed on the following aspirational target:

Corangamite CMA will – by ongoing measurement, monitoring and experimentation – attempt to sustainably manage the region's salinity impacts.

6.2 Achievable resource condition targets

The National Framework defines achievable resource condition targets as "…specific, timebound and measurable targets, relating largely to resource condition, against the minimum set of matters for regional targets *(set out in Table 6.1)*. The timeframe for achievement of these targets is likely to be 10-20 years. These targets must be pragmatic and achievable. They would be developed iteratively, including through a benefit/cost analysis. Examples could include: average salinity of X ECs at specific end-of-valley site by year Y; X hectares of specific native vegetation type within region at year Y maintained or regenerated; X stream sites within region in specific river condition category by year Y. Within their regional plans, regional bodies may also wish to set targets for matters that are additional to the minimum set." (NRM Ministerial Council, 2003a, page 4).

In setting the RCTs the most current knowledge in the research, investigations and studies within the Corangamite CMA region have been taken into account (Dahlhaus *et al.* 2005b). The resulting RCTs are considered pragmatic and achievable as required by the National Framework (NRM Ministerial Council, 2003a).

The 37 RCTs set for the target areas can be grouped into four broad categories
(termed types L, W, E & I):

Type L – Land salinity –

RCTs have been set as no net gain in secondary salinity over 2005 levels in the eight target areas where land salinity has been identified as a threat to assets.

Type W – Surface water salinity –

These RCTs are set in two categories:

a) a quantitative end-of-valley target for those target areas where there is sufficient data to determine a trend.
b) a stated action to establish a target for those target areas where more data is required before a trend can be determined.

Type E – Aquatic and estuarine ecosystem integrity –

two distinct types of RCTs have been set to maintain the integrity of aquatic ecosystems:

a) actions to establish a range for the salinity of specific lakes identified as threatened by increasing or decreasing salinity.
b) no net loss of primary salinity in target areas where primary saline ephemeral wetlands have been identified as under threat from changed hydrology and salinity.

Type I – Infrastructure integrity –

RCTs have been set to protect:

a) roads in target areas where they have been identified as threatened by salinity.
b) a reduction in the urban infrastructure at risk in the City of Colac.

Their relationship to the Corangamite SAP target areas is tabulated *(Table 6.2)*, and they are listed in full on the following pages *(Table 6.3)*.

Mattter for Target	Indicator or measure	Lake Corangamite	Morrisons – Sheoaks	Upper West Moorabool	Colac – Eurack	Geelong – Lake Connewarre	Illabarook	Pittong	Lismore – Derrinallum	Murdeduke	Warncoort	Modewarre	Lara
		SAP Target area											
National													
Land salinity.	Area of land threatened by secondary salinity.	✔			✔	✔		✔	✔	✔	✔	✔	
Surface water salinity in freshwater aquatic environments.	In-stream salinity.	✔	✔	✔			✔	✔	✔		✔	✔	
Inland aquatic ecosystems' integrity (rivers and other wetlands).	River condition (water EC only).	✔	✔	✔			✔	✔	✔		✔	✔	
	Wetland ecosystem extent and distribution.	✔			✔	✔							✔
	Wetland ecosystem condition (salinity range).	✔			✔	✔			✔			✔	
Estuarine, coastal and marine habitat integrity.	Estuarine, coastal and marine habitat extent and distribution.					✔							✔
Local													
Rural and urban infrastructure integrity.	Reduced threat to roads.	✔			✔	✔			✔	✔	✔	✔	
	Reduced threat to urban assets.				✔								

Table 6.2: Revised RCTs and their relationship to National Matters for Target and Indicators

Type	No.	Upper West Moorabool
W	1	By 2015, maintain the EC measured in the Lal Lal Reservoir (tower surface) below 700 μS/cm 95% of the time.
W	2#	Maintain an EC of less than 1000 μS/cm for 90% of the time as measured at the Lal Lal gauging station (# 232210) on the West Branch of the Moorabool River.
		Morrisons – Sheoaks
W	3#	By 2015, maintain the EC measured at the Sheoaks off-take below 1000 μS/cm 90% of the time (note: 1000 μS/cm does not meet Australian drinking water standards).
W	4#	Maintain an EC of less than 2500 μS/cm for 90% of the time for the Moorabool River as measured at the Batesford gauging station (# 232202).
		Pittong
W	5#	Maintain an EC of less than 8000 μS/cm for 90% of the time for Woady Yaloak River as measured at the Cressy gauging station (# 234201).
W	6	By 2012, establish a target for EC measured in the Naringhil Creek at the edge of the Pittong target area.
L	7	By 2015, there is no net increase in the area of land salinity in the Pittong target area (compared with the area in 2005).
		Illabarook
W	8#	Maintain an EC of less than 8000 μS/cm for 90% of the time for Woady Yaloak River as measured at the Cressy gauging station (# 234201).
W	9	By 2012, establish targets for EC measured in the major tributaries to the Woady Yaloak River at the edge of the Illabarook target area.
		Lismore – Derrinallum
E	10	By 2010, establish the target range for salinity measured at appropriate sites in Lake Tooliorook to ensure the integrity of the aquatic ecosystem.
W	11	By 2008, establish a target for EC measured at the gauging station in Browns Waterholes (# 234212).
I	12	By 2015, ensure that 80% of the roads in saline areas (in the Lismore – Derrinallum target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
L	13	By 2015, there should be no net gain in the area affected by secondary saline discharge in the Lismore – Derrinallum target area (compared with 2005).
		Lake Corangamite
E	14	By 2010, establish targets for the ranges of salinity measured at appropriate monitoring sites in Lake Corangamite, Lake Gnarpurt, Lake Martin and Cundare Pool to ensure the integrity of the aquatic ecosystems.
W	15#	Maintain and EC of less than 2500 μS/cm for 90% of the time for the Pirron Yallock Creek as measured at the Pirron Yallock gauging station (# 234203).
I	16	By 2015, ensure that 80% of the roads in saline areas (in the Lake Corangamite target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
L	17	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Lake Corangamite target area, compared with 2005. ***(Note: This target will be reviewed in line with outcomes of research being undertaken to determine the impact / no impact within the Lake Corangamite target area if the lake level reaches 118.1 AHD.)***
E	18	By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Lake Corangamite target area, compared with 2005.

Table 6.3: Revised RCTs for the Corangamite SAP

Type	RCT	Upper West Moorabool
W	19	By 2015, all new developments in land affected by salinity (saline discharge areas) within the urban areas of the City of Colac should be appropriately engineered.
E	20	By 2010, establish targets for the ranges of salinity measured at appropriate monitoring sites in Lake Colac, Lake Beeac and Lough Calvert to ensure the integrity of the aquatic ecosystems.
I	21	By 2015, ensure that 80% of the roads in saline areas (in the Colac – Eurack target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
L	22	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Colac – Eurack target area, compared with 2005.
E	23	By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Colac – Eurack target area, compared with 2005.
		Warncoort
W	24#	Maintain an EC less than 25,000 μS/cm for 95% of the time for the Birregurra Creek as measured at the Ricketts Marsh gauging station (# 233211).
L	25	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Warncoort target area, compared with 2005.
I	26	By 2015, ensure that 80% of the roads in saline areas (in the Warncoort target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
		Murdeduke
L	27	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Murdeduke target area, compared with 2005.
I	28	By 2015, ensure that 80% of the roads in saline areas (in the Murdeduke target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
		Modewarre
L	29	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Modewarre target area, compared with 2005.
E	30	By 2010, establish targets for the ranges of salinity measured at appropriate sites in Lake Modewarre, Gherang and Browns Swamps to ensure the integrity of the aquatic ecosystems.
W	31	By 2008, establish an appropriate end of valley target for salinity measured in Thompson Creek at the edge of the Modewarre target area.
I	32	By 2015, ensure that 80% of the roads in saline areas (in the Modewarre target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
		Geelong – Lake Connewarre
E	33	By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Geelong – Lake Connewarre target area, compared with 2005.
L	34	By 2015 there should be no net gain in the area of land affected by secondary salinity in the Geelong – Lake Connewarre target area, compared with 2005.
E	35	By 2010, establish targets for the ranges of salinity measured at appropriate sites in the Lower Barwon wetlands and the Thompson Creek estuary to ensure the integrity of the aquatic and estuarine ecosystems.
I	36	By 2015, ensure that 80% of the roads in saline areas (in the Geelong – Lake Connewarre target area) are managed to prevent deterioration at rates equivalent to non-saline areas.
		Lara
E	37	By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Lara target area, compared with 2005.

NB RCT targets identified with a # indicate the targets are more refined than identified in the RHS and State Environment Protection Policy for waters. The above targets will be used by the Corangamite CMA.

6.3 Management action targets

Management action targets are the short-term (1 – 5 years) targets which relate to salinity management actions or capacity building. These targets contribute to progress towards the longer-term RCTs. The MATs for the draft SAP were derived in consultation with the managers of assets which were considered at risk due to salinity (Background Report 4, Nicholson *et al.* 2003). As detailed in Section 4.5, the MATs have since been revised based on the experience of the SAP implementation over the past two years (refer also to Background Report 8, Nicholson 2005).

The following management action targets are proposed for the first three years of the SAP *(Table 6.4)*. Where areas of very high and high conservation significance are included in the discharge treatment area, secondary targets are also stated *(Table 6.5)*.

6.4 Management action targets and their relationship to resource condition targets

The setting of RCTs requires iterative calculations to ensure that the proposed MATS *(Table 6.4)* would achieve the RCTs for each target area. A summary of the assumptions used in these calculations and the likely outcomes is tabulated in Appendix C.

Only two of the 37 RCTs may not be achieved, depending on the decision in relation to the recommendations for the Woady Yaloak Diversion Scheme and raising the level of Lake Corangamite. In addition, a degree of uncertainty remains with respect to the RCTs related to the no net loss of saline wetlands, as their current condition and best management are yet to be determined.

Target location	Recharge treatments (ha over 3 years)				Discharge treatments (ha over 3 years)				
	1. High-density tree planting	2. Tree planting interception belts.	3. Shallow surface drains to intercept lateral flow of perched groundwater.	4. Tree planting adjoining or near saline discharge.	5a. Protection & management of discharge areas to allow natural vegetation recovery (fencing only).	5b. Protection & management of discharge areas to allow natural vegetation recovery (with trees).	6. Protection & management of discharge areas with establishment of additional vegetation.	7. Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover.	8. Water logging control.
Lake Corangamite					81 (private)	81 (private)	131 (private)		
Morrisons – SheOaks	660[12] 96[13]			15				15	
Colac – Eurack					27 (public) 66 (private)	132 (private)	18 (public) 78 (private)		
Geelong – Lake Connewarre					99 (public) 81 (private)	111 (private)	12 (private)		
Pittong		567	582	66				132	435
Illabarook	54 (public) 51 (private)			21				178	
Lismore – Derrinallum					21 (public) 69 (private)		48 (private)		
Warncoort						90 (private)			
Murdeduke							87 (public/private)	39 (public/private)	
Modewarre					72 (public/private)		48 (public/private)		
Lara					21 (public)				
Upper West Moorabool	**No on-ground targets set until current studies are completed**								

Table 6.4: Management action targets for the first three years of the SAP

[12] Based on a once-off payment, primarily design for private forestry companies

[13] Based on a once-off payment to private landholders.

[14] Based on once-off payment at establishment

From the analysis, some of the discharge areas intercept near or within a very high and high conservation significance area. The recommended action is to treat or manage at least 50% of these high conservation significance areas.

<table>
<tr><th rowspan="2">Target location</th><th colspan="5">Discharge treatments
(ha over 3 years)</th></tr>
<tr><th>5a. Protection and management of discharge areas to allow natural vegetation recovery (fencing only).</th><th>5b. Protection and management of discharge areas to allow natural vegetation recovery (with trees).</th><th>6. Protection and management of discharge areas with establishment of additional vegetation.</th><th>7. Waterlogging control on discharge areas in conjunction with establishment of additional vegetative cover.</th><th>8. Water logging control.</th></tr>
<tr><td>Lake Corangamite</td><td colspan="3">147</td><td></td><td></td></tr>
<tr><td>Morrisons – SheOaks</td><td></td><td></td><td></td><td>9</td><td></td></tr>
<tr><td>Colac – Eurack</td><td colspan="3">162</td><td></td><td></td></tr>
<tr><td rowspan="2">Geelong – Lake Connewarre</td><td>99 (public)</td><td></td><td></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="3">78</td></tr>
<tr><td>Pittong</td><td></td><td></td><td></td><td colspan="2">66</td></tr>
<tr><td>Illabarook</td><td></td><td></td><td>39</td><td></td><td></td></tr>
<tr><td>Lismore – Derrinallum</td><td>69</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Warncoort</td><td></td><td></td><td>57</td><td></td><td></td></tr>
<tr><td>Murdeduke</td><td></td><td></td><td colspan="2">96</td><td></td></tr>
<tr><td>Modewarre</td><td>Part of 60 ha</td><td></td><td>Part of 60 ha</td><td></td><td></td></tr>
<tr><td>Lara</td><td>21</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 6.5: Management action targets for very high and high conservation significance areas in the first three years of the SAP

6.5 Monitoring

A monitoring program has been developed primarily to measure the progress towards achieving the RCTs. The program focuses on the matters for target and indicators as described in *Table 6.2*. The monitoring program and schedule of monitoring tasks is summarised in *Table 6.6*.

Land salinity

Only three potential monitoring sites have been established to monitor these RCTs in the Corangamite CMA region, *viz:* the Victorian Dryland Salinity Monitoring Network sites at Pittong and Beeac (Colac – Eurack SAP target area), and the Sustainable Grazing on Saline Land site at Pittong.

The monitoring of trends in land salinity requires a number of sites in each target area to ascertain the net gain or reduction of secondary salinity. In addition, the monitoring of trends in land salinity outside of the current SAP target areas is equally important, so that emerging threats to assets can be identified. For this reason, the continued monitoring of all the Victorian Dryland Salinity Monitoring Network sites and research organisations undertaking salinity mapping or monitoring in the region for their own purposes is supported.

Additional land salinity monitoring sites are to be established by 2008 in each of the target areas where land salinity RCTs have been set. The sites will be established using rapid geophysical surveying, soil sampling, vegetation indicators, groundwater monitoring and surface water sampling as appropriate. In addition, a region-wide audit of the land salinity is planned to commence in 2010 to establish trends in target areas and non-target areas and identify emerging threats to assets.

Continued monitoring of the groundwater levels across the region is essential, with preference given to the key bores identified in the groundwater monitoring review (Dahlhaus & Feltham, in prep). In addition, the groundwater salinity in key bores across the region will be monitored every five years, commencing immediately.

Surface water salinity

Monitoring for the majority of the RCTs is already carried out by the DSE for the Victorian Water Quality Monitoring Network, Barwon Water and Central Highlands Water. While the RCTs relate water salinity in those target areas where the water quality asset is threatened, region-wide monitoring by research organisations, universities, schools, landcare and community groups for programs such as Waterwatch is supported.

A gauging station in Naringhil Creek is required downstream from the Pittong SAP target area. This action was recommended in a number of investigations, including SAP Background Reports 6 (Dahlhaus *et al.* 2003) and no 9 (Dahlhaus *et al.* 2005b) and in a report on benchmarking streams (SKM 2005b). Similarly, salinity monitoring of Illabarook Creek, Mount Misery Creek, Kuruc A Ruc Creek and Ferrars Creek is required downstream from the Illabarook SAP target area.

At present there is little or no waterwatch data available for the Woady Yaloak River system, and the relative proportion of salt contributed by the tributaries is unknown. Regular monitoring of salinity in the tributaries draining the Illabarook target area will help target the salinity management actions.

Salinity monitoring at Browns Waterholes has only recently recommenced and the data record is too short for the setting of a target. By 2008 the record of monitoring should be sufficient to set an EC target. Similarly, the intermittent record and poor-quality EC data from the Thompson Creek gauge at Ghazeepore (235255) needs to be investigated so that an EC target can be set by 2008. This investigation was also recommended (albeit a low-priority recommendation) in the SKM Benchmarking report *(refer to Table 4.5)*.

Aquatic and estuarine ecosystem integrity

Monitoring protocols and catchment health sites need to be established for monitoring the loss or gain in the primary saline land and/or wetlands. Although the methods are yet to be established, the PIRVic salinity monitoring protocols (Clark & Allan 2005) and the Index of Wetland Condition (DSE 2005d) provide the guiding framework. Organisations already involved in water salinity monitoring, the monitoring of salinity in wetlands and estuaries outside of the SAP target areas are supported.

Infrastructure integrity

A monitoring program jointly undertaken with the municipalities represented in each target area is proposed for the monitoring of road management. It is probable that the maintenance records of municipal road works would be used where possible. The threats to urban infrastructure in the City of Colac will require monitoring before and after the proposed SMO (EnPlan in prep.) and other changes to the planning scheme are implemented.

Target area	Year							
	2005 - 2006	2006 - 2007	2007 - 2008	2008 - 2009	2009 - 2010	2010 - 2011	2011 - 2012	2012 - 2013
Catchment-wide on-going groundwater levels and salinity monitoring								
Land salinity monitoring								
Monitor SGSL sites at Illabarook (2 sites); Pittong (1 site)								
Monitor VDSMN sites at Pittong (1 site), Modewarre (1 site), Colac – Eurack (1 site) and 3 others in wider catchment								
Establish monitoring sites at Pittong (1 site), Lismore – Derrinallum (3 sites), Lake Corangamite (4 sites), Colac – Eurack (3 sites)								
Establish monitoring sites at Warncoort (2 sites), Murdeduke (3 sites), Modewarre (2 sites), Geelong – Lake Connewarre (3 sites)								
Undertake catchment-wide salinity mapping audit								
Monitor all target areas where monitoring sites have been established								
Surface water salinity monitoring								
Establish salinity monitoring gauge at Pittong (Naringhil Creek)								
Commence monitoring creeks draining Illabarook target area								
Establish RCT for Lismore – Derrinallum (Browns Waterholes gauge)								
Establish RCT for Modewarre (Thompson Creek gauge)								
Inland aquatic and estuarine ecosystem integrity monitoring								
Review existing data and commence monitoring at Lismore – Derrinallum (1 lake), Lake Corangamite (4 lakes), Colac – Eurack (3 lakes), Modewarre (3 lakes), Geelong – Lake Connewarre (3 lakes, 1 estuary).								
Review existing data and commence monitoring at Lake Corangamite, Colac – Eurack, Geelong – Lake Connewarre, Lara								
Infrastructure integrity monitoring								
Commence monitoring road maintenance at Lismore - Derrinallum, Lake Corangamite, Colac – Eurack, Warncoort, Murdeduke, Modewarre, and Geelong – Lake Connewarre in conjunction with municipalities.								
Monitor urban salinity controls in Colac – Eurack (City of Colac)								

Table 6.6: Monitoring schedule

7. Implementation

The Corangamite SAP must engage a wide range of asset mangers and stakeholders with different needs and in different ways. Successful implementation will hinge on having the flexibility and capacity to treat each priority area differently, to conduct research and investigation through a range of parties, to have the means to create strategic partnerships and to measure and evaluate progress.

7.1 Implementation structure

The Corangamite CMA is ultimately responsible for the implementation of the SAP. Recently the CMA has put in place a new structure to oversee the implementation of the suite of plans and strategies.

There are five portfolio groups dedicated to strategy, plan and policy implementation. These are salinity and soils, waterways, landcare, pest plants and animals and biodiversity. Each portfolio group consists of a small number of people skilled in the topic area and with expertise in planning, research and evaluation. They also reflect the political and community realities in which the program will operate.

Primary responsibility for the implementation of the SAP should rest with the salinity and soils portfolio group. However, given the obvious synergies with waterways and biodiversity as well as the practical delivery requiring involvement of pest plant and animal staff and landcare, an integrated approach is required. The implementation synergies are outlined *(Table 7.1)*.

Delivery of a successful regional program requires the services of a leader who can bring together and manage a vibrant, positive and possibly diverse team. The broader salinity program will involve many agencies, staff, researchers, landcarers and landholders. The ability to provide regular communication, management and support processes for this collective team will determine the effectiveness of the cumulative effort. A full-time position, located in the Corangamite CMA is required.

7.2 Common implementation themes

The consultation with asset managers and stakeholders resulted in several common themes in relation to future implementation and engagement for salinity management. These are discussed below:

Integrated delivery

It is essential on-ground delivery is integrated with other land management programs. The salinity program runs the risk of only considering the individual elements for which they are attempting to tackle. This consultation has revealed that asset managers are demanding that the salinity program be delivered in an integrated manner and that it accounts for the broader catchment and land-management issues being tackled. All asset managers face the huge task of managing land, water, infrastructure and other assets for the full ranges of issues (salinity, water quality, soils, biodiversity, pests etc). In some instances they are also seeking to derive commercial return from their enterprise. On-ground delivery of the salinity program must ensure that local asset managers have access to support that assists them to deliver a wider range of land-management programs rather than just salinity alone.

The Department of Sustainability and Environment is currently investigating the concept of integrated delivery in the Morrisons – Sheoaks target area (Leigh Dennis pers comm.). The project aims to deliver multiple outcomes through co-ordinated delivery of a range of natural resource programs. Salinity is one of the key programs to be integrated into this project.

CCMA portfolio group	Direct synergies
Waterways	Treating rising salinity in the Moorabool and Woady Yaloak rivers. Investigating the cause of rising salinity in Upper West Moorabool storage. Management of water flows into Lake Corangamite.
Biodiversity	Management of high and very high conservation significant vegetation at risk by changing salinity status. Understanding and appropriate management of saline wetlands.
Pest plant and animals	Rabbit control preceding revegetation activities.
Landcare	Delivery of on-ground works through existing landcare structures.

Table 7.1: Direct synergies between portfolio groups

Customised delivery to each location

The consultation has highlighted the need to allow flexibility to deliver local salinity mitigation programs according to what will be the most efficient and effective for each particular district. The temptation to 'standardise' delivery and guidelines in the quest for ease of implementation must be avoided, as this can seriously undermine the location-by-location approach needed and in the long run cost more in implementation because of the dis-incentive this creates at the local level. The implementation program needs to be accepted that 'case-by-case' program delivery is needed and will be endorsed.

Use existing delivery mechanisms where appropriate

Where community groups or mechanisms exist, the obvious choice in delivering an expanded salinity program is by working with these groups or agencies. In some instances, new or renewed partnership programs will need to be developed and the first critical steps will involve formation and development of these new delivery mechanisms which have full and ongoing ownership of local asset managers and stakeholders.

Devolve responsibility to asset managers

Devolution of responsibility for implementation is sought by many of the asset managers consulted. Commensurate with this devolved responsibility is to ensure local asset managers are given full administrative and technical support to enable them to continue to make informed decisions and to effectively achieve implementation. Devolving responsibility means trusting local organisation and groups to implement salinity outcomes in ways best suited to the locality.

These concepts are explored in greater detail in Background Report 4 (Nicholson *et al.* 2003).

7.3 Emerging issues

During the development of the SAP and experiences from recent implementation, several issues have emerged that need to be carefully considered. These issues are explored in greater detail in Background Report 4 (Nicholson *et al.* 2003) and Background Report 8 (Nicholson 2005). Only a brief summary is provided in this document.

The impact of water management on salinity

In the development of the SAP it has become apparent that the way in which water resources are managed can be the dominant influence on the salinity risk to assets. These include aspects such as the increasing allocation and extraction of groundwater, surface water drainage installed for raised-bed cropping or discharge site rehabilitation and water management by urban communities.

A difficulty arises because the Corangamite CMA is the responsible authority for salinity management, but it is not the responsible authority for water management.

A decision made by other authorities or organisations may have far-reaching impacts on the salinity of water resource assets and is capable of negating years of investment in treatments for salinity management. If the investment in protecting assets from salinity is to provide maximum benefit, then there is a need for the responsible authority (Corangamite CMA) to influence the decisions made by the authorities with responsibility for water management. These include municipalities (stormwater), Central Highlands Water, Barwon Water and South West Water (urban supply and wastewater), Southern Rural Water (irrigation and farm allocations) and Environment Protection Authority (wastewater) among others. It is recommended that the Corangamite CMA negotiate with DSE and the authorities for water management for a greater influence in decisions which impact on the salinity of water quality assets.

Profitable agricultural systems

Nine of the 12 suggested target locations identified in the SAP require the implementation of solutions on private land. In some instances, the desired treatments are on recharge areas and require actions that have more dis-benefits that benefits to the individual owner. On discharge areas, the introduction of salt-tolerant species is a significant investment and the potential returns are marginal, so understandably landholders are reluctant to treat these areas.

Profit seems to be a 'dirty' word in natural resource management. Yet it is probably the biggest single driver in getting voluntary adoption of a practice or treatment by individuals on private land. Voluntary adoption is funded from profits and there is a need to increase the emphasis on improving the profitability aspects of salinity treatment options. It is suggested improving the profitability of treatment option on private land is embraced and partnerships actively pursued with agricultural industry groups.

Tall wheat grass

Concerns have emerged regarding the planting of tall wheat grass on saline areas. Tall wheat grass is currently the most commonly used species for planting into saline land. Examples have been cited where tall wheat grass has spread from the origin of planting into other saline and non-saline areas. Some of these saline areas are of high conservation significance, resulting in tall wheat grass becoming an invasive weed. However, if planted in the appropriate locations and managed correctly (rather than being left ungrazed), tall wheat grass can be a highly valuable species (DPI 2005).

Guidelines are required to accompany the future sale of tall wheat grass to inform potential users of the invasive nature of the plant under certain management conditions and actions to take to minimise spread. Similar information is needed in areas where tall wheat grass has already been established.

Inconsistencies between investment and management practices of private and public land managers.

Salinity management actions need to occur on both private and public land. Previous emphasis in salinity management has been toward private land managers, providing assistance, technical advice and incentive to conduct various treatments. It has been assumed public land managers are able to conduct salinity management works within existing budgets and expertise. It would appear this is not always the case.

Department of Primary Industries staff have provided examples of contradictory management actions being conducted by public and private land managers on different parcels of adjacent land. In some cases this involved private lease arrangements over public land where the accepted management was at odds with the treatments being recommended on private land. This included being able to conduct agricultural activities on the public land, eg: cropping, grazing, where recommendations on private land discourage this practice. These inconsistencies have made salinity discharge implementation difficult and can only be solved on a case-by-case basis which requires devolution of responsibility to those directly involved with implementation. It is recommended the resources and technical expertise be provided to public land managers to improve the management of saline land assets under their control.

The use of incentive payments to achieve land-use change.

The incentive payments outline in the SAP are intended to compensate people for adopting practices that incur a net cost to the adopter but which have environmental and broader community benefits. The incentive offered needs to be large enough to firstly generate interest and to compensate for the losses compared with current practice. The logic behind the use of these types of incentives is well documented (Nicholson 2005).

Historically, the salinity program has offered incentives as a once-off payment at a fixed rate per hectare. This payment is intended to be large enough to maintain the land-use change after the initial establishment. In two of the target areas (Morrisons – Sheoaks and Illabarook), it has been demonstrated once-off payments to individual landholders (farmers) insufficient to provide enough incentive to implement the practice (Nicholson 2005). In contrast the same payment in the Morrisons – Sheoaks area has been sufficient to encourage commercial timber companies to accept the invitation to establish large-scale planting in priority high-recharge areas. This clearly shows the ‘trigger’ is variable between, and for that matter, within each asset manager group, as some landholders will accept an offer whereas other will not.

Establishing the ‘trigger value’ to achieve participation is difficult and given the variability of response by different asset managers, a set value per hectare is not realistic, nor is it wise (although a set value is used for benefit-cost analysis and overall budgeting purposes). The SAP supports the use of incentives based on the principal of offsetting a proportion of the cost incurred by the asset manager. This approach requires identification of the items of expenditure that are eligible and the proportion of that cost which is to be subsidised. This approach has been trialed successfully within the region (eg The Woady Yaloak Catchment Group), resulting in every project incurring a unique incentive payment based on the costs incurred.

The eligible items of expenditure and the proportion of re-imbursement are described in Section 5.

Climate change – the impact of the current dry climate pattern on stakeholder perceptions.

It is important to understand the climatic context under which the SAP has been developed. The consultation with asset managers has been undertaken during an extended dry period (seven years) which has implications in terms of their perceptions and observations associated with salinity impacts. A return to a wetter climate cycle is likely to draw higher attention to land salinity than that currently expressed.

The current dry cycle has also possibly amplified the observed salinity impacts associated with surface water qualities due to the reduced freshwater component usually contributed by overland run-off. Run-off producing rainfall events has been few and far between in recent years and this has lead to an observed increase in surface water salinities which may not necessarily continue if wetter climate cycles return. Limited research in south-west Victoria (eg. Jones 1995; Coram *et al.* 1998) has shown that changes in climate can be the dominant driver of hydrologic change, with far greater impact than land-use change.

Predictions of climate change (greenhouse models) may have significant consequences for the expansion or mitigation salinity in the medium to long-term future and should be considered for future research projects in the Corangamite CMA. The CMA should implement a research program within the first five years of the plan to review the effect of climate on the effectiveness of salinity investment.

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Appendix A: List of acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
AROTS	Australian Rare or Threatened Species
BCA	Benefit Cost Analysis
BCLPG	Birregurra Creek Land Protection Group
BCR	Benefit Cost Ratio
BCS	Bioregional Conservation Status
BVLG	Barwon Valley Landcare Group
BW	Barwon Water
CAS	Catchment and Agriculture Services
CCMA	Corangamite Catchment Management Authority
CHW	Central Highlands Water
Ck	Creek
CLPR	Centre for Land Protection Research
CMA	Catchment Management Authority
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSP	Native vegetation conservation significance (potential)
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EC	Electrical Conductivity (used as a measure of salinity)
ECC	Environment Conservation Council
EPA	Environment Protection Authority
EPBC	Environment Protection & Biodiversity Conservation Act
EVC	Ecological Vegetation Class
GDE	Groundwater dependent ecosystem
GFS	Groundwater flow system
GHD	GHD Pty Ltd (consultants)
GIS	Geographic Information System
GMA	Groundwater Management Area

GSHARP	Geospatial Salinity Hazard Asset Risk Prioritisation
ICSRP	Integrated Catchment Salinity Risk Prioritisation
ISC	Index of Stream Condition
IWC	Index of Wetland Condition
LLPG	Lismore Land Protection Group
MAT	Management Action Target
MDBC	Murray Darling Basin Commission
ML	Megalitre. This is equivalent to 10 cm of water spread over one hectare.
MRGRP	Moorabool River Gorge Recovery Program
NAP	National Action Plan for Salinity and Water Quality
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NPV	Net Present Value
DNRE	Department of Natural Resources and Environment (now DSE & DPI)
NRM	Natural Resource Management
PAR	Participatory Action Research
PIRVic	Primary Industries Research Victoria
RCS	Regional Catchment Strategy
RCT	Resource Condition Target
RHS	River Health Strategy
SAP	Salinity Action Plan
SKM	Sinclair Knight Merz (consultants)
SMO	Salinity Management Overlay
SOBN	State Observation Bore Network
SRW	Southern Rural Water
SWW	South West Water
TAFE	Technical and Further Education
VROTS	Victorian Rare or Threatened Species
VWQN	Victorian Water Quality Network
WYCG	Woady Yaloak Catchment Group
μS/cm	microSiemens per centimetre, the usual unit for measuring EC in water.

Appendix B: Glossary

A

Aquifer - A geological unit, such as a layer of rock, that can store and transmit water at rates fast enough to supply reasonable amounts to bores or springs.

Asset Based Approach - The asset-based approach to Natural Resource Management investment planning focuses on protecting or maintaining biophysical 'things' that are of value to people, rather than focusing on issues as has been the traditional approach. At its simplest, assets are tangible physical elements of our environment that are of value to people for a variety of reasons. More specifically, the environment (the landscape) is made up of natural resources (assets) which society uses or appreciates/values in a variety of ways (services) *(DSE 2005)*.

Asset - The environment (the landscape) is made up of natural resources (assets) which society uses or appreciates/values in a variety of ways (services). In some instances these assets and services are threatened by changing environmental conditions. Natural assets are geographically identifiable physical elements of our environment. Assets can be described at a variety of scales *(DSE, 2005)*.

ANUCLIM - It is a software package of programs that enable the user to obtain estimates of monthly mean climate variables, bioclimatic parameters and indices relating to crop growth. It is produced by the Centre for Resource and Environment Studies (CRES) at the Australian National University *(ANU webpage)*.

B

Baseflow - The component of flow in a stream or river that is contributed by groundwater discharge. River or stream flow is a seasonally variable combination of surface water (overland flow) and groundwater (baseflow).

Benefit cost analysis - A quantitative evaluation of the costs which would be incurred versus the overall benefits to the general public of a proposed action such as the establishment of tree plantations in a highly responsive recharge zone *(DoE, WA webpage).*

Benefit-Cost Ratio (BCR) - Is equal to the present value of benefits divided by the present value of costs. A project is normally considered desirable if the BCR is greater than one *(Salinity Action Plan, Background report No.5).*

D

Discharge - Water flowing out of a catchment (catchment discharge), in a stream (stream discharge), or from the groundwater system to the land or surface water system (groundwater discharge).

Dryland salinity - The salinisation of land or water that is not due to irrigation. The term does not imply that the land is dry, as these areas are often waterlogged during winter or affected by rising watertables. Dryland salinity is attributed to the change in the water and salt balance that has resulted from the current land uses.

Dry Sheep Equivalent - A measure based on the feed requirement of grazing animals, hence can be used to assess the capacity of land to carry livestock. The standard unit is represented by the ability to maintain a 45 kg wether at constant body weight from one year to the next.

E

Electrical conductivity (EC) units - The measure of a solution's ability to conduct electricity. EC units are used to express salinity levels in soil and water. When salt is dissolved in water the conductivity increases, so the more salt, the higher the EC value. Another salinity measurement is the total dissolved solids (TDS) *(Australian Academy of Science, Webpage)*.

End-of-Valley Salinity Targets - A maximum value of salinity (usually stated as EC) measured at a point where a river or stream leaves a sub-catchment, that is not to be exceeded within a prescribed timeframe. These targets describe the quality of water that the Corangamite Catchment Management Authority is seeking to achieve in a particular river or stream by the stated year.

Exceedence Curve - It is a graph which shows the percentage of time that the stream water exceeds any given EC value *(Salinity Action Plan, Background report No.9)*.

F

Flowtube - Is a simple one-dimensional groundwater calculator based on Darcy's Law developed by CSIRO for use by agency staff, consultants and farmers to allow "what if" questions to be asked of management options (www.aqua.civag.unimelb.edu.au).

G

Groundwater - Water stored naturally below the land surface in the pore spaces of the soil or rocks. The upper surface of this groundwater is called the watertable, below which the soil or rock is fully saturated.

Groundwater dependent ecosystems - Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence or influence of groundwater *(SKM, 2001)*.

Groundwater discharge - The water that moves out of the groundwater system to the ground surface or surface water system. This includes springs, seeps, soaks, baseflow to rivers, lakes and wetlands, evaporation from shallow watertables and groundwater used by plants.

Groundwater discharge zone - An area where groundwater emerges to the ground surface or into a surface water body as groundwater discharge.

Groundwater Flow Systems (GFS) - Have been developed in the National Land and Water Audit (Audit) as a framework for dryland salinity management in Australia. They *"…characterise similar landscapes in which similar groundwater processes contribute to similar salinity issues, and where similar salinity management options apply"* (Coram *et al.*, 2001). GFSs are characterised by their hydrological responses and flow paths into local, intermediate and regional systems *(NLWRA, 2001)*.

I

Index of Wetland Condition - Is a hierarchical index with six "fundamental characteristics" of the wetland, *viz*: wetland catchment, hydrology, water properties, soils, biota and physical form *(SAP, 2005).*

N

Net Gain - Defined as the outcome for native vegetation and habitat where overall gains are greater than overall losses and where individual losses are avoided where possible *(SAP, 2005)*.

Net Present Value (NPV) - Is the difference between the discounted values at a required discount rate of future benefits and costs associated with the project. A positive NPV indicates that there is a greater value being generated than resources consumed and therefore, based on pure economics, the project should be undertaken. If the NPV is negative, the project is not economically viable *(Salinity Action Plan, Background Report No.5)*.

M

Management Action Targets - Is specific action required in particular areas to achieve the Catchment Targets. It is part of the National requirement to set short-term targets (1-5 years), relating mainly to management actions or capacity-building. These targets must contribute to progress towards the longer-term resource condition targets. In setting these targets, the Corangamite Salinity Action Plan takes into account of national indicators and associated guidelines and protocols for measuring and reporting, as set out in the National Framework for NRM Monitoring and Evaluation. Examples of management action targets include: X hectares of recharge zones within region to be revegetated by year Y; Xkm of riparian zone to be fenced and managed for conservation and landscape function, X% of farms covering Y% of region with whole farm plans *(Natural Resource Management Ministerial Council, October 2002)*.

P

Primary salinity - Or naturally occurring salinity is part of the Australian landscape and reflects the development of this landscape over time. Examples are the marine plains found around the coastline of Australia and the salt lakes in central and western Australia. Salts are distributed widely across the Australian landscapes. They originate mainly from depositions of oceanic salt from rain and wind. Salt stored in the soil or groundwater is concentrated through evaporation and transpiration by plants. In a healthy catchment, salt is slowly leached downwards and stored below the root zone, or out of the system *(Australian Dryland Salinity Assessment 2000)*.

R

Ramsar - Commonly used name to describe the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, which was signed in Ramsar, Iran, in 1971 (www.environment.nsw.gov.au).

Recharge - Water that infiltrates through the soil to replenish an aquifer (DoE, WA webpage). Recharge is normally provided by rainfall, but can also occur from leaking dams, wetlands, rivers, streams, broken pipes, watering of gardens and irrigation of crops.

Recharge Zone - An area through which water from the ground or surface-water system percolates to replenish (recharge) an aquifer. A recharge zone for a shallow watertable aquifer usually covers the entire surface area of the aquifer. A recharge zone for an aquifer which is confined by less permeable rocks occurs in specific areas where water leaks from overlying aquifers, or where the aquifer outcrops at the ground surface.

Resource condition targets - Are specific, timebound and measurable, against the minimum set of matters for national targets. The timeframe for achievement of these targets is likely to be 10-20 years. These targets must be pragmatic and achievable. They would be developed iteratively, including through a benefit/cost analysis. Examples could include: average salinity of X ECs at specific end-of-valley site by year Y; X hectares of specific native vegetation type within region at year Y maintained or regenerated; X stream sites within region in specific river condition category by year Y. Within their regional plans, regional bodies may also wish to set targets for matters that are additional to the minimum set *(Natural Resource Management Ministerial Council, October 2002)*.

Regolith - A layer of loose, heterogenous material covering solid rock. The origins of regolith are formed from weathering and biological processes; if it contains a significant proportion of biological compounds it is more conventionally referred to as soils (http://www.answers.com).

S

Saline soils - Soils which contain sufficiently large quantities of soluble salts, usually sodium chloride, to affect plant growth adversely *(Gilpin 1990)*.

Saline Wetland - Wetlands in which salinity exceeds 1,000 parts per million Total Dissolved Solids throughout the whole of the year *(Gilpin 1990)*.

Salinity - The presence of mineral salts such as sodium chloride (NaCl), potassium chloride (KCl), lime (calcium carbonate or $CaCO_3$), gypsum (calcium sulphate or $CaSO_4$) and others, either in solution or as solids. Salinity occurs as a result of natural landscape processes or in landscapes disturbed through clearing or other activities that interfere with the water and salt balance (www.lwa.gov.au & www.environment.nsw.gov.au).

Salinity and Soils Portfolio Group - A group of four community members appointed by the Corangamite CMA to oversee the implementation of both the Salinity Action Plan as well as the Soil Health Strategy for the Corangamite CMA. The group reports to the Regional Implementation Committee.

Salinisation - The process by which land or water becomes affected by salt. Land salinisation occurs through the accumulation of salts in the root zone and on the soil surface, usually by the evaporation of saline groundwater from shallow watertables. Water salinisation occurs through an increase in the concentration of salt in the water, usually by the removal of fresh water through evaporation, harvesting or diversion.

Salt load - The amount of salt carried from a catchment over a period of time. Salt load is usually expressed as the mass of salt in solution in a body of water, such as a river or stream, moving past a particular point over a period of time (such as tonnes per day).

Salt scald - An area where salt crystals accumulate on the soil surface, suppressing plant growth and often leading to surface soil erosion (which can expose saline subsoils) *(ABC webpage)*.

Salt tolerant - Species able to withstand high levels of salinity *(Salinity Resource Centre webpage)*.

Secondary salinity - Is the salinisation of land and water resources due to land-use impacts by people. It includes salinity that results from watertable rises from irrigation systems – irrigation salinity – and from dryland management systems – dryland salinity. Both forms of salinity are due to rising watertables mobilising salt in the soil. There is no fundamental difference in the hydrologic process *(Australian Dryland Salinity Assessment 2000)*.

Sodicity - Refers to soil containing levels of sodium that affect its stability. Sodic soils are dispersible and are thus vulnerable to erosion *(ABC webpage)*.

Soil-water - Refers to that part of the water in the soil that can be absorbed by plant roots, that can be held between field capacity and the moisture content at which plant growth ceases.

W

Watertable - The upper surface of groundwater. Below the watertable the soils and rocks are fully saturated, above the watertable the soils and rocks are unsaturated.

Appendix C: Relationship of RCTs to MATs

Type	No.	Resource condition target	Likely result if management action targets are met
		Upper West Moorabool	
W	1	*By 2015, maintain the EC measured in the Lal Lal Reservoir (tower surface) below 700 µS/cm 95% of the time.*	*No MAT set until research is completed (Dec 2008) RCT is currently achieved and has been set as an interim benchmark.*
W	2	*By 2015, maintain the EC measured in the Lal Lal Reservoir (tower surface) below 700 µS/cm 95% of the time.*	*No MAT set until research is completed (Dec 2008) RCT is currently achieved and has been set as an interim benchmark.*
		Morrisons – Sheoaks	
W	3	*By 2015, maintain the EC measured at the Sheoaks off-take below 1000 µS/cm 90% of the time (1000 EC does not meet Australian drinking water standards).*	*3070 ha of recharge and 50 ha of discharge will be treated. This is calculated to decrease salinity by 6.5 EC. Current trend in salinity is not known for the Sheoaks off-take but assuming the same trend as for further downstream, salinity will continue to increase, however treatment will ensure the 1000 EC target is unlikely to be exceeded.* **RCT expected to be achieved.**
W	4	*Maintain an EC of less than 2500 µS/cm for 90% of the time for the Moorabool River as measured at the Batesford gauging station (# 232202).*	*3070 ha of recharge and 50 ha of discharge will be treated. This is calculated to decrease salinity by 6.5 EC. This will reduce the current trend in salinity (+23.7 EC/yr). Salinity will continue to rise but the exceedence target will be achieved.* **RCT expected to be achieved.**
		Pittong	
W	5	*Maintain an EC of less than 8000 µS/cm for 90% of the time for Woady Yaloak River as measured at the Cressy gauging station (# 234201).*	*4050 ha of recharge and 440 ha of discharge will be treated. Recharge treatment is calculated to decrease the mean salinity from 5265 EC to 4559 EC, dramatically lowering the chances of the 8000 EC trigger to be exceeded. Benefits from discharge management are not included but are believed to be significant.* **RCT expected to be achieved.**
W	6	*By 2012, establish a target for EC measured in the Naringhil Creek at the edge of the Pittong target area.*	*Stream salinity monitoring station established by 2007. Five years of data then required to establish salinity range.* **RCT expected to be achieved.**
L	7	*By 2015 there is no net increase in the area of land salinity in the Pittong target area (compared to the area in 2005).*	*440 ha of discharge will be treated. The current increase in discharge is estimated at 8% per year. Achieving the MAT will reduce the current area of land salting by 62 ha.* **RCT expected to be achieved.**

Type	No.	Resource condition target	Likely result if management action targets are met
		Illabarook	
W	8	*Maintain an EC of less than 8000 µS/cm for 90% of the time for Woady Yaloak River as measured at the Cressy gauging station (# 234201).*	*420 ha of recharge and 260 ha of discharge will be treated. This is calculated to decrease the mean salinity measured at Cressy by 75 EC and will more than reverse the predicted rise of 35 EC (if nothing is done). This result is expected to lower the chances of exceeding the 8000 EC target.* **RCT expected to be achieved**
W	9	*By 2012, establish targets for EC measured in the major tributaries to the Woady Yaloak River at the edge of the Illabarook target area.*	*Monitoring commenced 2006. Five years of data required to establish salinity range.* **RCT expected to be achieved.**
		Lismore – Derrinallum	
E	10	*By 2010, establish the target range for salinity measured at appropriate sites in Lake Tooliorook to ensure the integrity of the aquatic ecosystem.*	*Priority monitoring project identified and due for completion by 2010, allowing EC target range to be developed.* **RCT expected to be achieved**
W	11	*By 2008, establish a target for EC measured at the gauging station in Browns Waterholes (# 234212).*	*Priority monitoring project identified and due for completion by 2009, allowing EC target to be developed.* **RCT expected to be achieved**
I	12	*By 2015, ensure that 80% of the roads in saline areas (in the Lismore – Derrinallum target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**
L	13	*By 2015, there should be no net gain in the area affected by secondary saline discharge in the Lismore – Derrinallum target area (compared to 2005).*	*160 ha of secondary salinity discharge will be treated. No trend data for land salting is available but anecdotal evidence would suggest salinity is not increasing. Therefore proposed discharge action should result is a positive reduction in saline land.* **RCT is expected to be achieved.**
		Lake Corangamite	
E	14	*By 2010, establish targets for the ranges of salinity measured at appropriate monitoring sites in Lake Corangamite, Lake Gnarpurt, Lake Martin and Cundare Pool to ensure the integrity of the aquatic ecosystems.*	*Priority monitoring project identified and due for completion by 2010, allowing EC target range to be developed.* **RCT expected to be achieved.**
W	15	*Maintain an EC of less than 2500 µS/cm for 90% of the time for the Pirron Yallock Creek as measured at the Pirron Yallock gauging station (# 234203).*	*No actions are proposed as the RCT has been set as a trigger for future action (if it is exceeded). Current trend data would suggest this trigger will not be exceeded by 2015.* **RCT is expected to be achieved.**
I	16	*By 2015, ensure that 80% of the roads in saline areas (in the Lake Corangamite target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**

Type	No.	Resource condition target	Likely result if management action targets are met
		Lake Corangamite (continued)	
E	18	*By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Lake Corangamite target area, compared with 2005.*	*Achieving the RCT will be influenced by the decision on the water level in Lake Corangamite. If the 118m water level height in the lake is adopted, 106 ha of primary saline land will be inundated, resulting in a loss of land but a gain in saline wetlands. A further 540 ha of primary saline land will treated above 118m. If the lake is not raised, the same 540 ha of primary saline land will be treated however the gain in saline wetlands will not be achieved.* **RCT for primary saline land will be achieved but uncertainty surrounds achieving the saline wetland RCT.**
		Colac – Eurack	
I	19	*By 2015, all new developments in land affected by salinity (saline discharge areas) within the urban areas of the City of Colac should be appropriately engineered.*	*Salinity management overlay (SMO) project will be completed by 2006. If adopted by council planners, the changes to the planning scheme should reduce the risk of salinity to developments in saline areas.* **RCT expected to be achieved.**
E	20	*By 2010, establish targets for the ranges of salinity measured at appropriate monitoring sites in Lake Colac, Lake Beeac and Lough Calvert to ensure the integrity of the aquatic ecosystems.*	*Priority monitoring project identified and due for completion by 2010 allowing EC target range to be developed.* **RCT expected to be achieved.**
I	21	*By 2015, ensure that 80% of the roads in saline areas (in the Colac – Eurack target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by 2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**
L	22	*By 2015 there should be no net gain in the area of land affected by secondary salinity in the Colac – Eurack target area, compared with 2005.*	*1070 ha of saline discharge will be treated, including 320 ha of secondary salinity. Trends in land salting indicate a decrease in land salting in the area (1 site only) so the combination should ensure* **the RCT will be achieved.**
E	23	*By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Colac – Eurack target area, compared to 2005.*	*1070 ha of saline discharge will be treated, including 750 ha of primary salinity.* **RCT for primary saline land will be met but uncertainty surrounds achieving the saline wetland RCT.**
		Warncoort	
W	24	*Maintain an EC less than 25000 µS/cm for 95% of the time for the Birregurra Creek as measured at the Ricketts Marsh gauging station (# 233211).*	*Water quality trend analysis indicates the salinity in the Birregurra Creek is falling. 380 ha of saline land will be treated, further educing salt wash-off.* **RCT expected to be achieved.**
L	25	*By 2015 there should be no net gain in the area of land affected by secondary salinity in the Warncoort target area, compared with 2005.*	*380 ha of saline land will be treated. No land salting trend data is available but anecdotal evidence would suggest salinity is not increasing.* **RCT expected to be achieved.**
I	26	*By 2015, ensure that 80% of the roads in saline areas (in the Warncoort target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by 2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**

Type	No.	Resource condition target	Likely result if management action targets are met
		Murdeduke	
L	27	*By 2015 there should be no net gain in the area of land affected by secondary salinity in the Murdeduke target area, compared with 2005.*	*420 ha of saline land will be treated. No land salting trend data is available but anecdotal evidence would suggest salinity is not increasing.* **RCT expected to be achieved.**
I	28	*By 2015, ensure that 80% of the roads in saline areas (in the Murdeduke target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by 2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**
		Modewarre	
L	29	*By 2015 there should be no net gain in the area of land affected by secondary salinity in the Modewarre target area, compared with 2005.*	*420 ha of saline land will be treated. Land salting trend data suggest salinity is decreasing (by 7%) and watertables dropping.* **RCT expected to be achieved.**
E	30	*By 2010, establish targets for the ranges of salinity measured at appropriate sites in Lake Modewarre, Gherang and Browns Swamps to ensure the integrity of the aquatic ecosystems.*	*Priority monitoring project identified and due for completion by 2010 allowing EC target range to be developed.* **RCT expected to be achieved.**
W	31	*By 2008, establish an appropriate end-of-valley target for salinity measured in Thompson Creek at the edge of the Modewarre target area.*	*Priority monitoring project identified and due for completion by 2009, allowing end-of-valley target to be developed.* **RCT expected to be achieved.**
I	32	*By 2015, ensure that 80% of the roads in saline areas (in the Modewarre target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by 2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**
		Geelong – Lake Connewarre	
E	33	*By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Geelong – Lake Connewarre target area, compared with 2005.*	*780 ha of saline discharge will be treated, including 740 ha of primary salinity. No land salting trend data is available but anecdotal evidence would suggest salinity is not increasing.* **RCT for primary saline land will be met but uncertainty surrounds achieving the saline wetland RCT.**
L	34	*By 2015 there should be no net gain in the area of land affected by secondary salinity in the Geelong – Lake Connewarre target area, compared with 2005.*	*40 ha of secondary saline discharge will be treated, No land salting trend data is available but anecdotal evidence would suggest salinity is not increasing. However a small increase in land salting could offset the gains made by treating saline discharge.* **RCT likely to be achieved.**
E	35	*By 2010, establish targets for the ranges of salinity measured at appropriate sites in the Lower Barwon wetlands and the Thompson Creek estuary to ensure the integrity of the aquatic and estuarine ecosystems.*	*Priority monitoring project identified and due for completion by 2010, allowing EC target ranges to be developed.* **RCT expected to be achieved.**
I	36	*By 2015, ensure that 80% of the roads in saline areas (in the Geelong – Lake Connewarre target area) are managed to prevent deterioration at rates equivalent to non-saline areas.*	*Training of road engineers completed by 2007. Assumes practices are adopted by shires.* **RCT is expected to be achieved.**
		Lara	
E	37	*By 2015 there should be no net loss in the area of primary saline land and saline wetlands in the Lara target area, compared with 2005.*	*140 ha of primary saline discharge will be treated. Saline wetlands actively managed by Cheetham salt.* **RCT for both primary saline land and saline wetlands will be achieved.**

Appendix D: Funding requirements (3 – year)

Year 1			Catchment-wide	Upper West Moorabool	Morrisons – Sheoaks	Pittong	Illabarook	Lismore – Derrinallum	Lake Corangamite	Colac – Eurack	Warncoort	Murdeduke	Modewarre	Geelong – Lake Connewarre	Lara	Total Salinity Program
Supporting Programs																
Education & extension program		$	810,000													810,000
Management & support		$	120,000													120,000
Training programs for roads staff		$	0	0	0	0	0	4,900	0	4,900	4,900	4,900	4,900	4,900	0	29,400
Total for supporting programs			930,000	0	0	0	0	4,900	0	4,900	4,900	4,900	4,900	4,900	0	**959,400**
Research & Investigation																
Research funding		$	262,500													262,500
Technical consultancy		$	0													0
Post-graduate research		$	0													**262,500**
Total for research & investigation			262,500													
Monitoring																
Gauging station installed		$	0													0
Bores installed		$	0													0
Sites maintained and replaced		$	28,750													28,750
Sites monitored		$	30,000													30,000
Total for monitoring programs			58,750													**58,750**
Works																
Recharge	private	$		0	306,262	156,890	35,744	0	0	0	0	0	0	0	0	498,896
	public	$		0	0	0	0	0	0	0	0	0	0	0	0	0
Discharge	private	$		0	3,264	57,469	16,333	13,298	90,248	123,399	75,042	17,672	10,468	100,616	0	507,807
	public	$		0	0	0	0	1,228	0	5,261	0	0	0	7,473	1,346	15,307
Total for on-ground works			0	0	309,526	214,359	52,077	14,525	90,248	128,660	75,042	17,672	10,468	108,089	1,346	**1,022,010**
Total public funding			*1,251,250*	*0*	*309,526*	*214,359*	*52,077*	*19,425*	*90,248*	*133,560*	*79,942*	*22,572*	*15,368*	*112,989*	*1,346*	***2,302,660***
Total private funding				*0*	*103,175*	*71,453*	*17,359*	*4,433*	*30,083*	*41,133*	*25,014*	*5,891*	*3,489*	*33,539*	*0*	*335,568*

Year 2			Catchment-wide	Upper West Moorabool	Morrisons – Sheoaks	Pittong	Illabarook	Lismore – Derrinallum	Lake Corangamite	Colac – Eurack	Warncoort	Murdeduke	Modewarre	Geelong – Lake Connewarre	Lara	Total Salinity Program
Supporting Programs																
Education & extension program		$	810,000													810,000
Management & support		$	120,000													120,000
Training programs for roads staff		$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for supporting programs			930,000	0	0	0	0	0	0	0		0	0	0	0	120,000
																930,000
Research & Investigation																
Research funding		$	309,166													309,166
Technical consultancy		$	80,000													80,000
Post-graduate research		$	70,000													**389,166**
Total for research & investigation			459,166													
Monitoring																
Gauging station installed		$	50,000													50,000
Bores installed		$	0													0
Sites maintained and replaced		$	28,750													28,750
Sites monitored		$	30,000													30,000
Total for monitoring programs			108,750													**108,750**
Works																
Recharge	private	$		0	326,249	156,890	36,447	0	0	0	0	0	0	0	0	519,586
	public	$		0	0	0	0	0	0	0	0	0	0	0	0	0
Discharge	private	$		0	3,264	57,469	16,333	13,298	90,248	123,399	75,042	17,672	10,468	100,616	0	507,807
	public	$		0	0	0	0	1,228	0	5,261	0	0	0	7,473	1,346	15,307
Total for on-ground works			0	0	329,513	214,359	52,780	14,525	90,248	128,660	75,042	17,672	10,468	108,089	1,346	**1,042,700**
Total public funding			*1,497,916*	*0*	*329,513*	*214,359*	*52,780*	*14,525*	*90,248*	*128,660*	*75,042*	*17,672*	*10,468*	*108,089*	*1,346*	***2,470,616***
Total private funding				*0*	*109,838*	*71,453*	*17,593*	*4,433*	*30,083*	*41,133*	*25,014*	*5,891*	*3,489*	*33,539*	*0*	*342,464*

Year 3			Catchment-wide	Upper West Moorabool	Morrisons – Sheoaks	Pittong	Illabarook	Lismore – Derrinallum	Lake Corangamite	Colac – Eurack	Warncoort	Murdeduke	Modewarre	Geelong – Lake Connewarre	Lara	Total Salinity Program
Supporting Programs																
Education & extension program		$	810,000													810,000
Management & support		$	120,000													120,000
Training programs for roads staff		$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for supporting programs			930,000	0	0	0	0	0	0	0		0	0	0	0	120,000
																930,000
Research & Investigation																
Research funding		$	196,666													196,666
Technical consultancy		$	60,000													60,000
Post-graduate research		$	90,000													90,000
Total for research & investigation			346,666													**346,666**
Monitoring																
Gauging station installed		$	0													0
Bores installed		$	0													0
Sites maintained and replaced		$	28,750													28,750
Sites monitored		$	30,000													30,000
Total for monitoring programs			58,750													**58,750**
Works																
Recharge	private	$		0	346,235	156,890	37,151	0	0	0	0	0	0	0	0	540,276
	public	$		0	0	0	0	0	0	0	0	0	0	0	0	0
Discharge	private	$		0	3,264	57,469	16,333	13,298	90,248	123,399	75,042	17,672	10,468	100,616	0	507,807
	public	$		0	0	0	0	1,228	0	5,261	0	0	0	7,473	1,346	15,307
Total for on-ground works			0	0	349,499	214,359	53,483	14,525	90,248	128,660	75,042	17,672	10,468	108,089	1,346	**1,063,390**
Total public funding			*1,335,416*	*0*	*349,499*	*214,359*	*53,483*	*14,525*	*90,248*	*128,660*	*75,042*	*17,672*	*10,468*	*108,089*	*1,346*	***2,308,806***
Total private funding				*0*	*116,500*	*71,453*	*17,828*	*4,433*	*30,083*	*41,133*	*25,014*	*5,891*	*3,489*	*33,539*	*0*	*349,361*

Total			Catchment-wide	Upper West Moorabool	Morrisons – Sheoaks	Pittong	Illabarook	Lismore – Derrinallum	Lake Corangamite	Colac – Eurack	Warncoort	Murdeduke	Modewarre	Geelong – Lake Connewarre	Lara	Total Salinity Program
Supporting Programs																
Education & extension program		$	2,430,000													2,430,000
Management & support		$	360,000													360,000
Training programs for roads staff		$	0	0	0	0	0	4,900	0	4,900	4,900	4,900	4,900	4,900	0	29,400
Total for supporting programs			2,790,000	0	0	0	0	4,900	0	4,900	4,900	4,900	4,900	4,900	0	2,819,400
Research & Investigation																
Research funding		$	768,332													768,332
Technical consultancy		$	140,000													140,000
Post-graduate research		$	160,000													160,000
Total for research & investigation			1,068,332													**1,068,332**
Monitoring																
Gauging station installed		$	50,000													50,000
Bores installed		$	0													0
Sites maintained and replaced		$	86,250													86,250
Sites monitored		$	90,000													90,000
Total for monitoring programs			226,250													**226,250**
Works																
Recharge	private	$		0	978,746	470,671	109,342	0	0	0	0	0	0	0	0	1,558,758
	public	$		0	0	0	0	0	0	0	0	0	0	0	0	0
Discharge	private	$		0	9,792	172,406	48,998	39,893	270,743	370,197	225,126	53,015	31,405	301,848	0	1,523,421
	public	$		0	0	0	0	3,683	0	15,784	0	0	0	22,418	4,037	45,922
Total for on-ground works			*0*	*0*	*988,538*	*643,077*	*158,340*	*43,575*	*270,743*	*385,981*	*225,126*	*53,015*	*31,405*	*324,266*	*4,037*	***3,128,101***
Total public funding			*4,084,582*	*0*	*988,538*	*643,077*	*158,340*	*48,475*	*270,743*	*390,881*	*230,026*	*57,915*	*36,305*	*329,166*	*4,037*	***7,242,083***

Appendix E: Summaries of Background Reports

1. Regional Overview and Development Considerations (Background Report 1)

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 it 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 Woady 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 1990s. 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.

2. Process for the Initial Selection and Validation of Target Areas for Salinity Management (Background Report 2)

This report documents the process for the initial selection and validation of target areas for salinity management in the Corangamite CMA second-generation Salinity Action Plan.

The process is based on a framework containing three fundamental components, *viz:* landscape disaggregation to provide consistency in methods; salinity risk assessment based on a variety of asset classes; and an analysis of temporal changes or trends in salinity values.

The outcomes of two recently completed projects have been critical in the target area selection process:
– the Groundwater Flow Systems (GFS) project and the Geospatial Salinity Hazard and Asset Risk Prediction (GSHARP) project. The GFS project has contributed an understanding of the applicability of various salinity management options in terms of their hydrological response. GSHARP has contributed a spatial picture of salinity hazard and where assets are at risk within the Corangamite region. Additional to these projects, a method for determining target areas for salinity management to protect stream water quality is also documented.

Together these tools provide an objective, transparent and accountable method of determining the target areas for salinity management. The combined process will allow future iterations to be run with relative ease, as continuous improvements are made to the input data sets, the methods and the scientific conceptualisation of the salinity processes within the Corangamite region.

Although there are many knowledge gaps or omissions in the data sets and some of the salinity processes are speculative, the methodology is arguably a more important outcome than the selection of the target areas. Provided that the process is valid, the continuous improvement of data and knowledge in conjunction with regular monitoring and evaluation will provide the means to update the salinity target areas to maximise the investment benefit on an annual basis.

This initial process has resulted in 13 areas being delineated as interim target areas for salinity treatment. Validation of the assets at risk in these areas has been checked in the field. Discussions with the asset managers will further clarify the actual risk that salinity imposes on these assets and assist in developing appropriate management options. Further refinement of the target areas is an expected outcome of these discussions.

3. Salinity Target Areas: assessment, trends, resource condition targets & management options (Background Report 3)

This report is the third in a series of background reports on the development of the Corangamite Salinity Action Plan (SAP) for the Corangamite Catchment Management Authority (CCMA). The second-generation plan is being developed in line with Victoria's Salinity Management Framework – Restoring our Catchments (DNRE, 2002) which sets out broad and challenging targets for management of salinity across the state. The SAP will be incorporated into the broader Corangamite Regional Catchment Strategy (RCS), a draft version of which is currently available (Thomas & Colliver, 2002).

The CCMA SAP has selected 12 target areas for salinity management based on an objective, accountable and transparent process documented in Background Report No.2 (Dahlhaus, 2003). This report details the current condition and trends, the salinity processes, the appropriate salinity management options, the no-change and change scenarios and sets resource condition targets for each area.

The current condition and trends highlights two major salinity issues for the Corangamite CMA region:

- the rapidly deteriorating urban water quality sourced from the Moorabool River, and
- the threat to irreplaceable international environmental assets, especially Lake Corangamite.

Other valuable assets at risk from salinity are:

- Residential areas in the City of Colac
- Productive Agricultural Land
- Roads infrastructure

Salinity processes in most target areas have been poorly investigated and are not well understood. In general, previous investigations have been focused on analysing data, but have failed to scientifically validate the link between the cause and effect. Models have been conceptualised and speculated, but few investigations (if any) have taken the next step of proving the conceptual models. In some new target areas, groundwater data has not been previously collected, making the salinity processes entirely speculative. In those salinity target areas that were formerly salinity "Hot Spots" under the previous salinity management plan ("Restoring the Balance"), more data exists, but is often lacking in quality.

The lack of scientifically validated salinity processes limits the confidence in appropriate salinity management options. The management of saline groundwater discharge by reducing the groundwater recharge through biological control (tree planting) is recommended for three salinity target areas: Pittong, Illabarook, and Morrisons – Sheoaks. In the remaining target areas recharge control is considered ineffective to control saline groundwater discharge.

The productive use and rehabilitation of saline land (discharge management) is the preferred management option in seven of the salinity target areas:
Lismore – Derrinallum, Lake Corangamite, Colac – Eurack, Warncoort, Modewarre, Murdeduke and Geelong – Lake Connewarre. The appropriate management options for the Upper West Moorabool and Lara areas are to be determined following research and investigation.

However, engineering options are the most effective management tool for the high-value assets at risk. The management of water allocations in the Moorabool River catchment will have a far greater control over the rapidly decreasing urban water quality than any land management options. Similarly, the management of the water diversions in the Woady Yaloak Diversion Scheme and the Lough Calvert Drainage Scheme have the dominant impact on the salinity of Lake Corangamite and the surface water bodies in the Lake Corangamite, Colac – Eurack, Warncoort and Murdeduke salinity target areas. Both water management issues are currently being reviewed and the appropriate management options are pending these studies (GHD, in prep; SKM, in prep.)

Scenarios are presented for the no-change condition and the changed condition under the appropriate management. The no-change scenarios have been predicted on the basis of the available trends, conceptual models, numerical modelling (Flowtube), or mapped salinity as appropriate for each area. In some areas the paucity of data has resulted in more speculative scenarios. The change scenarios have been based on the adoption of appropriate management actions, rather than the actual likely adoption rates. The management action targets for each area are being derived through a separate process involving workshops with asset managers and stakeholders in each area (Nicholson *et al.*, 2003).

Resource condition targets were set according to the National Framework for Natural Resource Management (NRM) Standards and Targets. A difficulty in setting achievable resource condition targets for some areas is that salinity trends are not evident in the short monitoring record (or in some cases, no monitoring record). In other cases, where a trend is measurable, there is no knowledge of what is causing the trend. In these cases the targets have been set as a commitment to establishing a measurable target within a reasonably short timeframe.

4. Asset Manager Consultation, Preferred Methods of Implementation and Management Targets (Background report 4)

Asset manager consultation was based on a highly targeted approach, by speaking directly to those parties whose assets are directly affected by salinity or whose participation is required to implement proposed salinity treatment options. Discussions were based on a semi structure interview process, using the program logic approach developed by the Corangamite Salinity team in the mid 1990s. This targeted consultation approach was endorsed by the Corangamite Catchment Management Authority in February 2003.

The main groups of asset managers consulted were:

- Infrastructure managers
- Utility managers
- Agricultural land managers
- Water resources managers
- Environmental groups, primarily government agencies
- Those responsible for cultural and heritage assets

Consultation allowed potential adoption rates for each treatment at each target location to be identified.

Analysis of the comments from asset managers clearly identified their preferred method of implementation and opportunities for potential partnerships.
However, to capitalise on these opportunities, several aspects needed to be considered *including:*

- Adopting best practice delivery
- Creating meaningful partnerships by rewarding desirable actions
- Integrated delivery
- Customising delivery for each target location
- Devolving responsibility for implementation to the asset managers.

Each topic is explored in this document and provides valuable ‘market intelligence’ to help guide implementation.

During consultation a number of region-wide themes and common issues also emerged.
They included:

- The need to manage expectations in priority and non-priority areas.
- Appreciating the impact water management has on the effectiveness of salinity management actions
- Integrating salinity management with other environmental responsibilities
- The development of more profitable agricultural systems to help achieve adoption
- Appreciating the impact the current dry climatic pattern is having on stakeholder perceptions.

Common salinity issues included:

- The need to expand the saline land treatment options available to land managers
- The opportunity for commercial forestry development to assist in achieving regional salinity outcomes
- The role of community education for regional education and salinity training programs
- Opportunities to increase the skills of road and infrastructure engineering staff with municipalities to better protect assets from salinity threats
- The 'value' of salinity management overlays and technical support for local government.

These are discussed in detail in the report.

The working notes from individual consultations are also included for future reference.

5. Investment Plan: Benefit-cost Analysis, Cost Sharing and Priority Setting (Background report 5)

This report is the fifth in a series of background reports on the development of the Corangamite Salinity Action Plan (SAP) for the Corangamite Catchment Management Authority (CCMA). The report uses information presented in these other reports to develop an investment plan for salinity in the Corangamite CMA region.

The benefit-cost analysis used in the Corangamite SAP models the difference between the 'No-Plan' and the 'With-Plan' scenarios.

A number of investment criteria are available to evaluate a project based on economic merit. This Benefit-Cost Analysis considers the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) of implementing the salinity management actions and programs outlined in this plan.

As required by government guidelines, 4% and 8% discount rates were used in this benefit-cost analysis. The lifespan on all project activities and impacts are assumed to be 30 years. Projects with a Benefit-Cost Ratio (BCR) of at least 1:1 and a positive Net Present Value (NPV) at 4 per cent are considered economically attractive.

Each Salinity Management Zone (SMZ) or target area of the Corangamite catchment is unique in the knowledge and extent of the salinity problem, the mix of actions proposed, and the projected level of adoption.

The benefit-cost model is presented in three parts:

- **Target area analysis**, which examines the costs and benefits for the 12 target locations.
- **Whole catchment analysis**, identifies the costs of the research and investigation, monitoring and program support aspects of the SAP.
- **Catchment-wide analysis**. This is the result of combining the target area analysis and the whole catchment analysis.

The catchment-wide analysis combines the target area analysis and the whole catchment analysis.

The catchment-wide Benefit-Cost Analysis provides a complete and accurate analysis for the region as a whole, providing a basis for investment decisions. The target area specific analysis was completed in order to help the investment prioritisation process.

Discount rates	NPV Costs ($)	BCR
4%	($498,668)	0.98
8%	($6,312,268)	0.65

Table 7.1: Net present value and benefit-cost ratio for catchment-wide activity

The results show a catchment-wide benefit-cost ratio slightly less than one. This is not surprising given that many salinity costs are directed at protecting or enhancing assets, which have not been assigned an economic value.

In addition to the catchment-wide Benefit-Cost Analysis for the entire SMP, BCRs for each target area were completed in order to help the investment prioritisation process. Each of the target areas were assigned benefits for the on-ground salinity management activities within their boundaries, thus allowing the target area specific BCR to be calculated.

To set priorities for the target areas that require the most immediate action and funding under the SAP, we have taken a three-step approach.

Step 1. Rank the target areas based on the Benefit-Cost Analysis

Step 2. Rank the target areas based on Non-Market & Unquantifiable Criteria

Step 3. Combine the two rankings to provide overall priorities

The overall investment priority ranking of SMZs is presented in *Table 1.2*. This provides the CCMA with a basis for determining priorities for investment.

Rank	Market ranking	Non-market ranking	Overall ranking
1	Lismore – Derrinallum	Lake Corangamite	Lake Corangamite
2	Murdeduke	Morrisons – Sheoaks	Morrisons – Sheoaks
3	Modewarre	Upper West Moorabool	Upper West Moorabool
4	Morrisons – Sheoaks	Colac – Eurack	Colac – Eurack
5	Pittong	Geelong – Lake Connewarre	Geelong – Lake Connewarre
6	Illabarook	Pittong	Lismore – Derrinallum
7	Lake Corangamite	Illabarook	Illabarook
8	Colac – Eurack	Lismore – Derrinallum	Pittong
9	Geelong – Lake Connewarre	Modewarre	Murdeduke
10	Warncoort	Murdeduke	Modewarre
11		Warncoort	Warncoort
12		Lara	Lara

Table 7.2: Target areas' overall ranking

Two of the target areas were not ranked based on the Benefit-Cost Analysis as we could attribute no dollar benefits to them. These were Upper West Moorabool and Lara.

6. Catchment Health Sites, Monitoring and Research (Background report 6)

This report is the sixth in a series of background reports on the development of the Corangamite Salinity Action Plan (SAP) for the Corangamite Catchment Management Authority (CCMA). The second-generation plan is being developed in line with Victoria's Salinity Management Framework – Restoring our Catchments (DNRE, 2002) which sets out broad and challenging targets for management of salinity across the state. The SAP will be incorporated into the broader Corangamite Regional Catchment Strategy (RCS), a draft version of which is currently available (Thomas & Colliver, 2002).

Other background reports to the CCMA SAP have documented the process for the selection of target areas for salinity management, resource condition targets, management options and targets and benefit-cost analyses. This background report documents the suggested monitoring program, catchment health sites and research program for salinity in the Corangamite CMA region.

The suggested monitoring program collects appropriate data to monitor trends which can be matched to the SAP targets. Targets have been set in accordance with the National Framework for Natural Resource Management (NRM) Standards and Targets in the National Action Plan (NAP) for salinity and water quality and Victoria's Salinity Management Framework – Restoring our Catchments (DNRE, 2002). Monitoring measures parameters with which to evaluate resource condition targets and the management action targets. In addition, it may be desirable to monitor some catchment-wide salinity trends, management actions, community values, demographic changes and land-use changes. This report states what should be monitored but not specifically how it should be monitored or who should do the task. The reasons for adopting this approach are discussed further in the document.

Catchment health sites are regarded as more than the physical locations in the landscape where data is collected to assess the resource condition. The SAP recognises that catchment health sites should include less tangible 'locations' or virtual places where monitoring the social health of the catchment is equally important as the biophysical sites. Salinity is a creeping threat and is not always recognised an urgent issue requiring immediate management response. Achieving the resource condition targets for the salinity management areas will be challenging for the Corangamite CMA and will require a sustained commitment to salinity action. Therefore, evaluating trends in the attitude and response of the SAP implementation committee and partners is just as important as monitoring trends at any biophysical site within the catchment. Monitoring the willingness and effectiveness of the CMA and partners to implement the salinity action is essential, if the resource condition targets are to be achieved.

Development of the second–generation SAP followed a seven-step process *(refer to Background Report No.1)*. Progression through each of these steps has identified deficiencies in the data sets and methods used to draw the conclusions at each stage. As a result, a number of research projects have been identified at various points in the process which have, by default, determined a priority list for research. The research projects suggested are only identified for the next three years. It is strongly recommended that after this period, the seven-step model is re-run. Re-running the model should identify further high-priority research needs for the next phase of the program.

The scale of the research projects and how they may best delivered has also been suggested. In some instances University post-graduate research has been suggested as the most appropriate, in other cases specialist consultant, may be needed, and for other work, departmental staff may be best suited to the task. In determining research priorities, the deliberations of staff currently in the salinity program (Nicholson, 2002) have also been considered.

7. Response to comments on the Regional Draft – 2003 (Background report 7)

This report is the seventh in a series of background reports on the development of the Corangamite Salinity Action Plan (SAP) for the Corangamite Catchment Management Authority (CCMA). The second-generation plan is being developed in line with Victoria's Salinity Management Framework – Restoring our Catchments, which sets out broad and challenging targets for management of salinity across the state. The SAP also relates to the Corangamite Regional Catchment Strategy 2003 – 2008 as one of its sub-strategies and action plans which provide the investment framework for integrated catchment management.

A regional draft of the SAP was distributed for public comment in July 2003. Comments were received from the Department of Sustainability and Environment (DSE) and the Department of Primary Industries (DPI), Barwon Water, Golden Plains Shire, and Moorabool Shire. Of these, the vast majority were from DSE and DPI (163 comments) which were collated and sent to the Corangamite CMA in March 2004. The comments were then reviewed by a panel convened on April 1st 2004, however the panel's responses were apparently not lodged with DSE at that time. With changes to project management staff and the implementation committee responsible for salinity management, the original responses are no longer available.

In August 2005 the original consulting team was engaged to finalise the SAP, and its responses to the comments are listed in this report. In reviewing the comments, four broad categories were apparent, *viz*;

- Relevant comments that resulted from ambiguous wording, inadequate explanation, omissions, or where the completion of subsequent work has since improved the available information (123 of the 163 comments, or about 75%).
- Comments that indicated that the respondent had not read the entire document and/or background reports (35 comments, or around 20%).
- Comments that were ambiguous, vague or not understood (3 comments).
- Comments that are disputed, rejected, or on which guidance was sought. These comments related to the priority area selection process (GSHARP), the community consultation process, the view of primary salinity as an asset, the importance of urban water supply, the economic analysis and the technical rigour.

To clarify the required level of responses to the comments a meeting was held with Mr Shayne Annett, Senior Policy Analyst Landscape Change, DSE, at the Corangamite CMA office in Geelong on 15th September 2005. At that meeting a number of comments were subsequently clarified.

The response to the comments is tabulated on the following pages. The table includes reference to the report, section and page of the regional draft or background report, and the report, section and page of the final SAP or background report in which the comment has been addressed.

8. Reflections on asset manager and stakeholder response to implementation (Background Report 8)

The preliminary draft of the Corangamite Salinity Action Plan (Nicholson et al, 2003) was completed in July 2003 and has been used by the Corangamite Catchment Management Authority to guide salinity implementation up to the present day.

Implementation occurred in seven of the 12 target locations identified in the draft Salinity Action Plan (SAP). Given this experience and some significant recharge and discharge investigations, it seemed prudent to include insights from this initial implementation period in the finalisation of the draft Corangamite SAP. Rather than attempt to modify existing documents, it was decided to write this companion background report. Twenty-one people were consulted in the preparation of this report.

This document entitled Reflections on asset manager and stakeholder response to implementation (June 2003 to September 2005) tests the assumptions and figures stated in background reports No. 3 (Dahlhaus, 2003) and No 4 (Nicholson, Anderson and Stephens, 2003). It confirms many of the points raised in the initial consultation in 2003, but also identifies new issues and challenges not anticipated during the initial consultation phase.

Using these insights, potential annual and 10-year management actions for each of the 12 priority locations are calculated. Additional consideration was given to native vegetation threatened by salinity.

These management actions require benefit-cost analysis and deliberation before inclusion in the final SAP as targets.

9. Reflections on asset manager and stakeholder response to implementation (Background Report 8)

This report is the ninth in a series of Background Reports on the development of the Corangamite Salinity Action Plan (SAP) for the Corangamite Catchment Management Authority (CCMA). The SAP is the second-generation salinity plan for the Corangamite region developed with guidance from the National Action Plan (NAP) for Salinity and Water Quality; Victoria's Salinity Management Framework – Restoring our Catchments; and the Corangamite Regional Catchment Strategy 2003-2008. Each of these documents set broad and challenging targets for management of salinity in the national, state and regional context. A Regional Draft of the Corangamite SAP and six of the Background Reports were published in July 2003 for comment.

The National Framework for Natural Resource Management Standards and Targets provides the principles and requirements for targets which are used to guide the investment in regional salinity management. The framework outlines a minimum set of matters for which regional targets are required, with guidelines and protocols for target-setting, monitoring and reporting. These targets set by the CCMA are considered by the Commonwealth and State as part of the accreditation process prior to investment by governments in the SAP. The targets relate to an absolute improvement in resource condition, or a decrease in the rate of degradation, and are usually expressed as numbers or percentage changes. The targets are categorised into three levels: aspirational targets, achievable resource condition targets and management action targets.

This report details the revision of the interim Resource Condition Targets (RCTs) set in the Regional Draft SAP (2003). The revision takes into account the most current knowledge in the research, investigations and studies within the Corangamite region. They are considered pragmatic and achievable as required by the National Framework.

The total number of RCTs for SAP target areas reduced from 42 in the Regional Draft SAP, to 37.
The revised RCTs can be grouped into four broad categories:

- **Land salinity** – RCTs have been set as no net gain in secondary salinity over 2005 levels in the eight target areas where land salinity has been identified as a threat to assets.
- **Surface water salinity** – these RCTs are set in two categories:
  - a) a quantitative end-of-valley target for those target areas where there is sufficient data to determine a trend
  - b) a stated action to establish a target for those target areas where more data is required before a trend can be determined.
- **Aquatic and estuarine ecosystem integrity** – two distinct types of RCTs have been set to maintain the integrity of aquatic ecosystems:
  - *a)* actions to establish a range for the salinity of specific lakes identified as threatened by increasing or decreasing salinity
  - *b)* no net loss of primary salinity in target areas where primary saline ephemeral wetlands have been identified as under threat from changed hydrology and salinity.
- **Infrastructure integrity** – RCTs have been set to protect
  - *a)* roads in target areas where they have been identified as threatened by salinit
  - *b)* a reduction in the urban infrastructure at risk in the City of Colac.

The SAP monitoring requirements and research requirements have also been revised, taking into account the completed research, the research underway, the revised RCTs, and the new knowledge and information listed in this report. The recommended monitoring and research programs highlight the need for improved knowledge in high-priority salinity target areas before management actions can be formulated.

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