Corangamite Soil Health Strategy 2006-2012

A guide for investment to protect natural and built assets

Australian Government

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CORANGAMITE CMA HEALTHY CATCHMENTS - HEALTHY WATERWAYS

Corangamite Soil Health Strategy 2006-2012

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The development of the Corangamite Soil Health Strategy involved the collective effort from many interested members. The Department of Primary Industries coordinated and wrote the Corangamite Soil Health Strategy on behalf of the Corangamite Catchment Management Authority. A community-based steering committee was formed to guide the development of the strategy. Many other technical and industry-based experts also provided input into the development of the strategy.

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Authored by:

Troy Clarkson[1], Ian Crook[2], Peter Dahlhaus[3]

[1]Department of Primary Industries

[2]Crossfield Business Management Group

[3]University of Ballarat on behalf of the Corangamite Catchment Management Authority

The Corangamite Soil Health Steering Committee who guided the development of the Soil Health Strategy included:
Peter Hirth, Troy Clarkson, Cam Nicholson, Peter Dahlhaus, Ian Crook, Leigh Dennis, John Turner, Nick McCristal, Ron Page and Richard MacEwan.

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Abbreviations

Acronym	Description
AROTS	Australian Rare or Threatened Species
ASS	Acid Sulphate Soils
BMP	Best Management Practices
CAP	Coastal Action Plan
CAMS	Catchment Activity Management System
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EMO	Erosion Management Overlay
EPA	Environment Protection Authority
ESP	Exchangeable Sodium Percentage
GRDC	Grains Research & Development Corporation
LRA	Land Resource Assessment
LS	Landcare Strategy
LUIM	Land Use Impact Model
MAT	Management Action Target
NAP	National Action Plan for Salinity and Water Quality
NHT	Natural Heritage Trust
NLP	National Landcare Program
NPV	Net Present Value
NRM	Natural Resource Management
NVP	Native Vegetation Plan
PASS	Potential Acid Sulphate Soils
PIRVic	Primary Industries Research Victoria
RAV	Relative Asset Value
RAP	Rabbit Action Plan
RCIP	Regional Catchment Investment Plan
RCS	Regional Catchment Strategy
RCT	Resource Condition Target
RDS	Research and Development Strategy
RHS	River Health Strategy
RIC	Regional Implementation Committee
RSF	Relative Severity Factor
SALMIC	Sustainable Agriculture Land Management Implementation Committee
SAP	Salinity Action Plan
SFS	Southern Farming Systems
SHS	Soil Health Strategy
VROTS	Victorian Rare or Threatened Species
WAP	Weed Action Plan
WGLA	Working Group on Land Resource Assessment
WQS	Water Quality Strategy
WS	Wetland Strategy

Executive Summary

The Corangamite Soil Health Strategy aims to guide investment in a range of actions that will protect and enhance natural and built assets in the Corangamite region from a number of soil-based threats or threatening processes. The strategy identifies specific assets that should be protected or enhanced, the various threats, the asset managers and other stakeholders who have been involved in its development and will potentially be involved in its implementation.

The Soil Health Strategy focuses on the development and validation of priorities for investment to protect and enhance important natural and built assets in the Corangamite region. Importantly, these investment priorities are based on careful assessment of the relative value of assets and risks posed by threats.

The Corangamite region extends over some 1.3 million hectares of south-west Victoria, and includes many high-value and irreplaceable natural resources, including internationally recognised lakes and wetlands. The region is home to a human population of some 400,000; the social and commercial fabric of their lives is as varied as any other part of the country and ranges from extensive and diverse primary industries to important manufacturing and exporting enterprises.

The Corangamite region includes part or all of nine municipalities; the Corangamite Catchment Management Authority (CMA) has delineated 15 landscape zones within its boundaries.

In the development of the strategy, many sectors of the Corangamite community were consulted. In some cases, self-evident needs and priorities for action could be and were identified, funding was arranged and work was initiated well before the finalisation of this document. Great encouragement for the future of the strategy may be taken from these initiatives and the ways they were established since they highlight a strong sense of ‘ownership’ of the soil health issue by various sectors of the local community.

Services provided by the assets of the region are equally vital for the current and future well-being of the natural environment and the resident human population. The threats to these assets are real. Many are immediate; their effects have been and are currently being felt, seen and measured.

Protection and enhancement of the assets through investment – which must be targeted because the task is so large – is a responsibility that cannot be denied. A critical issue for the strategy has been the development and application of a robust logic for determining the investment priorities.

Foundations and direction

As a regional document, the strategy links to Victorian and Australian government strategies and fits within the broader framework set by their foundations, logic and direction. The Corangamite Soil Health Strategy aims to dovetail into and (in as many respects as possible), work closely with the wider state and national strategies, gaining more effective natural resource management outcomes all round.

The strategy takes a logical and objective approach to guiding investment based on definition of natural and built 'assets’ that are at risk from various soil-based ‘threats’ – almost all of which arise as a result of disturbance of the natural environment through human activity in urban and rural development, recreational and other activities.

Priorities for investment are identified through several key measures. These include Relative Asset Value, area under threat and the relative severity of the threat. A formula linking these measures provided “Relative Risk Values” for the threatening processes addressed by the strategy in each of the 15 landscape zones in the region. More than 140 “Relative Risk Values” were developed from this process. From these, 20 priorities for investment have been identified, with the highest ranking subjected to field and research-based validation.

Identifying assets and threats

Primary asset classes are identified: land, water quality, biodiversity, built infrastructure and cultural and heritage. In each primary class (except for 'cultural and heritage'), supporting secondary asset classes are defined.

There are 12 key threats: landslides, water erosion (sheet/rill and gully/tunnel erosion), acid sulphate soils, secondary salinity, waterlogging, soil structure decline, wind erosion, soil nutrient decline, soil acidification, soil contamination, soil organic carbon decline and soil biota decline.

Some of these act locally, virtually in situ with the asset, while others may be seen as 'mobile' in that they have the potential to impact other, off-site assets.

Five of the 12 threats were noted in the 20 highest Relative Risk Values: landslides, sheet/rill erosion, gully/tunnel erosion, secondary salinity and acid sulphate soils. All five impact on public assets and have the potential to impact all primary and secondary asset classes.

Assessment of Relative Risk Values by landscape zone to determine the ranking of the threats against each other, (i.e. the aggregate values across the 15 landscape zones) showed that secondary salinity had the highest aggregate Relative Risk Value, mostly because secondary salinity is relatively widespread and often interacts with large areas of agricultural production and high-value biodiversity areas. It also has the potential to impact on water quality, built infrastructure and cultural heritage sites.

Landslides had the second highest aggregate Relative Risk Value in the region and also have the potential to impact on all asset classes. Landslides have the highest Relative Severity Value, because they are capable of severely impacting invaluable and irreplaceable natural assets, destroying buildings and other built infrastructure and taking human life.

Water erosion, (sheet/rill and gully/tunnel) has the capacity to impact on all asset classes. These types of soil erosion pose greatest risk to water quality and agricultural production.

Acid sulphate soils (ASS) had one of the highest aggregate risk values. These soils were often found in wetlands. Acid sulphate soils have the potential to impact on all asset classes, with potentially catastrophic results.

Soil structure decline, *waterlogging, nutrient decline and soil acidification* had lower Relative Risk Values because they solely impact on agricultural production and not high-value public assets.

Wind erosion potentially causes impact on a range of assets. However, the likelihood of wind erosion events is relatively low compared with other threats to soil health in the region and therefore had a lower Relative Risk Value.

Priorities for investment

'Validated priorities for investment' – the highest Relative Risk Values after field validation provides the key guidance for investment:

Final Rank	Landscape Zone	Threat	Known assets at risk from priority threat
1	Gellibrand	Landslides	Lower Gellibrand River, Johanna River, Stafford Creek and Kennedy Creek. Princetown and Simpson River.
2	Lismore	Secondary Salinity	Lake Martin.
3	Woady Yaloak	Gully & Tunnel Erosion	Mount Misery Creek, Moonlight Creek and Woady Yaloak River. High to very high native vegetation conservation potential, mostly along waterways from Mount Mercer to Pittong. Some rural roads north of the Rokewood-Skipton Road.
4	Woady Yaloak	Sheet & Rill Erosion	
5	Stony Rises	Secondary Salinity	Lake Martin and the upper reaches of Barongarook Creek.
6	Otway Coast	Landslides	Great Ocean Road, Turtons Track and Wild Dog Road. Wild Dog Creek, Barham River and Smythe Creek.
7	Curdies	Landslides	Scotts Creek, Curdies River, Cowley Creek and Port Campbell Creek. Coastal recreational areas.
8	Moorabool	Sheet & Rill Erosion	Eclipse Creek, Tea Tree Creek, Anakie Creek and Deadman Gully. Central Highlands/Barwon Water-managed Proclaimed Water Reservoir.
9	Moorabool	Gully & Tunnel Erosion	
10	Woady Yaloak	Secondary Salinity	Woady Yaloak River, Lake Corangamite.
11	Murdeduke	Secondary Salinity	Native vegetation of very high to high conservation significance potential. Wetlands along Mia Mia Creek, Warrambine Creek north of Wingeel Swamp, and in groups of small wetlands east of Eurack near Hesse Road.
12	Leigh	Gully & Tunnel Erosion	Woodbourne Creek, Lower Williamson Creek, Yarrowee River and Leigh River.
13	Leigh	Sheet & Rill Erosion	
14	Upper Barwon	Landslides	Roads along the flanks of the Otway Ranges. Waterways along the western flanks of the Barwon River Valley, south of Birregurra.
15	Aire	Landslides	Aire River and the west branch of the Ford River.
16	Upper Barwon	Sheet & Rill Erosion	Wormbete Creek, Yan Yan Gurt Creek and Barwon River.
17	Upper Barwon	Gully & Tunnel Erosion	
18	Thompsons	Sheet & Rill Erosion	Thompson Creek and Spring Creek.
19	Bellarine	Acid Sulphate Soils	Point Henry environments.
20	Thompsons	Acid Sulphate Soils	Breamlea Wetlands and Lower Thompson Creek.

Resource condition targets and management action targets have been developed for the strategy to help monitor the effectiveness of implementation. These targets will be improved as further research is completed.

The cost of addressing the priorities in the Corangamite Soil Health Strategy in the next five years of implementation is approximately $5,500,000. However, this figure may change significantly as new information becomes available.

Partnerships and joint action to address the threats

Perhaps most importantly of all, the strategy recognises the pivotal role of partnerships in the effective implementation of the various actions.

A diverse range of public and private sector asset managers and other stakeholders influence soil-management practices, and therefore soil health, in the region. These same individuals and entities also make significant inputs to other aspects of natural resource management. Their involvement in partnership approaches to soil health actions is therefore essential.

As part of its facilitation and communication, the Corangamite CMA has a central role in ensuring that multi-agency or multi-asset manager projects are proposed in common, implemented in collaboration and reported to investors as a whole, thus enabling the achievement of multiple outcomes.

Targeted actions have been developed to address the 20 highest validated priorities for investment. An important task now is the communication of these priorities and the development of partnership-based projects and funding applications.

To guide the development and operation of these partnerships and the entire implementation program, four 'Principles of Implementation' are included in the strategy.

Conclusion

There are real, active and latent soil-related threats to the natural and built assets of the Corangamite region. These are identified, linked and ranked via a logical and objective framework in this strategy. Validated priorities for investment are identified with specific action plans, targets and monitoring activities.

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1.1 Purpose of the Corangamite Soil Health Strategy

The Soil Health Strategy aims to guide investment in a range of actions that will protect and enhance natural and built assets in the Corangamite region from a number of soil-based threats or threatening processes.

The Soil Health Strategy (SHS) identifies specific assets that should be protected or enhanced, the various threats and the asset managers and other stakeholders who have been involved in its development and will potentially be involved in its implementation.

This introduction provides the background and current context of the strategy including concepts of 'soil health' as an asset, important natural resource and built assets that are under threat, features and characteristics of the Corangamite region and other topics that 'set the scene' for the strategy.

Strategy objectives

Principal objectives:

- improve the understanding of soil-based threats to private and public assets
- develop the logic and implement the processes that identify priorities for investment that meet Victorian and Australian government guiding principles
- identify suitable and feasible actions to address identified priority threats to assets
- formulate implementation guidelines and principles
- define and explore opportunities to create mutually beneficial partnerships with other strategic natural resource management plans, contexts and investors
- raise the profile of soil health management with specialists and the wider community in the Corangamite region
- develop a range of suitable targets to measure the effectiveness and success of implementing the SHS.

Soil health as an asset

In their natural, undisturbed state soils tend to be 'healthy', in that they support local life in various forms that is adapted to the characteristics of the local soil.

Activity – principally human activity in the pursuit of agricultural, forestry or urban development and their ongoing enterprises – tends to disturb or even degrade soil health.

Healthy soils support their natural local ecosystems. Disturbance disrupts these systems. In many cases, disruption leads, sooner or later , to unintended consequences for other natural assets – such as waterways, biodiversity, vegetation – or leads to impacts on built assets such as human habitation, roads, pipelines and other structures.

Unintended consequences of urban and agricultural development may include but are not limited to deterioration in water quality, secondary salinity, erosion or landslides. These consequences are referred to in this strategy as 'threats'. Elements of the natural environment and the built environment are referred to as 'assets', which may be impacted by the threats.

Maintaining soil health is one way to help protect natural assets – many of which are invaluable and irreplaceable if lost. Maintaining soil health – for instance, maintaining slopes in a condition that tends to lessen the risk of landslips or landslides – will help to lower the chances of rocks and soil falling into and probably contaminating downslope creeks. In this case, apart from the asset of farm land being lost, the asset of 'water quality' would be affected by stream contamination. Of course, landslides may also have effects on a range of built assets – for example roads, railways, urban or rural houses and buildings.

This strategy identifies a suite of soil-related threats and a range of natural and built assets in the Corangamite region that are at risk.

Once disturbed, soils are unlikely to ever be returned to their natural undisturbed state but actions to maintain and improve soil health have benefits that extend far beyond the individual public or private landholder, right through to the wider community in the region, the state and the nation.

This strategy, although focused on soil health, recognises that soil health is closely linked with river health, biodiversity, salinity, water quality and other issues outlined in the Regional Catchment Strategy (CCMA 2003).

Resources available for managing soil health in the Corangamite region include:

- partnerships between asset managers, investors and collaborators
- technical resources developed within public and private entities that link research and practice change – in some cases best management practices specific to soil-related threats
- effective and demonstrated outcomes from soil health projects implemented in the Corangamite region over recent years
- definition and understanding of the nature and distribution of threats in relation to assets.

History of developing the Corangamite Soil Health Strategy

The Corangamite Regional Catchment Strategy identified the need for a more strategic approach to soil health. As a result, the Corangamite CMA commissioned a Discussion Paper in 2003 that assessed the potential value of a soil health context for its investment decisions. Findings from this paper supported the need for a soil health strategy (MacEwan 2003).

Following the successful application for funds through the National Action Plan (NAP) for Salinity and Water Quality, the Corangamite CMA commissioned the development of a soil health strategy. The Victorian Department of Primary Industries (DPI) was commissioned to develop the strategy under the guidance of a Steering Committee and Technical Working Group (Appendix J).

With the support of NAP funds, the first draft of the strategy was developed from September to December 2003. During this period, the soil-based threats were identified and their severity assessed. This activity showed that there was little documented information for the majority of the threats that was specific to the Corangamite region.

During the September to December 2003 period, assets in the Corangamite region were identified and given some initial ranking. Soil and landform data (Robinson et al 2003) were used to classify the susceptibility of the region's soils to a range of degradation processes.

A land use impact model (LUIM) was used carry out a regional assessment of the likelihood degradation based on current land use practices (McNeill and MacEwan 2004).

Attempts were made to determine the risk that threats were posing to assets, but this activity was judged unsuccessful due to the limited quantity and quality of data.

Actions were also developed that would enable stakeholders to address the threats; management action targets (MATs) were developed, predicting the likely uptake of various management practices. An economic consultancy firm was engaged to carry out a benefit-cost analysis – mostly private assets, (for instance, agricultural production).

Funding was not granted to complete the strategy in the 2003/04 year. However, NAP funding was regained for further development of the strategy in 2004/05 and 2005/06. During this time, NAP funds were used to identify the distribution of erosion, landslides and acid sulphate soils. With additional information to hand, new processes were developed and a risk-to-asset analysis was conducted for many threats recognised in the strategy.

During the development of the SHS, it became clearly evident that a number of important actions needed to be taken without delay. Several are progressing well, even before this strategy is confirmed and released.

Some of these actions have helped build improved definition and understanding of the distribution and activity of threats. Actions that are currently underway include:

- mapping soil erosion and landslides in the Corangamite region
- developing Erosion Management Overlays for the City of Greater Geelong and Colac Otway Shire
- assessing the risk of acid sulphate soils in the City of Greater Geelong
- mapping soil erosion and landslide susceptibility at 1:25,000 for the Corangamite region
- delivering priority soil extension activities, such as field days, whole farm planning courses, accreditation of soil training activities and developing information packages
- stabilising erosion sites threatening priority waterways and other high-value assets.

1.2 Understanding the regional environment

Social aspects of the Corangamite region

The Corangamite region covers approximately 1.3 million hectares of south-west Victoria, with a human population of approximately 400,000 in 2006; population is increasing at around 5% per annum (Thomas & Collier 2002).

Nine local government municipalities lie within the catchment – the City of Greater Geelong, Surf Coast Shire, Colac Otway Shire, Ballarat City, Golden Plains Shire, Moorabool Shire, Corangamite Shire, Pyrenees Shire and the Borough of Queenscliff *(Fig.1.1)*.

Ballarat and Geelong are expanding, encroaching on surrounding rural areas. The spatial distribution of the population within the Corangamite region is changing, with significant expansion in the coastal areas as well as the Ballarat to Geelong 'corridor'. The northern parts of the Colac Otway and Corangamite shires have been suffering significant population decline. The population of farmers, who manage more than two thirds of the land in the Corangamite region, is at best stable, but more likely falling, particularly in the broadacre farming areas.

Figure 1.1: Municipalities of the Corangamite region

Climate in the Corangamite region

Climate in the Corangamite region is temperate. Rainfall is predominantly in winter and spring, and is greatest along the ridge of the Otway Ranges in the south (1500 mm – 1800 mm) and the Western Uplands in the north (1000 mm – 1100 mm). The central Victorian Volcanic Plain experiences much lower rainfall (500 mm – 600 mm), with the lowest rainfall recorded east of the Brisbane Ranges (400 mm – 500 mm) *(Fig.1.2).*

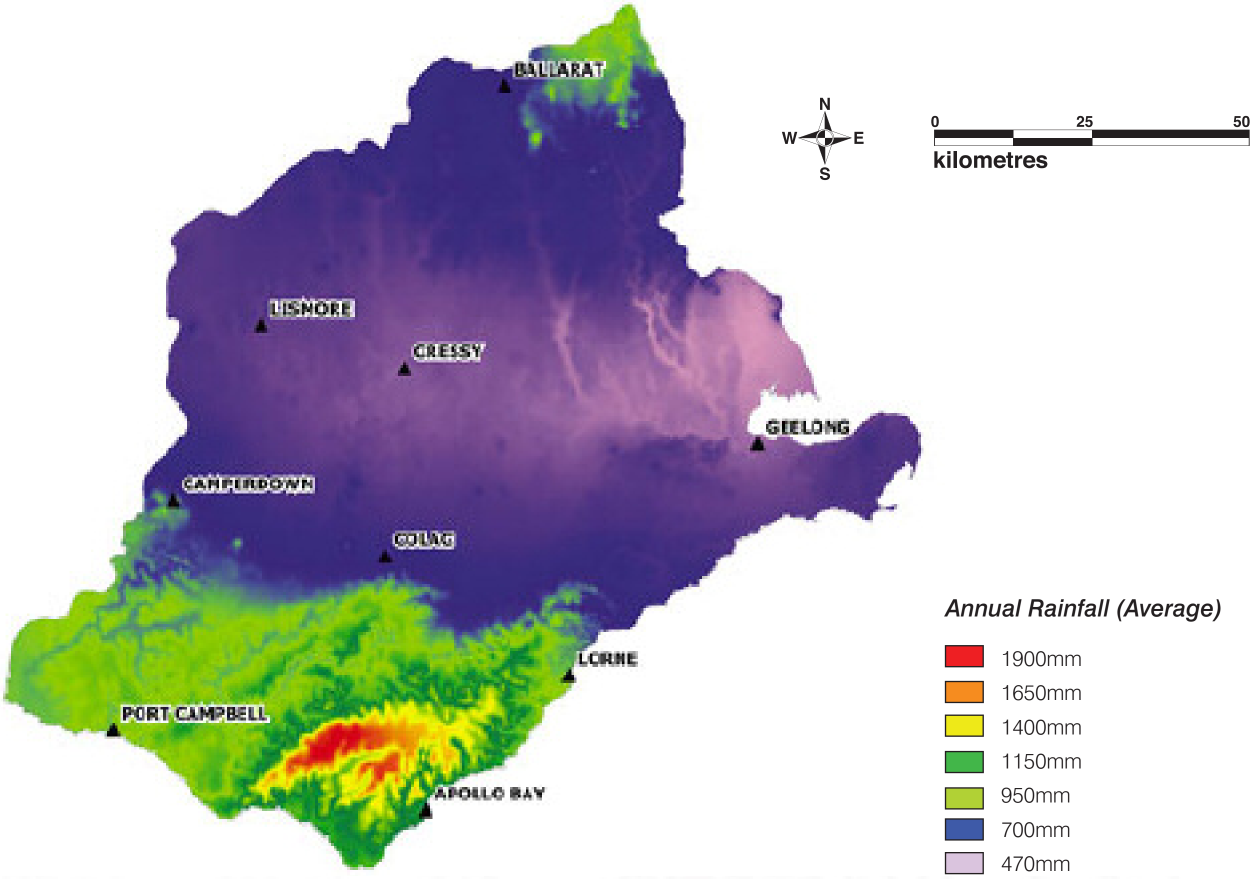


Figure 1.2: Annual average rainfall in the Corangamite region

Landforms and geology in the Corangamite region

The Corangamite region comprises some of the most spectacular landscapes in Victoria, including coastlines, volcanic features and lakes that are of international significance. These landscapes occur in a variety of geological settings.

The evolution of landscapes throughout the Corangamite region reflects the events of the geological past, which included mountain building, continental break-ups, vast periods of erosion, large changes in sea levels and climates and volcanic eruptions. The region is characterised by three major geomorphic divisions (Joyce *et al.* 2004), *viz*. the Victorian Western Uplands, the Victorian Southern Uplands and the Victorian Western Plains *(Fig. 1.3).*

1. Victorian Western Uplands

Dissected uplands form the northern highlands of the Corangamite region, which are characterised by a variety of interwoven landforms preserved by substantial uplift during the past 50 million years. Undulating hills and broad valleys characterise the landscapes formed on folded sedimentary rocks and granite plutons formed around 450 to 350 million years ago. Remnants of an ancient plain, formed about 40 to 30 million years ago, occur as caps of gravels sporadically distributed at various elevations. A remnant of the sands deposited during the retreat of the sea around four million to two million years ago fringes the southern bedrocks as a dissected tableland. Around the same time, volcanic eruptions filled the broad valleys to form elongate basalt plains and a variety of other volcanic landforms. The last remnants of this period of volcanism are the prominent volcanic cones of Mount Buninyong (745 m), Mount Warrenheip (741 m) and Tipperary Hill (743 m), which are now the highest elevations in the Corangamite region.

Three river systems drain the dissected uplands of the Corangamite region – the Moorabool River (east), Leigh River (central) and Woady Yaloak River (west). The waters in the Moorabool River are utilised for urban supply to the cities of Ballarat and Geelong, as well as a number of smaller towns. Both the Moorabool and Leigh rivers join the Barwon River system to the south, whereas the Woady Yaloak River feeds Lake Corangamite, a saline wetland of international importance and Victoria's largest permanent inland lake. Within this geomorphic province, increasing salinity, nutrients and turbidity are the dominant threats to the health of the waterways and water bodies of the region.

2. Victorian Southern Uplands

The southern portion of the Corangamite region is dominated by the Victorian Southern Uplands, which form the deeply dissected Otway Ranges, moderately dissected Barrabool Hills and low hills of the Bellarine Peninsula. All three landscapes have been formed by the uplift of structurally controlled blocks of lithic sedimentary rocks around 140 to 100 million years old (i.e. the Otway Group rocks). The Barrabool Hills and Bellarine Peninsula are smaller fault-bounded uplift blocks at lower elevations than the Otways.

The headwaters of the major river in the Corangamite region – the Barwon River – drain the northern slopes of the Otway Ranges. The Barwon River is an important urban water supply for the City of Greater Geelong. The Gellibrand River, Aire River and other smaller waterways drain the Otway Ranges to the sea.

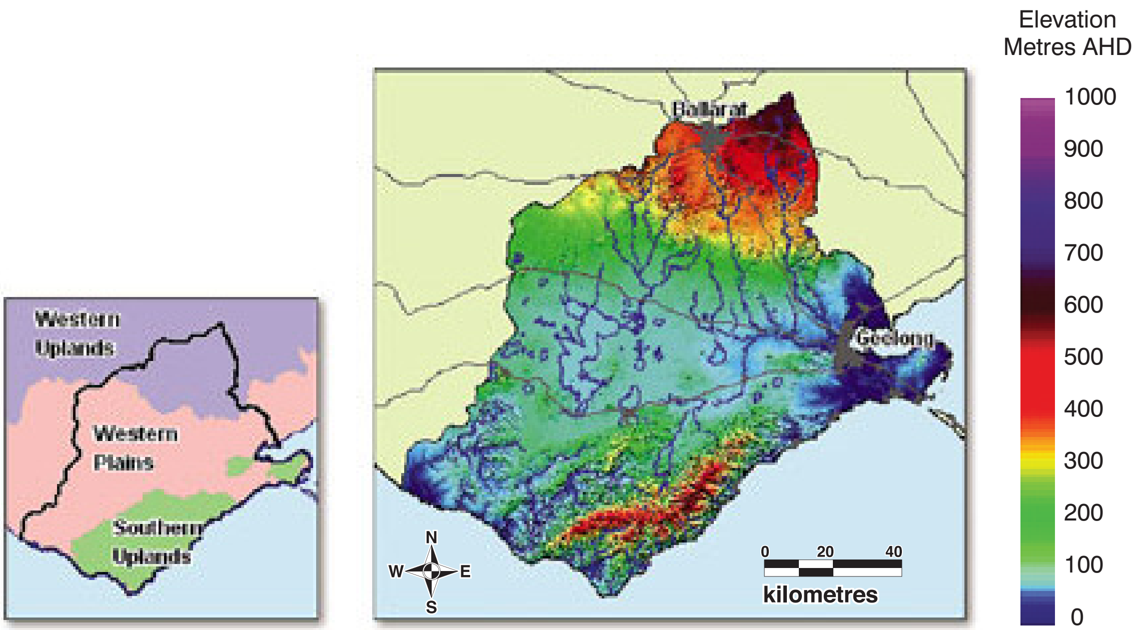


Figure 1.3: The three major geomorphic divisions (Joyce et al. 2004), and the elevation of land throughout the Corangamite region

3. Victorian Western Plains

The central Corangamite region lies within the Victorian Western Plains, the largest of the three geomorphic units which comprise undulating plains formed on both volcanic and sedimentary rocks. Volcanic plains make up the majority of the geomorphic unit, apart from the south-western portion, where dissected sand plains around two to four million years old overlie marls (geological unit), which is approximately 25 to 15 million years old. The volcanic eruptions commenced around four million years ago, forming plains of basalt, and concluded around 50,000 years ago with stony rises and scoria cones as more recent features. Exposures of the underlying Pliocene Age sands occur in places not covered by the volcanic eruptions or where the landscapes have since been dissected. Lakes and wetlands are the most important assets of the Western Plains, with the largest being Lake Corangamite.

Soil types in the Corangamite region

Soil types in the Corangamite region reflect the great diversity of their geological origins, landforms, climate, age and degree of weathering. Soil type, topography and local climate tend to exert a strong influence on land use. Soil types were mapped as part of the Land Resource Assessment (LRA) investigation carried out by Robinson *et al.* (2003). They identified and mapped over 200 soil-landform types in the Corangamite region.

Soil types in the Corangamite region can be simplified according to eight basic geology units *(Fig. 1.4).* A description of soil properties and land use types in these geological units includes:

1. Palaeozoic sedimentary rocks

These are older soils that generally exhibit naturally low levels of plant nutrients. Together with underlying dispersive subsoils, they are susceptible to gully and tunnel erosion. These soils are generally used for conservation, grazing and forestry, with limited areas of crop production in flat terrain.

2. Palaeozoic granitic rocks

These are older soils that have shallow depth of topsoil, poor structure and lower levels of fertility. The areas where these soils dominate are mostly dedicated to conservation, forestry and broadacre grazing. These soils are prone to a number of soil threats, particularly water erosion.

3. Cretaceous sedimentary rocks

Soils developed on these rocks vary from shallow stony soils and brown gradational soils in the Otway Ranges, to clay loams and brown duplex soils of the Barrabool Hills. The soils are used for forestry, grazing and dairying, with conservation as the dominant land use. Highly susceptible to landslides, tunnel erosion and gully erosion, these soils are also prone to nutrient decline and waterlogging.

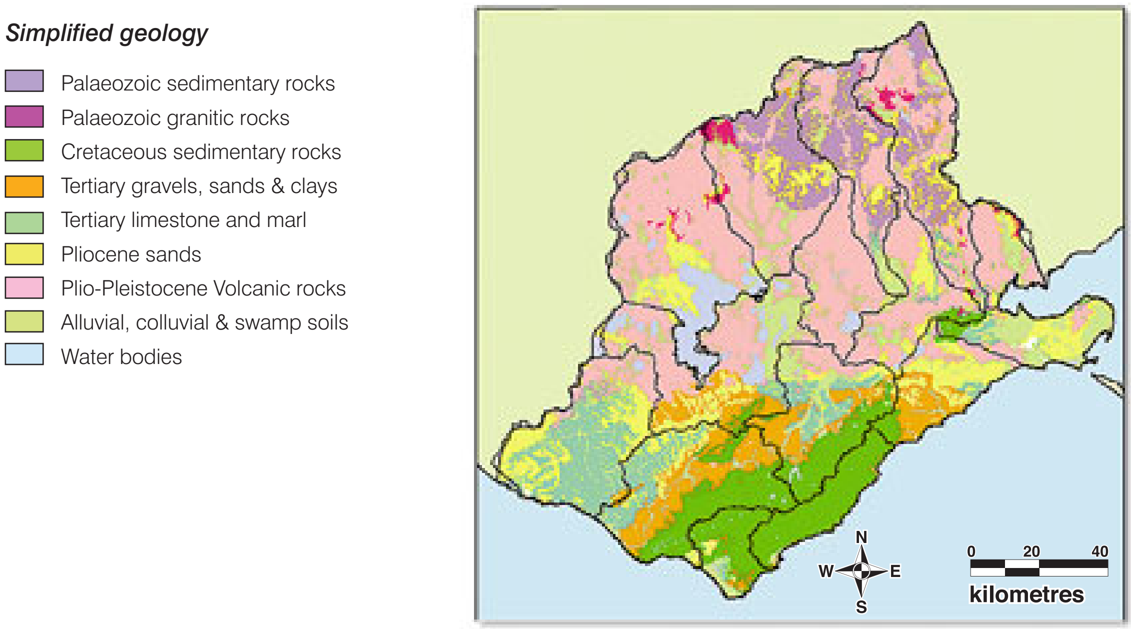


Figure 1.4: Simplified soil types in the Corangamite region, based on soil parent materials

4. Tertiary gravels, sands and clays

These soils, developed on gravels, sands, silts and clays, exhibit the most variability of the geological units. They range from grey sand soils through mottled gradational soils to sodic duplex soils with ironstone hardpans. These soils are highly susceptible to all forms of erosion by water and are nutrient deficient. They support all land uses, with forestry, grazing, dairying, cropping and conservation being dominant.

5. Tertiary limestone and marl

The soils developed on the limestones and marls are mostly gradational soils, with some dark well-structured soils on the limestones. They are dominated by dairying and grazing and are prone to waterlogging, compaction (pugging) and landslides.

6. Pliocene sands

The soils of the sand plains and gently undulating landscapes vary in their sand, silt and clay content. They vary from gradational sandy loams to sodic duplex soils to podsolic soils developed on iron cemented 'coffee rock'. These soils mainly support cropping, forestry, grazing and dairying. They are prone to water and wind erosion, nutrient decline and acidification.

7. Plio-Pleistocene volcanic rocks

The volcanic soils are the most widespread and variable soils in the Corangamite region. Some of these areas have arguably the most valuable agricultural soils in the Corangamite region, such as the krasnozems found predominantly, though not exclusively, in the north-east of the region *(Fig. 1.4)*. These soils are characterised by high natural fertility, great depth, good structure (stability, water infiltration rate and aeration) and are generally devoted to rotational potato cropping. If left bare of ground cover over winter, they can also be subject to sheet and rill erosion.

On the broad volcanic plains, these soils vary from duplex soils with heavier subsoil layers which are more prone to waterlogging, to the shallow, stony, well-drained gradational soils of the stony rises and volcanic cones. These soils are generally used for broadacre cropping, grazing and dairy farming.

8. Alluvial, colluvial and swamp soils

Small areas of alluvial, colluvial and swamp soils include the calcareous sandy soils of coastal dunes, sandy and clay loams of lake-bordering lunettes, grey gradational soils of river flats and black organic heavy clays of swamps. Many of these soils have developed with impeded drainage and are often sodic, saline and prone to waterlogging. Sandier coastal and lunette soils are susceptible to wind erosion and nutrient decline.

1.3 History of land use and its implications for soil health

Land use in the Corangamite region

The Corangamite region supports a diverse range of land uses. The large urban centres of Geelong, Ballarat and Colac are supported by many smaller towns, villages and hamlets dispersed throughout the region. Peri-urban areas are generally found close to the larger regional centres.

The Corangamite region supports many categories and types of agricultural and horticultural enterprises, including wool production, lamb, beef, dairy, cereal crops, oilseeds, row crop vegetables, viticulture and intensive animal production.

There are a number of conservation areas, particularly along the coast in the Great Otway National Park. Forestry is conducted on public and private land. There are a number of mining enterprises in the region *(Fig. 1.5)*.

Significant events for soil health management

Soil health management in Australia, Victoria and more locally in the Corangamite region has gone through a number of phases since European settlement. Listed below are selected milestones in the history of soil health in Victoria in general and the Corangamite region in particular.

1. Land clearing for farming, timber and fuel production, gold mining and other land uses in the late 1800s and early 1900s brought rapid reduction in the quantity and quality of vegetative cover in the region. During this period, hoofed animals were introduced and wetlands were drained for agricultural purposes. A significant change in the condition of soil and water resources was caused by these activities (EWR 2006).
2. Soil nutrient decline across Australian soils was recognised late in the 1900s. Nitrogen and phosphorus deficiency were recognised by 1900. In the 1930s and 1940s, many trace element deficiencies were identified. Mineral fertilisers were developed and distributed, enabling large tracts of land previously nutrient deficient for farming, to be devoted to agriculture (EWR 2006).
3. In Victoria, severe soil erosion in the 1930s and 1940s resulted in the establishment of major, state-wide soil conservation programs. The Soil Conservation Authority (SCA) replaced the Land Conservation Authority in Victoria and was a body corporate under the Soil Conservation and Land Utilisation Act 1949 (1958).

4. Improved management of vegetative cover on farm land, resulting in a reduction of erosion, occurred from the late 1940s as a result of the use of subterranean clover and improved grazing management techniques in rotation with cereal crops accompanied by the widespread use of superphosphate fertiliser (EWR 2006).
5. Land appraisal techniques and concepts of land capability were introduced in the 1950s.
6. Rabbit control programs, including the release of the myxomatosis virus, occurred in the 1950s, significantly reducing soil erosion hazards and enabling more effective rehabilitation of rabbit warrens.
7. The Soil Conservation and Land Utilisation Act was introduced in 1958.
8. Whole farm planning concepts were promoted in the 1960s (EWR 2006).
9. Techniques with beneficial soil protection attributes (minimum tillage, trash retention, chemical weed control) were introduced in the 1980s (EWR 2006).
10. In 1983, the SCA was merged into the Department of Conservation Forests and Lands.
11. Secondary salinity management programs were introduced in 1985.
12. Integrated catchment management concepts were put into practice in the late 1980s (EWR 2006).
13. Understanding of acidification problems through investigations occurred in the 1990s (EWR 2006).
14. The Catchment and Land Protection Act was introduced in 1994.
15. In Victoria, ten catchment management authorities were formed in the late 1990s. These authorities have developed regional catchment strategies, setting the framework for other, more specific natural resource based sub-strategies (including soil health).
16. The soil extension program was introduced into the Corangamite region in 2000. DPI delivered this program for the Corangamite CMA. Activities have focused on raising the Corangamite community's awareness and capacity to treat soil threatening processes. The program was implemented on a demand-based approach.
17. The concept of asset-based approaches to investment in natural resource management was developed and introduced in 2002.
18. The Minister for the Environment endorsed the Corangamite Regional Catchment Strategy in 2003.

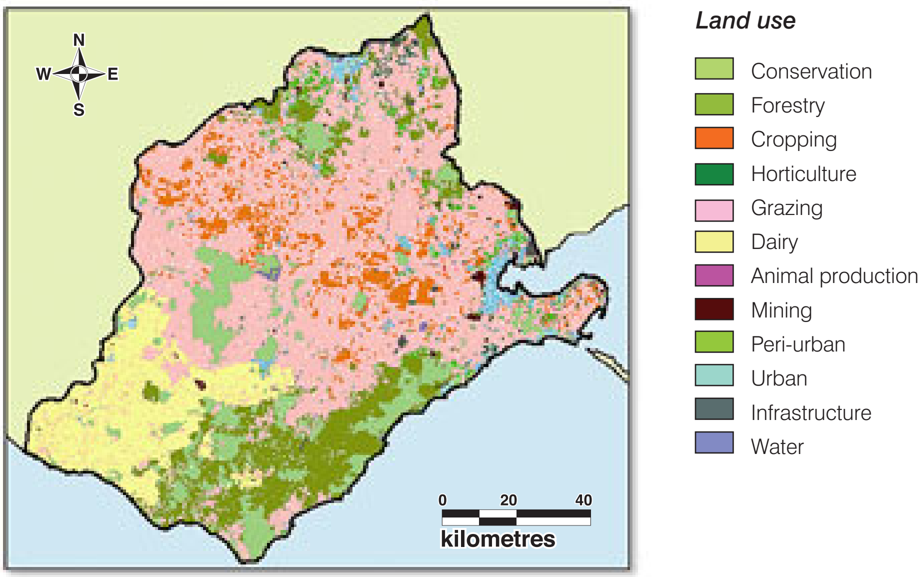


Figure 1.5: Land use in the Corangamite region

1.4 Linkages to national, state and regional contexts

This Soil Health Strategy focuses on the Corangamite region. As a regional document, the strategy links to Victorian and Australian strategies and fits within the broader framework set by their foundations, logic and direction. The Corangamite Soil Health Strategy aims to dovetail into and in as many respects as possible, work closely with the wider state and national strategies, gaining more effective natural resource management outcomes all round.

National contexts

Although there are no specific strategies linked to soil health at a national level, there are several that relate to other, closely related natural resource management (NRM) issues. Specifically, this Soil Health Strategy has a close and a direct association with:

- Commonwealth legislation, e.g. *Environment Protection and Biodiversity Conservation Act 1999; Aboriginal and Torres Strait Islander Heritage Protection Act 1984*
- Commonwealth policy, such as the National Strategy for Ecologically Sustainable Development
- the National Action Plan for Salinity and Water Quality
- Managing Natural Resources in Rural Australia for a Sustainable Future: A discussion paper for developing a national policy.

State contexts

A soil health framework for Victoria, 'Victorian State Soils Framework Draft' is currently being developed by the Victorian Department of Primary Industries. This will contribute to a broader understanding of soil health within DPI, across agencies and in the wider community. It aims to identify the key principles about soil health that include but are not limited to:

- improved understanding of soil health and its attributes
- better informed investment decision making for DPI and other providers
- better management of soil as a primary asset in farm business and industry sectors.

The draft Soils Framework suggests a legislative context that will enable investments in soil issues to be directed by an assessment of needs and potential benefits. The framework may also help to coordinate farm management principles across a broad range of agricultural enterprises and industry sectors.

A number of other Victorian frameworks and strategies also relate to the Corangamite Soil Health Strategy. These frameworks are not necessarily soil specific, but relate to soil health:

- *Victorian Archaeological and Aboriginal Relics Preservation Act 1972*
- *Catchment and Land Protection Act 1994*
- *Conservation, Forests and Lands Act 1987*
- *Environment Protection Act 1970*
- *Flora and Fauna Guarantee Act 1988*
- *Planning and Environment Act 1987* Victorian Planning Policy Framework; Municipal Strategic Statement – Local Planning Policy Framework
- *Victorian Fisheries Act 1995*
- *Water Act 1989*
- Management of Victoria's Ramsar Wetlands – Strategic Direction Statement
- Victorian Salinity Management Framework
- Victorian River Health Strategy
- Victorian Biodiversity Strategy
- Victorian Native Vegetation Management Framework 2002
- Victorian Pest Management Framework
- Waters of Victorian State Environment Protection Policy (SEPP).

Regional contexts

The Soil Health Strategy is a sub-strategy of the Corangamite Regional Catchment Strategy (RCS) *(Table. 1.1).*

The RCS sets the broader framework for natural resource management sub-strategies in the Corangamite region.

The RCS:

- has been developed in partnership with the Victorian and Australian governments and the Corangamite community
- provides a focus for on-ground actions and investment in land and water management within the region
- follows the principles of community involvement through partnerships with regional stakeholders and the integration of activities across policy development, investment, program implementation and outcomes.

The development of strong partnerships with these existing catchment programs offers huge potential for the Soil Health Strategy (SHS) to add value to current and future soil health initiatives. Greater catchment benefits can be achieved by working together than by working alone.

Essential to the process of working together is an understanding of other catchment programs and the identification of areas where mutually beneficial outcomes can be achieved. *Table 1.1* describes the objectives of each strategy in the Corangamite region and how they link to the SHS.

Document	Main Objectives	Links to the Corangamite Soil Health Strategy
Regional Catchment Strategy (RCS)	Direct NRM in the region and coordinate integration between strategies.	Provides an overall context for the SHS to link in with other regional strategies to provide multi-benefit outcomes.
Research and Development Strategy (RDS)	Identifies research and development needs of all NRM issues that fall under the RCS.	Outlines the soil health-related research and development requirements to be considered in the SHS.
Salinity Action Plan (SAP)	Aims to maintain those primary and wetland salinity areas recognised as an asset to biodiversity, and reduce the risk of secondary salinity through recharge and discharge management.	Both the SHS and SAP aim to address secondary salinity. The SAP will be the primary strategy addressing secondary salinity. The SHS will integrate with the SAP and may address high-risk areas outside SAP target areas. The SHS will assist the SAP to address the risk of secondary salinity.
River Health Strategy (RHS)	Protect the health of waterways, including water quality, riparian vegetation etc.	The SHS aims to address those soil-based threats posing a risk to water quality for priority waterways identified in the RHS.
Water Quality Strategy (WQS)	To monitor and understand water quality trends in waterways.	The SHS aims to understand the relationship between soil-threatening processes and water quality, and to set up monitoring sites that help investigate the impact of erosion and other threats to water quality.
Wetlands Strategy (WS)	Protect and enhance significant wetlands.	The SHS aims to implement actions to address soil-based threats posing risks to wetlands.
Native Vegetation Plan (NVP)	Protection and enhancement of native vegetation and biodiversity values.	The SHS aims to address soil-based threats posing a risk to significant vegetation.
Weed Action Plan (WAP)	Controlling weeds in priority areas.	The SHS aims to maintain soil health to increase its resilience to the introduction of noxious weeds.
Rabbit Action Plan (RAP)	Controlling rabbit populations in priority areas.	The SHS needs to work with rabbit-control programs to ensure that disturbance by rabbits does not compromise on-ground remedial works to control soil movement.
Landcare Strategy (LS)	Support for stakeholders implementing actions.	Developing partnerships with Landcare groups to improve soil health management is essential for the success of the SHS.

Table 1.1: Soil Health Strategy linkages with other natural resource management initiatives in the Corangamite region

2. Assets and threats to assets in the Corangamite Region

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

2.1 Asset identification

In this strategy, 'assets' are natural or built features in the landscape that are valued by the community. The SHS recognises asset classes that it aims to protect from various 'threats'. For the SHS, these threats are those specifically or generally related to soil health.

The Corangamite Regional Catchment Strategy has identified a range of primary and secondary asset classes that are applicable to the entire region. The most relevant and appropriate were selected for use in this Soil Health Strategy.

Selected primary asset classes:

1. Land
2. Water quality
3. Biodiversity
4. Built infrastructure
5. Cultural and heritage.

Secondary asset classes (as subsets of primary asset classes), define assets in greater detail. Secondary asset classes of the primary asset classes are:

- *Land* – urban, peri-urban, horticulture, dairy farming, broadacre cropping, broadacre grazing, forestry, intensive animal production, mining and public land
- *Water quality* – waterways and water supply reservoirs
- *Biodiversity* – wetlands and significant AROT and VROT areas
- *Built infrastructure* – roads and other infrastructure (e.g. telecommunication cables)
- *Cultural and heritage* is treated as one primary asset without secondary classes.

Land

Urban

There are approximately 27,000 ha of urban development within the Corangamite region. Cities and large towns include Geelong, Ballarat and Colac. Smaller towns and villages include Camperdown, Lorne, Lismore, Torquay, Meredith, Cobden, Timboon, Apollo Bay and Port Campbell. The Corangamite region hosts a diverse range of types and sizes of manufacturing and distribution industries, wholesale and retail trading, finance and business services, tourism and community services.

Peri-urban

Peri-urban areas comprise approximately 21,000 ha of the Corangamite region and are generally located around the region's cities and larger towns. Individual peri-urban properties range in size from two to 80 ha. These properties have little, if any, agricultural or forestry production, with the majority of owners having an off-farm income.

Horticulture

Horticultural crops are grown over some 5,000 ha in the region, dominated by potatoes, with more than 4,000 ha, and supported by a diverse range of other crops including vineyards, row-crop vegetables and intensive, 'glasshouse' enterprises including cut flowers. Although found in several localities within the region, the majority of the potato crop area is found on the fertile volcanic soils of the north-east, around Ballarat.

Dairy farming

Dairy farming is carried out over 167,400 ha of the region and contributes about 25% of Victoria's production by milk volume and accounts for approximately 44% of the region's agricultural production by value. Pasture production is predominantly dryland, as opposed to irrigation; calving and milk production are seasonal, as opposed to year-round. The importance of local dairy farming to the region and the state is expected to rise.

Dairy farming is centred in the south-west of the region and in the Colac area, where soils are fertile and rainfall is relatively high.

Broadacre cropping

Broadacre crops are grown over approximately 94,000 ha in the Corangamite region, predominantly on the basalt plains. The principal crops by area are wheat, canola and barley. The area of broadacre crops has been rising for some years as farmers pursue the higher margins per hectare from crops compared to livestock enterprises (meat and wool).

Broadacre grazing

Broadacre grazing covers approximately 592,000 ha in the Corangamite region and supports various livestock enterprises producing wool, sheep meat and beef. Grazing activities are conducted across the full range of soil types and landscapes found in the region, with a correspondingly large variation in pasture productivity.

Forestry

The region's forestry enterprises produce hardwood and softwood timbers on private and public land, involving 164,000 ha in the region, predominantly in the coastal fringes of the Otway Ranges, (Gellibrand, Upper Barwon, Otway Coast and Aire Landscape Zones). Forestry on public land in the region is in decline, but is increasing on private land, particularly with blue gum and pine plantations.

In 2001/02 approximately $160 million was derived from softwood plantation production; $4 million from hardwood plantations; and $68 million from native forests in the region (Central Victoria Farm Plantations Inc 2002).

Intensive animal production

Intensive animal production covers 645 ha of the Corangamite region, including poultry production for meat and eggs, pig meat and on-farm beef feedlots.

Mining

Crushed rock, gravel, sand and clay quarries are found in the Corangamite region. Clay is extracted for brick and tile manufacture and kaolin clay for use in manufacturing industries. A small coal mine is located at Anglesea. Ballarat hosts commercial gold mining.

Public land

There is a diverse range of public land categories in the region under the control of state and local governments. This includes various conservation areas: flora and fauna reserves, national, state and regional parks managed by Parks Victoria and Crown and state forest land managed by the Department of Sustainability and Environment (DSE).

In aggregate, 156,000 ha have been designated as parks or reserves, notably the Great Otway National Park and Lake Connewarre State Game Reserve.

There are many Crown Land allotments and reserves set aside for recreation, conservation and a number of other purposes.

Water quality

There are approximately 19,600 km of waterways in the Corangamite region *(Fig.2.1)*. The Great Otway National Park contains some of the most naturally intact waterways in Australia, featuring high water quality. In contrast, other waterways such as the Moorabool and Woady Yaloak rivers have experienced significant degradation and now exhibit poor water quality. Waterways in the Corangamite region have been assessed and valued by the Corangamite River Health Strategy (2006).

Three important Water Supply Proclaimed Areas (WSPA) are located in the Corangamite region, supplying domestic and farm water to areas within and adjacent to the region *(Fig. 2.1)*. Management of these WSPA is the responsibility of Barwon Water and Central Highlands Water; in aggregate, these authorities are responsible for supplying 55,000 ML of water annually to urban and industry areas within and adjacent to the Corangamite region.

Regional and local aquifers flow throughout the Corangamite region. Water from these aquifers is pumped out for irrigation and stock and domestic purposes. The quality of this water is important for many rural asset managers across the region.

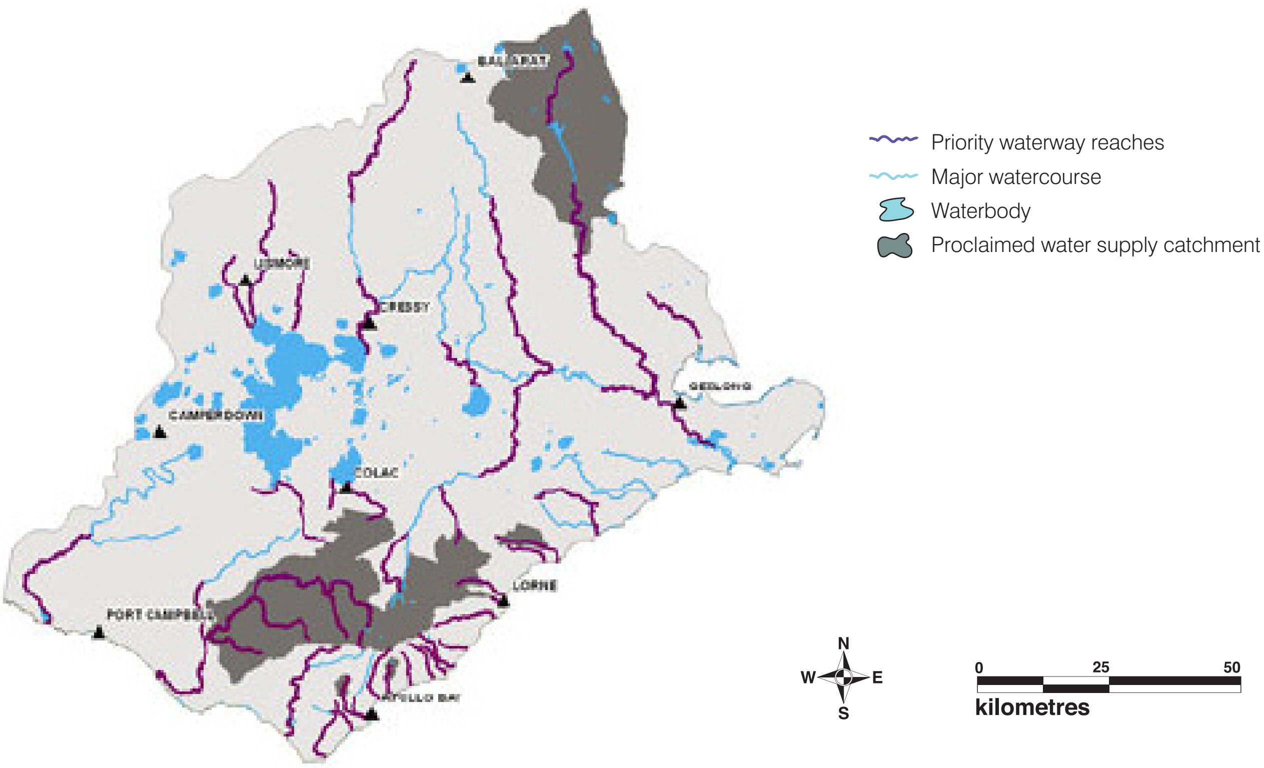


Figure 2.1: Waterways and Water Supply Proclaimed Areas in the Corangamite region

Biodiversity

Bioregions have been designed to help define patterns of biodiversity or ecological characteristics at a landscape scale. Bioregions are particularly relevant for this strategy because their location is strongly influenced by major soil class units and landforms. This influence is reflected in the names of the five bioregions within the Corangamite region *(Fig 2.2).* Parameters such as climate and local topography also play a major role in determining ecosystem types across the landscape. However, the correlation between bioregions and soil class units highlights the significant connection between soil health and biodiversity conservation.

Regional ecosystems are diverse and complex. Ecological Vegetation Classes (EVCs) tend to be used as a surrogate for biodiversity, in terms of strategic regional priority setting, as they help indicate the value and significance of biodiversity in different areas. EVCs provide a unit, which is relatively well known in terms of condition and extent, as well as security. Vegetation communities provide habitat for fauna species; in many cases the distribution of these species may be poorly mapped or, in some cases, migratory. In general terms, the appropriate conservation of vegetation communities is considered to provide security for biological assets more generally.

Less than one quarter of the original extent of (pre-European) native vegetation cover remains within the Corangamite region. This vegetation is defined as 'remnant vegetation.' Of this remnant vegetation, approximately half is considered to be under threat.

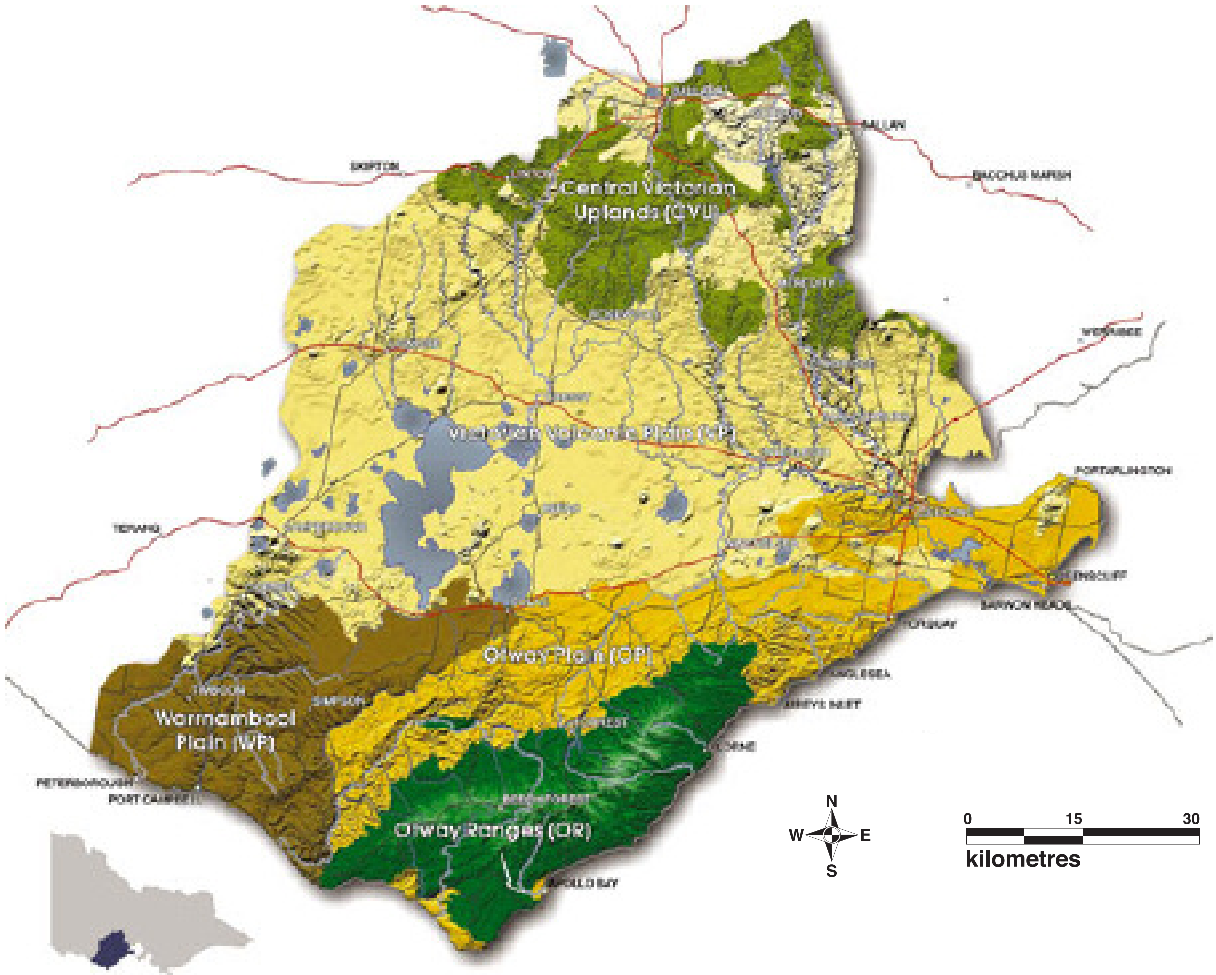


Figure 2.2: Bioregions defined for the Corangamite region

Wetlands

There are 1500 wetlands of varying size found in the region, widely distributed in aggregate they cover approximately 64,300 ha *(Fig. 2.3).* Thirteen Ramsar and 340 other significant wetlands are found in the region.

Threatened species

The Corangamite region contains 19 fauna and 50 flora species which are listed as Australian Rare or Threatened Species (AROTS) and more than 300 Victorian Rare or Threatened Species (VROTS) (CCMA 2003). Many of these species are uniquely endemic to the region and so if they become extinct from the region they are lost altogether.

Estimated Conservation Significance

Throughout this strategy, Estimated Conservation Significance (ECS) has been used as a means of identifying areas of high value biodiversity assets. ECS is a Geographic Information System (GIS) layer, which has been recently developed by DSE as a derivative of several other GIS layers. The ECS layer takes into consideration the Bioregional Conservation Status (BCS) of EVCs (a default condition score based on status) and a landscape context score that considers vegetation patch size and landscape connectivity. *Figure 2.3* indicates the range of medium to high ECS areas across the region.

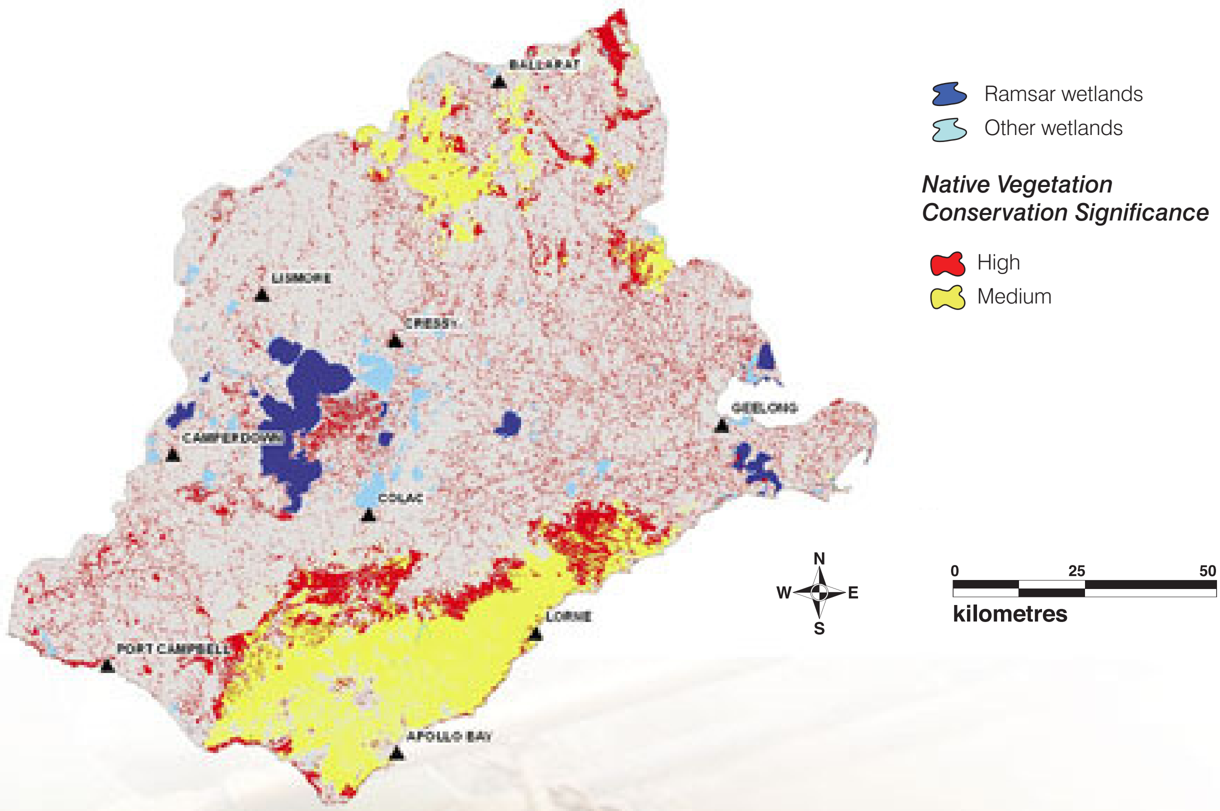


Figure 2.3: Wetlands and significant biodiversity areas in the Corangamite region

Built infrastructure

In the period since European settlement and especially during the 20th Century, a vast network of roads, tracks, railways, towns, villages and farms have been developed in the region, supporting and sustaining agricultural, industrial and urban development. These older-origin built infrastructure assets are augmented by more contemporary built infrastructure assets including electrical power and telephone cables, various communications towers and gas and water pipelines.

The Corangamite region has more than 10,600 km of public roads, managed by local government and VicRoads. A gas pipeline runs from Port Campbell to Lara, part of the Melbourne gas supply network. A range of fibre optic, microwave and conventional telecommunication networks, reticulated water networks and sewage schemes service the region.

These assets are of immense value and are subject to tight management by a range of private and publicly owned enterprises.

The Corangamite region has a large manufacturing industry concentrated in Geelong and Ballarat, featuring food processing, fabric, petrochemical, fertiliser, agricultural machinery and automobile manufacturing. Geelong is a major port for the region, with facilities for import and export of the region's manufacturing, forestry and agricultural industries.

Cultural and heritage

It is likely that humans have inhabited the Corangamite region for at least 35,000 years (Mulvaney and Kamminga 1999). Prior to European settlement it is estimated that the region's Aboriginal population varied between 2500 and 4000 people (Clark 1990), but it seems that these predominantly nomadic hunter/gatherer groups travelled across the landscape during the winter and early spring, taking advantage of the region's diverse plant and animal food types found on land and in water bodies. In the summer and spring, longer periods were spent near permanently fresh water bodies.

With strong evidence of relatively high indigenous populations, it is likely that there are a number of cultural heritage sites, including scarred trees, middens, quarry areas, mounds, stone arrangements and burial sites, to be found across the region. Exact locations are still not identified.

Post-European settlement sites of cultural heritage value are also found in the region and are generally more easily identified and capable of protection.

Notwithstanding these qualifications, more than 450 significant cultural and heritage assets have been identified in the region and are included on the Register of the National Estate. These range 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' rock formations off the coast near Port Campbell.

2.2 Relative Asset Values

Relative Asset Values (RAV) have been developed for those secondary assets and the primary cultural and heritage assets that fall under the scope of this Soil Health Strategy. These values help prioritise asset protection and enhancement actions.

In the development of RAV those assets, whether publicly or privately owned, with a public benefit were ascribed higher relative value than those with a private benefit. This is because damage to or loss of a public benefit asset generally creates a far greater impact on the community than damage to or loss of a private benefit asset.

Relative Asset Values were also developed and used in the strategy because many assets defy quantification or valuation in economic or simple 'dollar' terms. Waterways or significant biodiversity areas are judged to be beyond common valuation. As a result, these notional Relative Asset Values were developed with reference to the Corangamite RCS and associated sub-strategies. Relative Asset Values used in the SHS are outlined in *Table 2.1*.

Primary Asset	Secondary Asset	RAV	Justification of RAV
Land	Urban	9	Urban areas support the communities, including secondary and tertiary industries, essential for modern community life.
	Peri-urban	7	Support the urban centres.
	Mining	8	High-value outputs per unit land area. Essential to urban and rural communities.
	Animal production	7	Intensive animal production is expanding, and has high value per unit land area.
	Horticulture	5	High-value production in contrast to other enterprises on the same land. (Potato crop gross margins 2005/06: $8,070/ha).
	Dairy	4	Medium-value production in contrast to other enterprises on the same land. (Dairy gross margins 2004/05: $1,323/ha).
	Cropping	3	Relatively low-value production per hectare. Average gross margins for cropping for 2004/05: $291/ha.
	Forestry	3	High-value at harvest but annual contribution factors in a lower Relative Asset Value.
	Grazing	2	Relatively low-value production per hectare. (Average livestock grazing gross margins for 2004/05: $275/ha).
	Public land (non-conservation use)	7	Public land used for recreation, infrastructure and utilities. Generally already impacted by development in one form or another.
	Public land (conservation use)	10	This includes the Great Otway National Park and other terrestrial, aquatic and marine conservation areas and reserves. Irreplaceable if lost.
Water quality	Water Proclaimed Supply Areas	10	Urban and agricultural water supply resources, essential for the community. Invaluable.
	Waterways	10	At least 19,630 km of waterways including some of the most intact in the state (Otway Ranges).
Biodiversity	Wetlands	10	13 Ramsar-listed wetlands and 345 significant wetlands are listed in the region. Irreplaceable if lost. Invaluable.
	Significant flora & fauna	10	Regional AROTS include 19 fauna and 50 flora species, and more than 300 VROTS. Irreplaceable if lost. Invaluable.
Infrastructure	Roads	10	More than 10,600 km of roads service the region. An essential asset for the community. Generally high intrinsic value and replacement cost if damaged or lost.
	Utilities and services	10	Regional electrical power, gas, telecommunication conduits and transportation corridors are extensive. Generally high intrinsic value and replacement cost if damaged or lost.
Cultural and heritage	Heritage sites	10	The region has significant numbers of Aboriginal archaeological sites and Victoria’s earliest pastoral settlements. Irreplaceable if lost. Invaluable.

Table 2.1: Relative Asset Values (RAV) assigned to secondary and cultural and heritage asset classes

2.3 Identifying threats to assets

This strategy identifies 12 threats to assets that relate to soil health. These 12 pose sufficient threat to assets that they need to be addressed. Some of these threats act locally, virtually in situ with the asset, while other threats may be seen as 'mobile' in that they have the potential to impact other, off-site assets. For example, a landslide will have a local impact at its site and falling into a watercourse, but may have off-site impacts through the transportation of clay particles into other areas, affecting water quality, plant and animal life.

Table 2.2 shows the threats to high RAV assets. Greater detail about the processes, condition and management of the threatening processes is given in *Appendix A*.

Table 2.3 shows the 12 threats addressed by the SHS, providing an illustrative example of each and their distribution in the region.

Most threats to assets recognised in this Soil Health Strategy are natural processes, albeit some are the consequences of land clearing, agricultural, forestry and urban development and ongoing activity. The consequences of these threats impacting on assets have also become greater. For instance, built infrastructure has spread across wider areas, with a larger proportion of the population served by various utilities, roads etc. A growing and expanding human population requires larger volumes of water. High value biodiversity, wetlands and cultural heritage sites are considered more significant and valuable as their number has declined.

Table 2.4 outlines the threats and what triggers them to pose a risk to assets. The table also outlines the consequences that threats pose to assets.

		Soil-related Threatening Processes											
Primary Assets	**Secondary Assets**	1. Landslides	2. Water Erosion	3. Acid Sulphate Soils	4. Secondary Salinity	5. Waterlogging	6. Soil Structure Decline	7. Wind Erosion	8. Soil Nutrient Decline	9. Soil Acidification	10. Soil Contamination	11. Soil Organic Carbon Decline	12. Soil Biota Decline
Land	Urban/Peri-urban	■	■	■	■			■			■	■	■
	Agriculture/Forestry	■	■	■	■	■	■	■	■	■	■	■	■
	Public Land	■	■	■	■			■			■		
Biodiversity	Wetlands	■	■	■	■			■			■		
	Significant flora and fauna species	■	■	■	■			■			■		
Cultural Heritage Sites	Cultural and heritage sites	■	■	■	■			■					
Built Infrastructure	Infrastructure and utilities	■	■	■	■			■					
	Roads	■	■	■	■			■					
Water Quality	Water (dams, lakes, rivers etc.)	■	■	■	■			■			■		

Table 2.2: Identification of potential risk of soil-related threatening processes to asset classes

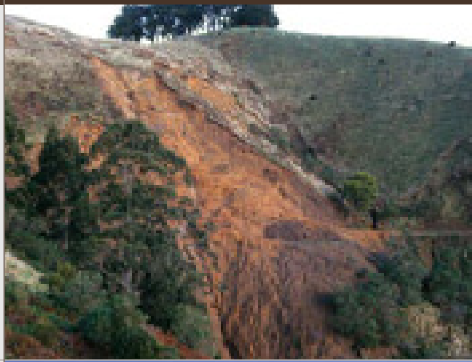
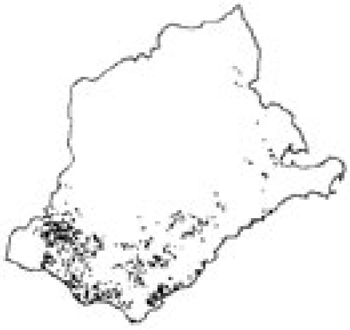
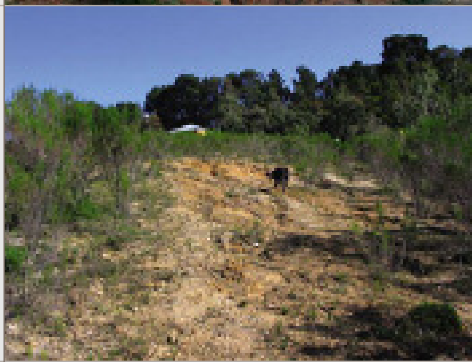
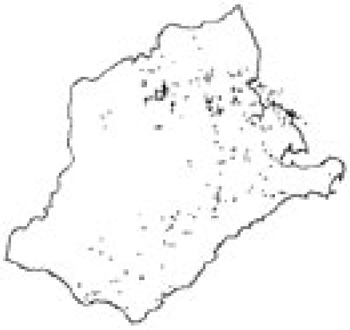
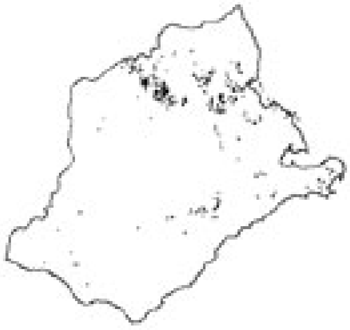
Definition of soil-threatening processes	Photograph of threat to asset	Distribution of soil-threatening process
Landslide – the movement of soil or rock down a slope. Landslides occur episodically, driven by gravity. Photograph: A. Miner 2005		
Sheet/rill erosion – soil particles suspended in water run-off are transported. Once sheet erosion water concentrates into small channels or streams, its speed leads to rill erosion as soil is moved from the stream base and banks. Photograph: W. Feltham 2006		
Gully erosion – normally involves a range of interacting factors and processes, involving larger volumes and closer concentration of water flow. Gullies start simply, leading to upstream and downstream complex erosion sites. Photograph: P. Dahlhaus 2003		
Tunnel erosion – occurs underground and is initiated by water movement along surface channels and cracks into dispersive subsoils that erode into the water moving below the soil surface.		*Map not available*

Table 2.3: Definition of soil-threatening processes addressed by the SHS, with illustrative photographs and distribution in the Corangamite region (continued over page)

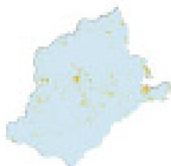
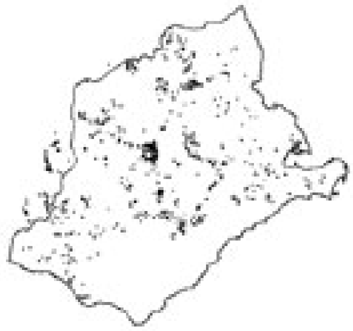
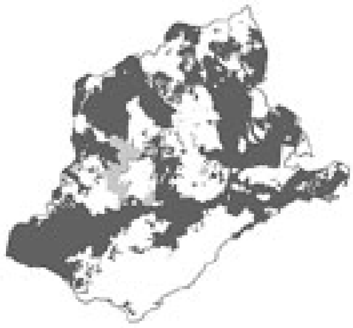
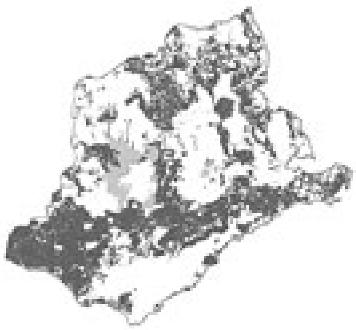
Definition of soil-threatening processes	Photograph of threat to asset	Distribution of soil-threatening process
Acid sulphate soils – when disturbed and exposed to air, these soils produce sulphuric acid as a result of the interaction of naturally occurring iron sulphides with water and oxygen. Disturbed acid sulphate soils may also release toxic quantities of iron, aluminium and heavy metals.		*Inland ASS distribution*  Total area: ~ 54sqkm Percentage of CCMA: ~ 0.40% *Coastal ASS distribution*  Total area: ~ 54sqkm Percentage of CCMA: ~ 0.44%
Secondary salinity – caused by changing land use and management, especially where this results in a change in the water balance and a rising watertable. Rising movement of soil water mobilises and lifts stored mineral salts towards the soil surface. Land clearing for agriculture has been the major cause of secondary salinity in Australia.		
Waterlogging – excess water in the plant root zone reduces soil aeration that is required by roots for plant growth. By changing the environment around the roots, waterlogging may affect the availability of various plant nutrients.		
Soil structure decline – 'Soil structure' describes the aggregation of soil particles (sand, silt, clay) and the pore spaces of the soil. Soil structure decline is a detrimental change in these soil characteristics, generally as a result of certain land use practices.		

Table 2.3: (Cont.)

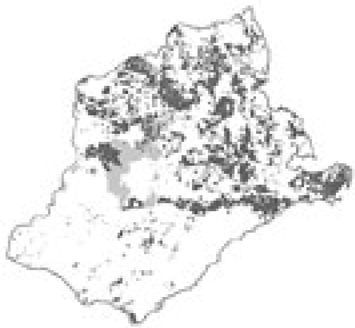
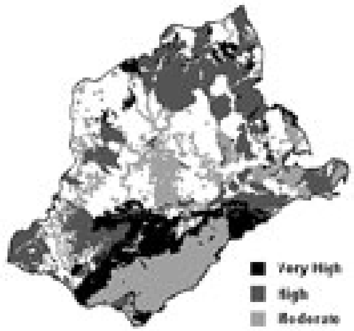
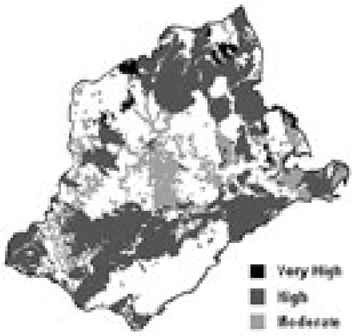
Definition of soil-threatening processes	Photograph of threat to asset	Distribution of soil-threatening process
Wind erosion – the action of wind on exposed sediments and friable rock formations causes erosion (abrasion) and entrapment of sediment and soil particles in the moving air.		
Soil nutrient decline – is the removal or transport of nutrients from soils by plant growth, wind or water erosion and by leaching beyond the root zone of the covering vegetation.		
Soil acidification – although acidic soils occur naturally in Victoria through processes of weathering and leaching, agricultural activities such as continued removal of alkaline plant material, excessive use of nitrogenous fertilisers and nitrate leaching lead inevitably to soil acidification. *Right: Sorrel, an acid soil indicator*		
Soil contamination – can be the result of a variety of practises, intentional and otherwise. The application of certain agricultural or industrial chemicals may lead to long-lasting soil contamination, affecting soil health, water quality and subsequent land use options.		

Table 2.3: (Cont.)

Definition of soil-threatening processes	Photograph of threat to asset	Distribution of soil-threatening process
Soil organic carbon decline – Soil organic carbon is the term used to describe the fractions of decomposed plant and animal material that remain in the soil after the organism's life is ended. Soil organic carbon is an important contributor to soil fertility. Generally, organic carbon is found in higher concentrations near the soil surface. Drought, fire and certain land management practices cause organic carbon decline.	 *A)*  *B)* *Two soils from adjacent paddocks* *A) is high in organic matter and has been managed correctly* *B) is low in organic matter and has been mismanaged*	
Soil Biota Decline – Reduction of the billions of biota (microscopic animals) in the soil as a result of soil management practices.	*Photograph not available*	*Map not available*

Table 2.3: (Cont.)

Soil-threatening process	Triggering factors that result in risk	Common consequences to assets
Landslides	• steep slopes • intense rainfall • poorly drained soils • clearing of forests, woodland or other ground-stabilising cover	• sedimentation of waterways • damage to infrastructure (roads, buildings etc.) • destruction of cultural heritage sites • loss of agricultural productivity • loss of human life • sedimentation of waterways and wetlands • loss of agricultural productivity
Sheet/rill Erosion	• low levels of vegetative ground cover combined with:- – high-intensity rainfall with low infiltration rates – ground slope – degraded surface soil structure – removal of soil organic matter	• sedimentation of waterways • loss of agricultural productivity
Gully/tunnel Erosion	• low levels of vegetative ground cover combined with:- – high intensity rainfall and low infiltration rates – concentrated run-off – dispersive subsoils – clearing of vegetation	• damage to roads, buildings and other built infrastructure • destruction of significant biodiversity areas • loss of cultural heritage sites

Table 2.4: Threats to assets, triggering factors and consequences (continued next page)

Soil-threatening process	Triggering factors that result in risk	Common consequences to assets
Acid Sulphate Soils	• drainage activities or other disturbance and exposure to air	• acidification of the site and waterways • destruction of built infrastructure • death of fish and other aquatic life • destruction of significant biodiversity areas, including wetlands • loss of cultural heritage sites
Secondary Salinity	• removal of vegetation in recharge areas • soil structure decline	• salinisation of waterways • loss of agricultural land • destruction of biodiversity areas • destruction of built infrastructure
Waterlogging	• duration of rainfall or surface run-off in compacted or poorly drained soils	• loss of agricultural productivity • loss of plant or animal life, biodiversity
Soil Structure Decline	• aggregate breakdown caused by a variety of secondary factors including dispersive clay behaviour, compaction by animal or machinery traffic, soil cultivation	• loss of agricultural productivity • increased run-off and higher potential for water erosion
Wind Erosion	• removal of organic matter and vegetative ground cover coupled to high surface wind speed and sandy soils	• air pollution • sedimentation of waterways • loss of agricultural productivity
Soil Nutrient Decline	• removal of nutrients through plants harvested in grazing or crop production • leaching of nutrients beyond the plant root zone • removal or decline in soil biota and organic carbon levels may raise the rate of leaching	• loss of agricultural productivity
Soil Acidification	• replacement of naturally occurring vegetation with introduced crops and pastures • removal of alkaline materials in plants • mineral fertiliser application	• loss of agricultural productivity
Soil Contamination	• intentional or unintentional application of agricultural of industrial chemicals or by-products to soil. NB Significantly different threats and risks if the contaminant is mobile or effectively 'fixed' in the soil	• contamination of waterways • impact to biodiversity • loss of land use options • impacts human and animal health
Soil Organic Carbon Decline	• decline and removal of vegetation • intensive agricultural practices	• loss of agricultural productivity • increased susceptibility to soil structure decline and erosion
Soil Biota Decline	• reduction of soil organic carbon and soil structure • soil acidification and the addition of contaminants to the soil	• loss of agricultural productivity • loss of food for fauna (e.g. worms for birds)

Table 2.4: (Cont.)

2.4 Other potential and real threats

Other potential threats and some opportunities in relation to soil health are outlined in this section of the strategy. Several are becoming more widely discussed in society or are issues not covered under the descriptions of the soil-related threatening processes.

Climate change and implications for soil health

There are undoubtedly relationships between climate change and soil health. For instance, greater uncertainty over annual rainfall and its seasonal distribution may make the farmer's task of managing farm land more difficult. In turn, uncertainty over ground cover may exacerbate the risk of water or wind erosion.

Higher levels of storm activity, drought and other climate events may all contribute to various threats to assets and the risk of adverse outcomes (Anderson 2006, who investigated climate change in the Corangamite region). Land management practices are almost certain to change in response to climate change. Various features of climate change, their implications for soil health and appropriate actions to address risks are outlined in *Table 2.5.*

The forecast climate change in the Corangamite region appears to present no threats or risks to assets that are not already covered by consideration of other, better defined threats (Anderson 2006). Consequently, no specific actions are planned in regard to climate change and its potential impact on soil health. However, research and development projects may be needed in the future to assess the impacts of climate change on soil health and the assets it supports in the Corangamite region.

Agricultural fertiliser application

The relationships between inappropriate application of agricultural fertilisers and the unintended release and effects of nutrients in waterways are becoming better understood.

A recent study in the Curdies Landscape Zone by DPI investigated the loss of applied mineral fertiliser nutrients from local dairy paddocks into waterways. One finding of the study was that on many paddocks, soil phosphorus levels were well in excess of the agronomic optimum of 20 – 25 mg/kg of 'Olsen P'. Ideally, these levels should be progressively cut back into the optimum range through more stringent management of fertiliser application against soil test data. Agricultural fertiliser applications in excess of the soil and pasture's capacity to use fertilisers or hold the applied nutrients is likely to result in unintended losses into waterways, impacting aquatic ecosystems.

Feature of climate change	Implications for soil health	Recognised actions to address the threat
Lower rainfall, higher temperatures	Greater incidence of drought, leading to a reduction in plant growth and soil biota, contributing to reductions in ground cover and soil organic carbon levels. Increase in wind and water erosion is likely. For areas normally located in high rainfall areas, growing conditions may be improved as waterlogging is reduced during winter months.	Adverse or beneficial effect depending on current rainfall and distribution, soil types and enterprises. For instance, may benefit some dairy and some broadacre cropping areas while impacting adversely on others. No specific actions other than already considered for existing circumstances.
More storm events	Potential for more water erosion and landslide activity. Greater costs to asset managers from more severe and sudden damage caused by landslides and erosion.	Addressing erosion and landslide risk through municipal planning schemes. Inform asset managers of where highly susceptible erosion and landslide areas are located. (Already considered for existing circumstances).
Rising sea levels from melting icebergs	Rising sea levels will start to impact coastal cliffs, leading to greater landslides. This may increase the impacts on roads, buildings and other built infrastructure close to the water's edge. Sands dunes will also be washed away by tidal movement, impacting existing high-value biodiversity areas.	Greater controls over future developments along coastal areas that account for rising sea levels and greater landslide risk.

Table 2.5: Features of climate change, implications and potential actions to address threats

3. Developing investment priorities for the Corangamite Soil Health Strategy

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

A logical process with supporting criteria and ranking system was developed to determine which threats pose the greatest risk to assets, and the locations within the region where the risks and potential losses are greatest.

In Section 2 of the strategy, the concept of 'Relative Asset Value' was introduced. In this section, the concept of Relative Risk Value is introduced and explained, together with summary lists of high-ranking locations and threats.

Relative Risk Value draws together the perceived value of the asset, the relative severity of the threat at that location and the area that is currently or would be affected.

3.1 Landscape zones in the Corangamite region

The Soil Heath Strategy has adopted and used the concept and boundaries of the 15 landscape zones that define the 15 sub-catchment areas within the Corangamite region. These zones were identified in the Corangamite Regional Catchment Strategy and are shown in *Figure 3.1.*

Figure 3.1: Fifteen landscape zones in the Corangamite region

3.2 Assessing risk to assets – Relative Risk Value

Relative Risk Value is determined using the equation below. The components are:-

Relative Asset Value – The concept of this factor is discussed in Section 2 with values for secondary asset classes appearing in *Table 2.1.* These values are from 1 to 10 with 10 as the most valuable.

Area under threat has been established through electronic interrogation and analysis of Geographic Information System (GIS) data, working through and storing data on a landscape zone basis. The area under threat is determined from:

- the location of each class of asset determined from the GIS with the location data stored for reference
- the different threats identified from the individual images they create in the GIS. A computer program 'looks up' the individual threats with a complementary program calculating the incidences or the area in ha over which the threat intersects with each asset. For example, the GIS can 'see' roads and the threat of salinity. The computer is then programmed to interrogate the GIS data and report the intersections of salinity with roads.

Relative severity of the threat is the potential magnitude of the impact of the threat on the asset. For example, a landslide will destroy a house, and will therefore have greater severity on the asset compared with soil acidification, which may slightly decrease agricultural production in a paddock.

$$\frac{\textbf{(A)}\ \text{Notional value of asset}\ \mathbf{x}\ \textbf{(B)}\ \text{Area under threat}}{\textbf{(C)}\ \text{Relative severity of the threat}} = \textbf{(D)}\ \text{Relative Risk Value}$$

After completion of the first 'run' of the data gathering and calculations of Relative Risk Values, a 'sensitivity test' was conducted on the results to ensure that the process was truly indicative of the values sought. The results of the sensitivity test confirmed the validity of the concept of Relative Risk Value and its calculation via the formula. Examples and further detail on the process used to determine Relative Risk Values are explained in *Appendix B.*

3.3 Relative Risk Values across Landscape zones and for various threats

Relative Risk Values were established for 10 key soil threatening processes in each of the 15 landscape zones. This produced 143 Relative Risk Values for threatened assets across the region.

Relative Risk Values could not be determined for three other threats – 'soil contamination', 'soil organic carbon decline' and 'biota decline' because there was insufficient information available.

Calculated Relative Risk Values were ranked from 1-143 *(Appendix B).* The highest 20 Relative Risk Values indicate potential investment priorities, are matters for attention and are listed *(Table 3.1).*

Five of the 12 threats were noted in the 20 highest Relative Risk Values. These threats are: landslides, sheet/rill erosion, gully/tunnel erosion, secondary salinity and acid sulphate soils. All five threats impact public assets and have the potential to impact all primary and secondary asset classes identified in the SHS.

A program of research and field work was carried out to validate the 20 highest Relative Risk Values before these were carried forward into the remainder of the strategy. The validation processes used and the final ranked priorities based on Relative Risk Value are outlined in Section 3.5.

A further assessment was made using the Relative Risk Values by landscape zone to determine the ranking of the threats against each other, taken on a Corangamite region basis i.e. the aggregate values across the 15 landscape zones.

Water erosion had the highest aggregate Relative Risk Value, which was calculated by adding sheet/rill and gully/tunnel erosion together. Water erosion is widespread and has the capacity to impact on all asset classes, particularly water quality and agricultural production *(Fig. 3.2).*

Secondary salinity had the second-highest aggregate Relative Risk Value, mostly because secondary salinity is relatively widespread and often interacts with large areas of agricultural production and high-value biodiversity areas *(Fig. 3.2).* It also has the potential to impact on water quality, built infrastructure and cultural heritage sites.

Landslides had the third highest aggregate Relative Risk Value in the region and also have the potential to impact on all asset classes *(Fig. 3.2).* Landslides have the highest Relative Severity Value *(Table B2)* because they are capable of severely impacting valuable and irreplaceable natural assets, destroying buildings and other built infrastructure and, sometimes, taking human life.

Acid sulphate soils (ASS) had the fourth-highest aggregate Relative Risk Value. These soils were often found in wetlands and have the potential to impact on all asset classes with potentially catastrophic results.

Soil structure decline, waterlogging, nutrient decline and *soil acidification* had lower Relative Risk Values because they only impact agricultural production *(Fig. 3.2)* and not high-value public assets.

Wind erosion potentially causes an impact on a range of assets. However, the likelihood of wind erosion events is relatively low compared with other threats to soil health in the region and therefore it had a lower Relative Risk Value *(Fig.3.2).* However, during drought conditions the likelihood of wind erosion will increase significantly.

Soil-Threatening Process	Landscape Zone	Relative Risk Value
Landslides	Gellibrand	3167
Secondary salinity	Lismore	2886
Acid sulphate soils	Bellarine	2748
Gully/tunnel erosion	Woady Yaloak	2501
Sheet/rill erosion	Woady Yaloak	2317
Secondary salinity	Stony Rises	1925
Landslides	Curdies	1903
Landslides	Otway Coast	1872
Sheet/rill erosion	Thompsons	1804
Secondary salinity	Woady Yaloak	1646
Sheet/rill erosion	Moorabool	1154
Secondary salinity	Murdeduke	1090
Gully/tunnel erosion	Leigh	938
Landslides	Upper Barwon	917
Gully/tunnel erosion	Moorabool	893
Sheet/rill erosion	Upper Barwon	752
Gully/tunnel erosion	Upper Barwon	743
Sheet/rill erosion	Leigh	734
Potential acid sulphate soils	Thompsons	557
Landslides	Aire	548

Table 3.1: 20 highest Relative Risk Values for soil threats in the Corangamite region

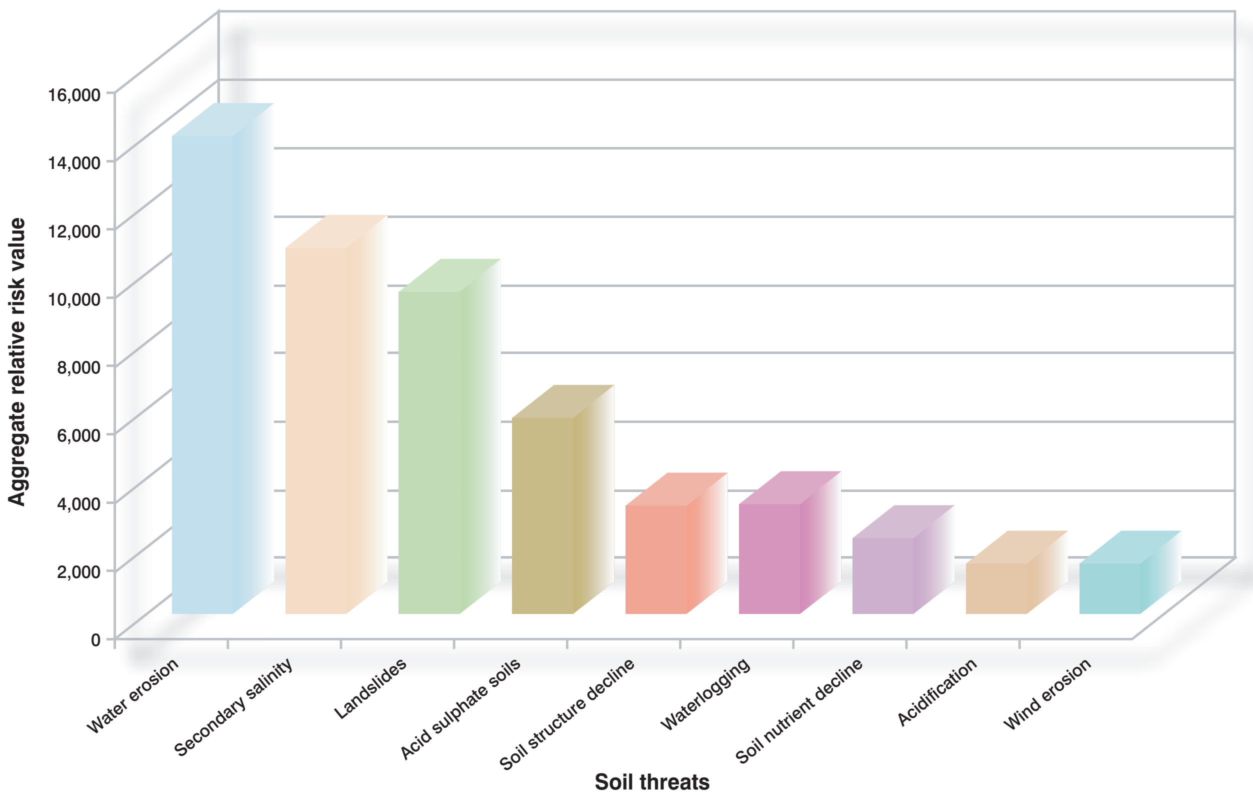


Figure 3.2: Aggregate Relative Risk Values for each soil threat in the Corangamite region

The aggregate Relative Risk Values of all threats were calculated for each landscape zone in the Corangamite region *(Fig. 3.3).*

Woady Yaloak, Gellibrand, Bellarine and Thompsons landscape zones had the highest aggregate Relative Risk Values. Aire, Middle Barwon, Murdeduke and Hovells had the lowest aggregate Relative Risk Values.

Generally, those landscape zones with the higher aggregate Relative Risk Values have significant landslide, water erosion, secondary salinity and/or acid sulphate soil risk. Those with lower aggregate Relative Risk Values are generally characterised by fewer hills and gentle slopes with threats that predominantly have impacts on agricultural production.

3.4 Assets and threats to assets in each landscape zone

This section describes the:

- assets in each landscape zone
- principal threats to these assets
- Relative Risk Values (Table 3.2) and importantly
- the detailed location of assets under threat in each landscape zone.

This section also describes which assets may be at possible risk from these threats.

Further details of land use, threats to assets and Relative Risk Values for each landscape zone are given in *Appendix C.*

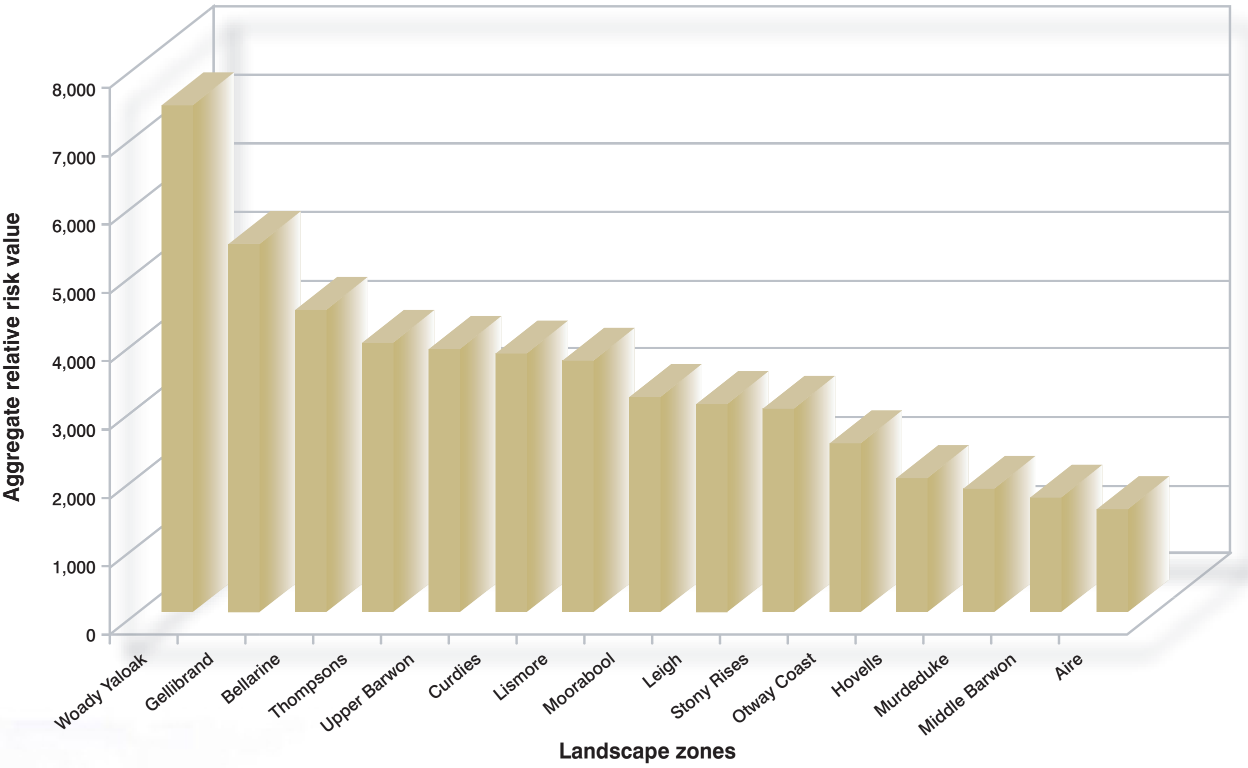


Figure 3.3: Aggregate Relative Risk Values from soil threats for 15 landscape zones in the Corangamite region

Landscape Zone	Summary of assets considered in the threat matrix	Five highest threats to assets with individual Relative Risk Values
Woady Yaloak	• 2117 km of waterways including the Woady Yaloak River, Naringhil Creek, Misery and Moonlight creeks , Kuruc-a-ruc Creek and Ferrars Creek. • 91 wetlands (0.8% of area). • Native vegetation conservation significance potential: 5.5% of total landscape zone is very high, 6.7% of total landscape zone is high. • 1000 km of roads, excluding the more recently subdivided areas west of Ballarat.	1. Gully/tunnel erosion (2,501) 2. Sheet/rill erosion (2,317) 3. Secondary salinity (1,646) 4. Acid sulphate soils (246) 5. Waterlogging (232)
Gellibrand	• 3107 km of waterways, including the Gellibrand River and coastal wetlands. • 47 wetlands (0.3% of area), with the coastal wetlands of the Lower Gellibrand River as significant assets. • Native vegetation conservation significance potential: 11.0% of total landscape zone is rated very high, 17.1% of total landscape zone is high. Many of these are included in national and state parks. • 548 km of roads including part of the Great Ocean Road. • Coastal assets include beaches, coastal cliffs, sea stacks (i.e. the Twelve Apostles), marine parks and sanctuary, cultural and heritage assets, (including Aboriginal archaeological sites, shipwrecks and buildings).	1. Landslides (3,176) 2. Secondary salinity (424) 3. Acid sulphate soils (398) 4. Sheet/rill erosion (336) 5. Soil structure decline (273)
Bellarine	• 425 km of waterways, including the Lower Barwon River in Geelong. • 139 wetlands (9.6% of area), including wetlands of international, national, state and local significance. The Lake Connewarre State Game Reserve is highly ranked. • Native vegetation conservation significance potential: 9% of total landscape zone is rated as very high, 14% of total landscape zone is rated as high. • At least 1243 km of roads, not including many of the urban roads in more recent subdivisions. • Major provincial City of Greater Geelong, including industrial and port facilities. • Cultural and heritage assets include many Aboriginal archaeological sites and Victoria's early pastoral settlement history. Coastline and marine parks.	1. Acid sulphate soils (2,748) 2. Secondary salinity (485) 3. Gully/tunnel erosion (317) 4. Soil structure decline (167) 5. Soil acidification (167)
Thompsons	• 1048 km of waterways and 56 wetlands (1.9% of area). • Native vegetation conservation significance potential: 4.6% of total landscape zone is very high, 25.6% of total landscape zone is high. • 713 km of roads, not including the more recently subdivided areas of Torquay and other coastal towns. • Coastal assets including beaches, cliffs and shore platforms, which are highly valued as tourist assets. Cultural and heritage assets, including Aboriginal archaeological sites, are associated with the coast.	1. Sheet/rill erosion (1,804) 2. Acid sulphate soils (557) 3. Landslides (518) 4. Secondary salinity (236) 5. Wind erosion (195)

Table 3.2: Individual assets under threat within landscape zones, showing their locations and the top five Relative Risk Values (described by threat) in each landscape zone (continued next page)

Landscape Zone	Summary of assets considered in the threat matrix	Five highest threats to assets with individual Relative Risk Values
Upper Barwon	• 1822 km of waterways including the Barwon River. • 53 wetlands (1.0% of area) including The Sanctuary (Lake Thurrumbong). • Native vegetation conservation significance potential: 3.2% of total landscape zone is very high, 15.9% of total landscape zone is high. Most are included in the Otway Ranges. • 533 km of roads and rural infrastructure. Birregurra is the main urban centre.	1. Landslides (917) 2. Sheet/rill erosion (752) 3. Gully/tunnel erosion (743) 4. Secondary salinity (525) 5. Soil structure decline (268)
Curdies	• 1891 km of waterways, including the Curdies River and estuary. • 93 wetlands (1.3% of area) including Lake Purrumbete. • Native vegetation conservation significance potential: 6.6% of total landscape zone is rated as very high, 10.2% of total landscape zone is rated as high. • 876 km of roads, including a section of the Great Ocean Road. • Coastline including beaches, coastal cliffs and sea stacks (e.g. Bay of Islands), marine sanctuary and marine parks which include significant cultural and heritage assets.	1. Landslides (1,903) 2. Waterlogging (482) 3. Soil structure decline (416) 4. Secondary salinity (399) 5. Soil nutrient decline (175)
Lismore	• 736 km of waterways and 187 wetlands (22.5% of area), including Ramsar and significant wetlands, such as Lake Corangamite. • Native vegetation conservation significance potential: 0.9% of total landscape zone is very high, 3.9% of total landscape zone is high. • 622 km of roads, including highways. Other infrastructure includes significant railway and power lines. • Cultural and heritage assets, especially Aboriginal archaeological sites associated with the lakes, waterways and wetlands.	1. Secondary salinity (2,886) 2. Waterlogging (228) 3. Acid sulphate soils (225) 4. Soil structure decline (165) 5. Wind erosion (78)
Moorabool	• Urban water supply catchments for the City of Ballarat, City of Greater Geelong and other urban centres (e.g. Meredith, Bannockburn). • 2151 km of waterways, including the Moorabool River and tributaries. 132 wetlands (1.1% of area). High value groundwater resources (Bungaree GMA). • Native vegetation conservation significance potential: 9.3% of total landscape zone is very high, 16.6% of total landscape zone is high. • 978 km of roads excluding the more recently constructed urban and peri-urban roads of newer subdivisions around Geelong and Ballarat. Extensive peri-urban development.	1. Sheet/rill erosion (1,154) 2. Gully/tunnel erosion (893) 3. Waterlogging (230) 4. Soil structure decline (219) 5. Landslides (136)
Leigh	• 1689 km of waterways, including the Leigh River and Leigh River Gorge. • 74 wetlands (0.8% of area), including Lake Wendouree which has high recreational value. • Native vegetation conservation significance potential: 5.2% of total landscape zone is very high, 11.7% of total landscape zone is high. • 1224 km of roads, not including the more recently constructed urban roads in Ballarat. • A portion of the City of Ballarat, which includes significant educational facilities, industry, mining, transport corridors and heritage assets.	1. Gully/tunnel erosion (938) 2. Sheet/rill erosion (734) 3. Secondary salinity (502) 4. Waterlogging (196) 5. Soil structure decline (192)

Table 3.2: (Cont.)

Landscape Zone	Summary of assets considered in the threat matrix	Five highest threats to assets with individual Relative Risk Values
Stony Rises	• 946 km of waterways and 535 wetlands (9.2% of area), including Ramsar and significant wetlands such as Lake Beeac and Lake Cundare. • Native vegetation conservation significance potential: 6.4% of total landscape zone is very high, 10.0% of total landscape zone is high. • 1054 km of roads, excluding the more recently subdivided areas around Colac and Camperdown. • Cultural and heritage assets include Aboriginal archaeological sites and buildings associated with the early pastoral settlement. • Urban centres of Colac and Camperdown, including manufacturing and service industries.	1. Secondary salinity (1,925) 2. Soil structure decline (256) 3. Waterlogging (254) 4. Soil nutrient decline (211) 5. Soil acidification (144)
Otway Coast	• 1282 km of waterways, mostly mountain streams. Barham River is the largest catchment. • Wetlands (<0.1% area). • Native vegetation conservation significance potential: 7.8% of total landscape zone is very high, 2.5% of total landscape zone is high. A significant proportion of the native vegetation is in the Great Otway National Park. • 284 km of roads, including the Great Ocean Road. • Cultural and heritage assets and high-value tourist sites.	1. Landslides (1,872) 2. Soil structure decline (225) 3. Soil nutrient decline (197) 4. Waterlogging (149) 5. Acid sulphate soils (81)
Hovells	• 251 km of waterways, with Hovells Creek and Limeburners Bay as the most significant. • 44 wetlands (3.0% of area), includes Ramsar and significant wetlands around Point Lillias and Point Wilson. • Native vegetation conservation significance potential: 16.1% of total landscape zone is very high, 10.4% of total landscape zone is high. • At least 694 km of roads, not including many of the more recently constructed suburban roads in Lara and Geelong. • Portions of the City of Greater Geelong, including significant urban and industrial infrastructure. • Cultural and heritage assets include Aboriginal archaeological sites and historical sites associated with the early pastoral settlement of Victoria.	1. Acid sulphate soils (506) 2. Sheet/rill erosion (444) 3. Soil structure decline (244) 4. Secondary salinity (243) 5. Gully/tunnel erosion (240)
Murdeduke	• 460 km of waterways, including Warrambine Creek and Mia Mia Creek. • 65 wetlands (4.1% of area), including Ramsar and significant wetlands (Lake Murdeduke). • Native vegetation conservation significance potential: 9.1% of total landscape zone is very high, 6.9% of total landscape zone is high. • 236 km of roads, rail line and minor rural infrastructure. • Cultural and heritage assets, including Aboriginal archaeological sites.	1. Secondary salinity (1,090) 2. Waterlogging (218) 3. Soil structure decline (196) 4. Wind erosion (93) 5. Acid sulphate soils (93)

Table 3.2: (Cont.)

Landscape Zone	Summary of assets considered in the threat matrix	Five highest threats to assets with individual Relative Risk Values
Middle Barwon	• 703 km of waterways including the Barwon River. • 104 wetlands (1.8% of area), mostly very small (Wurdee Boluc Reservoir and Lake Gherang are exceptions). • Native vegetation conservation significance potential: 14.8% of total landscape zone is very high, 9.2% of total landscape zone is high. • Infrastructure assets including 458 km of roads, along with main railway and power lines. Parts of the City of Greater Geelong and peri-urban fringe.	1. Secondary salinity (296) 2. Sheet/rill erosion (294) 3. Soil structure decline (268) 4. Waterlogging (257) 5. Landslides (107)
Aire	• Many of the 989 km of waterways are high-value assets because of their pristine condition. In particular, the Aire River estuary is a high-value environmental asset. • Wetlands (0.2% of area). • Native vegetation conservation significance potential: 17.8% of total landscape zone is rated as very high, 5.4% of total landscape zone is rated as high. ∑152 km of roads. • Great Otway National Park. • Cape Otway coastline and associated marine parks.	1. Landslides (548) 2. Acid sulphate soils (402) 3. Soil nutrient decline (184) 4. Soil structure decline (145) 5. Wind erosion (118)

Table 3.2: (Cont.)

3.5 Validation of Relative Risk Values

The Relative Risk Value analysis described in Section 3.2 was based on various assumptions. To validate the results of the analysis, a process was applied to test and modify the results according to field assessment by the strategy team and previous documented and evidence-based investigations by third parties.

The Relative Risk Value analysis assumed that if an asset appeared in the GIS data to intersect with a threat that was known to have an impact, such as a landslide impacting on a road or a waterway, then an actual or potential risk was present.

However, this assumption may have been flawed, potentially for a variety of reasons. For instance:

- identified intersection sites may be stable and unlikely to change over time, thus presenting a potential threat with little or no chance of developing and becoming a real threat to the subject asset
- alternatively, a threat may be shown by on-ground inspection to be too distant from the asset to pose an actual risk. Intersection sites may not have been mapped accurately in the GIS analysis and therefore a threat may not actually be near an asset
- some intersection sites may have been ameliorated since the GIS data were taken and with the passage of time there may no longer be a risk to assets.

As a result of these potential flaws, a field inspection was carried out for erosion and landslide intersection sites with a search of past investigation reports for secondary salinity and acid sulphate soils.

Validation of Relative Risk Value was conducted for the highest 20 Relative Risk Values: landslides, secondary salinity, sheet/rill erosion, gully/tunnel erosion and acid sulphate soils within the landscape zones that appear in *Table 3.1.*

Further results of the validation of Relative Risk Values are described in *Appendix D.*

The background report, ‘Validation of Priority Areas for Landslides and Erosion’ describes in detail the processes used and results found during the field verification of landslide and erosion risk.

Validation of landslide risk

Validation for Relative Risk Values for landslides was carried out in the Gellibrand, Curdies, Otway Coast, Upper Barwon and Aire landscape zones, using a field assessment technique. The technique validated the potential or actual risk to assets, particularly in those localities where multiple landslides could be found – i.e. the most landslide-prone areas.

The ranking of landscape zones altered slightly as a result of the field assessment. There was strong evidence of landslide risk, particularly to built infrastructure in Gellibrand and Otway Coast *(Fig. 3.4)*, but there was less evidence in the Curdies, where agricultural production was the main asset under threat *(Table 3.3)*.

	Asset Classes					
Priority Landscape Zones	**Land use**	**Water Quality**	**Bio-diversity**	**Infrastructure**	**Verification of risk score**	**Revised rank according to verification**
1. Gellibrand	3	4	1	4.5	**12.5**	**1**
2. Curdies	3.5	2	1	4	**10.5**	**3**
3. Otway Coast	2	2	3	5	**12**	**2**
4. Upper Barwon	2	4.5	1	1	**8.5**	**4**
5. Aire	1	3	2	2	**8**	**5**

Table 3.3: Field verification scores for landslide risk in the highest Relative Risk Value landscape zones. Risk to assets is indicated as: very high-5; high-4; medium-3; low/medium-2; low-1.

Figure 3.4: Remediated landslide next to dwelling in the Barham Valley (Otway Coast) Photograph: A. Miner 2006

Validation of erosion risk

Validation of Relative Risk Values for erosion threats was carried out using a field assessment technique. This was carried out in those landscape zones where gully/tunnel and/or sheet/rill erosion had shown high Relative Risk Values: Woady Yaloak, Moorabool, Leigh, Upper Barwon and Thompsons.

Verification found that erosion was mapped accurately, but differentiation of the threats and risks to assets from sheet, rill, gully and tunnel erosion was inconsistent in the GIS analysis.

Consequently, it was decided that in those landscape zones where sheet/rill erosion and gully/tunnel erosion occurred in the highest 20 Relative Risk Values, these should be ranked together.

Verification of Relative Risk Values for erosion changed the ranking of some landscape zones from their GIS-derived position.

On-site field assessment verified that erosion is a high risk in Woady Yaloak and Moorabool, particularly threatening water quality in creeks and rivers *(Fig. 3.5)*. There was little evidence to verify that erosion is a high risk in Thompsons *(Table 3.4)*.

	Asset Classes					
Priority Landscape Zones	**Land use**	**Water Quality**	**Bio-diversity**	**Infrastructure**	**Verification of risk score**	**Revised rank according to verification**
1. Woady Yaloak	4	4	3	2	**13**	**=1**
2. Moorabool	3	5	3	2	**13**	**=1**
3. Thompsons	1	2	2	1	**6**	**5**
4. Upper Barwon	2	3	2	1	**8**	**4**
5. Leigh	2	3	3	2	**10**	**3**

Table 3.4: Field verification scores for water erosion in the five highest Relative Risk Value landscape zones. Risk to assets is indicated as: very high-5; high-4; medium-3; low/medium-2; low-1.

Figure 3.5: Severe sheet, rill and gully erosion contributing large sediment loads with potential nutrient discharge into Moonlight Creek (Woady Yaloak)

Validation of acid sulphate soil Relative Risk Values

Relative Risk Values for acid sulphate soils appeared in the 20 highest Relative Risk Values in the Bellarine and Thompsons landscape zones *(Table 3.1).* The validation of acid sulphate soil risk in the Bellarine Landscape Zone used the results from the mapping of acid sulphate soils in the City of Greater Geelong investigation carried out in 2005 (CSIRO 2005).

The conclusion from the CSIRO study was that although acid sulphate soils are found throughout the City of Greater Geelong, they are mostly confined to public conservation and resource areas, and are unlikely to be disturbed by road or urban development activities and therefore unlikely to pose an actual risk.

An exception to this in the Bellarine Landscape Zone is the tidal flat adjacent to the smelting plant at Point Henry. The site at Point Henry was the only one tested which had any acid sulphate soil potential and this was considered marginal at most (CSIRO 2005).

There was no or little information available to verify the risk of acid sulphate soils in the Thompsons Landscape Zone. Consequently, it had to be assumed that the Thompsons Landscape Zone was similar to Bellarine and that most potential acid sulphate soils are to be found in wetlands that are already designated as conservation areas.

A potential acid sulphate soils mapping study completed by CSIRO in March 2007 identified more potential risk sites across the Corangamite region. However, not enough potential acid sulphate soil sites were identified that could warrant any landscape zone to be placed higher in the top 20 priorities.

Validation of Relative Risk Values for secondary salinity

During the development of the Corangamite Salinity Action Plan, field verification of salinity risk was conducted. Results from this salinity verification study were used to verify the high Relative Risk Values for secondary salinity that had been produced from the GIS analysis in this Soil Health Strategy.

Landscape zones in which verification was carried out included: Lismore, Stony Rises, Woady Yaloak and Murdeduke. This study validated the Relative Risk Values for secondary salinity.

3.6 Investment priorities for the Corangamite Soil Health Strategy

Benefit-cost analysis

The first draft of the Corangamite Soil Health Strategy was developed in 2003. At the time, the Corangamite CMA Sustainable Agriculture and Land Management Implementation Committee felt that a benefit-cost analysis was needed as a central component of the Soil Health Strategy. An economic consultant was briefed to carry out the work.

The 2003 benefit-cost analysis concentrated on private costs and benefits (URS & RMCG 2003).

In 2005, further funding became available and the Soil Health Steering Committee of the day decided to invest in improving the benefit-cost analysis, particularly to assess public costs and benefits. A further investigation was carried out in 2005. This work highlighted the fact that the study was problematical since many pertinent factors could not be quantified (e.g. value of water quality for aquatic ecosystems). For this reason, the 2005 benefit-cost analysis delivered indicators based on only some of the quantifiable costs and quantifiable benefits, but omitted those that defied quantification (URS 2005).

In general, the majority of benefits without a market value were not considered in the analysis. This greatly undervalued the public benefits derived from investment in management actions to improve soil health. For example, investment of one dollar in on-ground works to address gully erosion is calculated to return four cents in reclaimed agricultural production and improved farm access. However, the benefit of improved water quality in waterways and wetlands, the preservation of significant flora or fauna species, the protection of property, utilities, roads, heritage sites, etc., were not included in the analysis.

Table 3.5 outlines the benefit-cost ratios calculated for the five priority threats, the costs of implementing actions, marketable benefits used and non-marketable benefits not used in the analysis.

Soil-threatening process	Benefit-Cost Ratio	Management actions costed in the economic analysis	Benefits considered in the economic analysis	Benefits not considered in the economic analysis
Landslides	7.89	Development of tools and policies through the municipal planning schemes.	Reduction in catastrophic damage to environmental and infrastructure assets, loss of life, damage to infrastructure.	Reduction of sediments into waterways and wetlands. Preservation of biodiversity areas and heritage sites.
Secondary Salinity	4.04	On-ground works including vegetation, fencing & drainage.	Reduction in damage to infrastructure and utilities and agriculture production.	Reduction of salinity in waterways, wetlands and significant biodiversity areas.
Sheet/rill erosion	0.48	On-ground works including earthworks, fencing, and revegetation.	Reclaiming agricultural production and preventing the loss of production land.	Reduction of sediments into waterways and wetlands.
Gully/tunnel erosion	0.04	On-ground works including earthworks, fencing, revegetation and engineering works.	Retaining land from erosion, reclaimed production, better farm access.	Reduction of sediments into waterways and wetlands. Preservation of biodiversity areas, infrastructure, buildings, utilities and heritage sites.
Potential acid sulphate soils	5.88	Mapping occurrences and informing relevant stakeholders.	Avoiding damage to housing, buildings and infrastructure.	Maintaining water quality, fish numbers, aquatic ecosystems and human health.

Table 3.5: Summary of the costs and benefits considered in the economic analysis

High value public assets

The benefits that are realised from various soil health management actions will depend on the effectiveness of specific actions in reducing the threat to specific assets.

For example, on-ground works to reduce or stop active gully erosion in a Proclaimed Water Supply Area will have a greater benefit than on-ground works to reclaim an inactive gully outside the area.

In a similar vein (see the relative risk assessment outlined in Section 3.2 and *Appendix B*), it should be noted that the notional Relative Asset Value does not discriminate between the relative values of the same asset class.

Some high-value assets for priority areas are outlined in *Table 3.6.* The validation process outlined in the previous section considered the higher consequences on those high-value public assets (e.g. Ramsar Wetlands and WSPA). This influenced the risk score established from validation and influenced the ranking of the top 20 priority areas.

Ranked investment priorities

Ranked investment priorities will help guide investment. These priorities have been based on their validated Relative Risk Values, with high-value public assets at risk (e.g. water supply reservoirs, Ramsar wetlands).

If left without treatment, those that appear in the highest 20 priorities all have the potential for significant adverse impacts on public assets.

Table 3.6 outlines the final ranking of the 20 investment priorities in the SHS.

Final Rank	Landscape Zone	Threat	Relative Risk Value	Validation of risk to assets	High-value public assets at risk
1	Gellibrand	Landslides	3167	Very high	WSPA, tourism, Great Ocean Road
2	Lismore	Secondary Salinity	2886	Very high	Ramsar Wetlands
3	Woady Yaloak	Gully/tunnel Erosion	2501	Very high	Ramsar Wetlands
4	Woady Yaloak	Sheet/rill Erosion	2317	Very high	Ramsar Wetlands
5	Stony Rises	Secondary Salinity	1925	Very high	Ramsar Wetlands
6	Otway Coast	Landslides	1872	Very high	Great Ocean Road, Otway coast, tourism, national park
7	Curdies	Landslides	1903	Very high	High value estuary
8	Moorabool	Sheet/rill Erosion	1154	Very high	WSPA
9	Moorabool	Gully/tunnel Erosion	893	Very high	WSPA
10	Woady Yaloak	Secondary Salinity	1646	Moderate to high	Ramsar Wetlands
11	Murdeduke	Secondary Salinity	1090	Moderate to high	Ramsar Wetlands
12	Leigh	Gully/tunnel Erosion	938	Moderate to high	Threatened species
13	Leigh	Sheet/rill Erosion	734	Moderate to high	Threatened species
14	Upper Barwon	Landslides	917	Moderate	WSPA
15	Aire	Landslides	548	Moderate to high	Heritage river
16	Upper Barwon	Sheet/rill Erosion	752	Moderate	WSPA
17	Upper Barwon	Gully/tunnel Erosion	743	Moderate	WSPA
18	Thompsons	Sheet/rill Erosion	1804	Low to moderate	
19	Bellarine	Acid Sulphate Soils	2748	Low to moderate	Ramsar Wetlands
20	Thompsons	Acid Sulphate Soils	598	Low to moderate	

Table 3.6: Final ranked 20 investment priorities, based on risk to assets, benefit-cost analysis and high-value public assets at risk. Note, for each landscape zone high to very high ecologically significant areas are found.

4. Community Engagement

4.1 Significance of threats to assets perceived by various managers in the Corangamite region

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

The Corangamite CMA recognises the importance of working in partnership with asset managers to help address the threats and risks to various categories of publicly and privately-owned assets.

The principal asset managers with whom the Corangamite CMA is most likely to work with in partnerships during the implementation of the SHS, the important public and private assets they manage and perceived threats to those assets are outlined in *Table 4.1.* The perception of importance of threats was assessed by conducting semi-structured interviews and workshops with these asset managers. Results are found in the Community Engagement Background Report (DPI 2007).

Asset manager	Assets the Corangamite community perceives as 'of importance'	Corangamite community perception of the 5 greatest threats to assets (community's subjective perception)
Private landholders	1. agricultural production	1. waterlogging 2. soil structure decline 3. soil nutrient decline 4. soil acidification 5. soil organic carbon decline
Local Government	1. built infrastructure 2. biodiversity 3. water quality	1. landslides 2. gully/tunnel erosion 3. secondary salinity 4. acid sulphate soils 5. sheet/rill erosion
State Government	1. water quality 2. biodiversity 3. cultural heritage sites 4. built infrastructure 5. agricultural (forestry) production	1. landslides 2. gully/tunnel erosion 3. sheet/rill erosion 4. secondary salinity 5. acid sulphate soils
Water authorities	1. water quality (reservoirs) 2. built infrastructure	1. landslides 2. gully/tunnel erosion 3. sheet/rill erosion 4. secondary salinity 5. acid sulphate soils

Table 4.1: Asset managers, assets and threats

4.2 Community engagement processes in the development of the Corangamite Soil Health Strategy

Very early in the development of the Soil Health Strategy, it became apparent that important public and private assets that could be or are currently under threat from various processes, were in the care of a diverse range of private and public sector managers.

It was also clear that in the implementation of the Soil Health Strategy, the Corangamite CMA would need to create and foster partnerships with these asset managers, working together to understand and respond to the threats.

In particular, the common objective of these partnerships was likely to be about addressing a range of risks to assets through specific, targeted and prioritised actions. Consequently, it was considered important that these asset managers were involved with the development of the strategy, creating a base of understanding and the potential responses among a broader base in the community.

A Soil Health Strategy Steering Committee was established, which comprised community and agency members charged with helping to guide the development of the strategy and its components. The committee was responsible for ensuring that the strategy would meet the community needs and that processes used to prioritise actions and potential investments were soundly based and justifiable.

At various times through the development of the strategy, other asset managers likely to be involved with the implementation of the SHS were informed and invited to take part in various activities. Since the development of the strategy has been taking place over several years, many asset managers from the public and private sectors have already been actively involved.

Workshops have been held with the community to gauge perceptions of various threats including ‘greatest risk’ to assets in different parts of the Corangamite region. In some cases, such as the development of Erosion Management Overlays (EMO) for local government planning schemes, work has already been started and some overlays delivered.

4.3 Community engagement to identify technology needs, attitudes and capacity of asset managers to address high risks

The strategy team believed that direct, targeted consultations should be held with asset managers to inform the steering committee of their attitudes, capacity, treatment options and perceived technology gaps/needs in regard to various actions that would be required to protect assets from threats.

Semi-structured interviews were set up and conducted with asset managers. Questions were targeted towards only those soil-related threatening processes identified as high risk in their locality (e.g. local government officer) or on a wider, regional basis (e.g. highway or transmission cable managers).

Asset managers interviewed included farmers, staff from local and state governments, and employees from infrastructure and water authority organisations.

Once the Soil Health Strategy has been endorsed for implementation, more intensive and targeted community engagement will be conducted to ensure community input into detailed action plans.

Processes and results from the targeted community engagement process are illustrated in *Appendix E*.

5. Investing in Soil Health

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

The Australian and Victorian governments have laid out national and state-wide principles as 'cornerstones' of more local programs such as the Corangamite Soil Health Strategy. To these cornerstones, the Corangamite Regional Catchment Strategy has joined its foundation principles, which form the boundaries for the Soil Health Strategy.

Investments in 'soil health' must demonstrate that high-value public assets will be protected and enhanced through targeted programs that address the major threats identified in the SHS that pose an actual or potential risk.

5.1 Investing in priority landscape zones

Targeted actions have been developed to address the 20 highest validated priorities for investment shown in *Table 5.1*.

By focusing investments towards these threats in the identified landscape zones, the Corangamite CMA will help to ensure that high-value assets are protected and enhanced. Further investment opportunities to address lower ranked Relative Risk Values are discussed in Section 5.2.

Table 5.1 summarises the actions to be taken by a range of key asset managers to address the various threats in targeted landscape zones, and has been developed in part from consultation with these managers, technical and industry experts from whom advice has been sought and from the local knowledge and understanding of the steering committee. These actions are either preventative or treatment focused.

1. Objective: Reduce the impact of landslides on assets.

Desired Outcomes:
- No lives lost from landslides
- Reduction in the impact on built infrastructure
- Reduction in sediment loads entering waterways from landslides
- Less damage to built infrastructure from landslides
- Lower impacts on the natural environment from landslides

Actions for landslide risk	Priority landscape zones
1.1: *Investment Partners:* Dairy farmers and industry. *Objective:* Mitigate landslide impacts. **a.** Assisting landholders to revise the layout of farm assets such as dams, tracks, fences, drainage lines and buildings to avoid damage in highly susceptible areas. **b.** Provide technical expertise to landholders/managers in localities where landslides impact or threaten assets. **c.** Provide financial incentives to landholders to increase the adoption rate of appropriate landslide treatments.	Curdies, Otway Coast, Upper Barwon, Aire
1.2: *Investment Partners:* Broadacre graziers. *Objective:* Mitigate landslide impacts. **a.** Provide technical expertise to landholders/managers in localities where landslides impact or threaten assets. **b.** Identify, validate and market a range of cost-effective landslide treatment options to graziers.	Gellibrand, Curdies, Otway Coast, Upper Barwon, Aire

Table 5.1: Actions to address the 20 highest validated priorities for investment by landscape zone (continued next page)

Actions for landslide risk	Priority landscape zones
1.3: *Investment Partners:* Local councils. *Objective:* Prevent the impact of landslides through local planning schemes. **a.** Ensure that the Colac Otway Shire, Corangamite Shire and Surf Coast Shire are using active Erosion Management Overlays and/or other tools and policies. **b.** Ensure adherence of the Forest Code of Practices in plantation establishment and harvesting. **c.** Assist in the investigation and validation of alternative treatment options to protect or repair landslide damage to public assets.	Gellibrand, Curdies, Otway Coast, Upper Barwon, Aire
1.4: *Investment Partners:* VicRoads. *Objective:* To minimise the impact of landslides on VicRoads-managed roads. **a.** Assist VicRoads to investigate landslide prevention and remediation treatment options to protect or repair public assets.	Gellibrand, Curdies, Otway Coast, Upper Barwon, Aire
1.5: *Investment Partners:* State Government, local councils. *Objective:* To minimise the impact of landslides on public land. **a.** Ensure assistance is available to public land managers to identify high-risk landslide locations. **b.** Ensure technical expertise is available to inform public land managers of the available landslide treatment options and selection of the appropriate option.	Gellibrand, Curdies, Otway Coast, Upper Barwon, Aire
1.6: *Investment Partners:* Water authorities. *Objective:* To minimise the impact of landslides on potable water supply areas. **a.** Ensure water authorities are able to identify current and potential landslide risk areas within their private catchments. **b.** Ensure water authorities have access to technical advice that enables the selection and implementation of appropriate landslide amelioration and prevention treatment options.	Gellibrand, Curdies, Otway Coast, Upper Barwon, Aire
2. Objective: Reduce the impacts of sheet and rill erosion. **Desired Outcomes:** - Less sediment entering the waterways from sheet or rill erosion - Increased vegetative ground cover - Increased crop and pasture production per hectare	
Actions for sheet/rill erosion risk	**Priority landscape zones**
2.1: *Investment Partners:* State Government and local councils. *Objective:* To reduce the impact of sheet and rill erosion on public land. **a.** Create awareness of sheet and rill erosion processes, location, impacts and treatment options among public land managers at policy and field management levels. **b.** Confirm public land manager assertions that current treatment options are either ineffective at any price or are not cost-effective. Develop more appropriate treatment options for managing sheet and rill erosion on public land as required. **c.** Ensure public land managers have access to appropriate technical expertise to enable the selection and implementation of appropriate treatment options for sheet and rill erosion. **d.** Create expanded funding opportunities and options that provide greater incentives for public land managers to increase the rate of adoption of sheet and rill erosion treatments. **e.** Develop a tool that enables public land managers to prioritise treatment of active and potential sheet and rill erosion locations.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons

Table 5.1: (Cont.)

Actions for sheet/rill erosion risk	Priority landscape zones
2.2: *Investment Partner:* Private landholders. *Objective:* To manage sheet and rill erosion on private land, grazing and cropping, to protect public assets. **a.** Identify current active sheet and rill erosion areas on private land that impact on public assets and communicate these locations to the relevant private landholders. **b.** Identify and communicate to private landholders the appropriate treatments for locations where active sheet and rill erosion sites have been identified. **c.** Ensure private landholders are informed of incentives and financial support schemes for sheet and rill erosion control.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons
2.3: *Investment partners:* Local councils. *Objective:* To prevent the impact of sheet and rill erosion through planning processes. **a.** Ensure that active sheet and rill Erosion Management Overlays and/or other tools and policies are being used by the councils of: Colac Otway Shire, Ballarat City, Moorabool Shire, Surf Coast Shire and Golden Plains Shire. **b.** Raise awareness and understanding of the importance of sheet and rill erosion with staff from councils, focusing on the management of risk to assets. **c.** Ensure adherence to the Forest Code of Practices in plantation establishment and harvesting. **d.** Ensure the councils have access to and are able to apply appropriate technical advice for assessment and treatment of sheet and rill erosion.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons
2.4: *Investment partners:* VicRoads. *Objective:* To reduce the off-site impact of sheet and rill erosion on VicRoads roads. **a.** Ensure VicRoads is equipped to investigate and evaluate a range of treatment options to prevent or repair the damage to public road assets in its charge and prevent adverse effects on adjoining or affected private and public land assets. **b.** Ensure VicRoads is able to adhere to best management practices in road design, construction and drainage with respect to sheet and rill erosion.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons
2.5: *Investment partners:* Water authorities. *Objective:* To minimise the impact of sheet and rill erosion on potable water supply areas. **a.** Enable water authorities to identify and categorise active and potential sheet and rill erosion locations. **b.** Ensure that Barwon Water and Central Highlands Water have access to and are able to apply appropriate technical advice for sheet and rill erosion treatments.	Moorabool, Upper Barwon

Table 5.1: (Cont.)

3. Objective: Reduce the impacts of gully and tunnel erosion. **Desired Outcomes:** - Less sediment entering waterways from gully and tunnel erosion - Less destruction to roads, houses and other infrastructure caused by erosion undermining foundations - Less damage to cultural and heritage sites - Less agricultural land lost from production	
Actions to address gully-tunnel erosion risk	**Priority landscape zones**
3.1: *Investment partners:* State Government and local councils. *Objective:* Reduce the impact of gully and tunnel erosion on public land. **a.** Create awareness of gully and tunnel erosion processes, location, impacts and treatment options among public land managers at policy and field management levels. **b.** Confirm public land manager assertions that current treatment options are either ineffective at any price or are not cost-effective. Develop more appropriate treatment options for managing gully and tunnel erosion on public land as required. **c.** Ensure public land managers have access to appropriate technical expertise to enable the selection and implementation of appropriate treatment options for gully and tunnel erosion. **d.** Create expanded funding opportunities and options that provide greater incentives for public land managers to increase the rate of adoption of gully and tunnel erosion treatments. **e.** Develop a tool that enables public land managers to prioritise treatment of active and potential gully and tunnel erosion locations.	Woady Yaloak, Moorabool, Leigh, Upper Barwon
3.2: *Investment partners:* Landholders. *Objective:* To manage gully and tunnel erosion on private and public land to protect public assets. **a.** Ensure that landholders/managers are informed of more appropriate cost-effective treatment options for managing gully and tunnel erosion. **b.** Provide technical expertise to landholders/managers in localities where gully and tunnel erosion impact or threaten assets. **c.** Provide financial incentives to landholders to increase the rate of adoption of appropriate landslide treatments.	Woady Yaloak, Moorabool, Leigh, Upper Barwon
3.3: *Investment partners:* Local councils. *Objective:* To prevent the impact of gully and tunnel erosion through planning processes. **a.** Ensure that active gully and tunnel Erosion Management Overlays and/or other tools and policies are being used by the councils of: Colac Otway Shire, Ballarat City, Moorabool Shire and Golden Plains Shire. **b.** Raise awareness and understanding of the importance of gully and tunnel erosion with staff from councils, focusing on the management of risk to assets. **c.** Ensure adherence to the Forest Code of Practices in plantation establishment and harvesting. **d.** Ensure the councils have access to and are able to apply appropriate technical advice, assessment and treatment of gully and tunnel erosion.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons

Table 5.1: (Cont.)

Actions to address gully-tunnel erosion risk	Priority landscape zones
3.4: *Investment partners:* VicRoads. *Objective:* Minimise the impact of gully and tunnel erosion on VicRoads managed roads. **a.** Ensure VicRoads is equipped to investigate and evaluate a range of treatment options for gully and tunnel erosion to prevent or repair the damage to public road assets in its charge and prevent adverse effects on adjoining or affected private and public land assets.	Woady Yaloak, Moorabool, Leigh, Upper Barwon, Thompsons
3.5: *Investment partners:* Water authorities. *Objective:* Minimise the impact of gully and tunnel erosion on potable water supply areas. **a.** Enable water authorities to identify and categorise active and potential gully and tunnel erosion locations. **b.** Ensure that Barwon and Central Highlands Water have access to and are able to apply appropriate technical advice for gully and tunnel erosion treatments.	Moorabool, Upper Barwon
4. Objective: Reduce the impacts of acid sulphate soils. **Desired Outcomes:** - No potential acid sulphate soils disturbed	
Actions to address acid sulphate soil risk	**Priority landscape zones**
4.1: *Investment partners:* Landholders, State government, infrastructure managers. *Objective:* To prevent the disturbance of all acid sulphate soil (ASS) sites by all public and private asset managers. **a.** Create awareness of the location and importance of acid sulphate soils to public and private land managers, through education and a spatial database locating potential ASS sites. **b.** Develop and communicate protocols for managing potential ASS.	Bellarine, Thompsons
4.2: *Investment partners:* Local councils. *Objective:* To prevent the impact of acid sulphate soils through planning processes. **a.** Ensure that potential ASS sites are recognised by all councils in the Corangamite region and tools and policies are implemented to reduce the risk of disturbing these sites. **b.** Raise awareness and understanding of the importance of acid sulphate soils with staff from councils, focusing on the management of risk to assets. **c.** Ensure the councils have access to and are able to apply appropriate technical advice assessment and treatment of ASS sites.	Bellarine, Thompsons
4.3: *Investment partners:* VicRoads. *Objective:* To prevent the disturbance of acid sulphate soils by VicRoads, during road construction. **a.** Ensure that VicRoads has an understanding of the importance of ASS, with staff able to use appropriate tools and databases to locate potential ASS sites and prevent the disturbance of them during road construction.	Bellarine, Thompsons

Table 5.1: (Cont.)

5. Objective: Reduce the impacts of secondary salinity. **Desired Outcomes:** - Less infrastructure corroded by salinity - Less salt in waterways - Less agricultural land lost to discharge sites	
Actions to address secondary salinity risk	**Priority landscape zones**
5.1: *Investment partners:* Landholders, State government. *Objective:* In conjunction with the Salinity Action Plan (SAP), manage secondary salinity on private and public land to reduce impacts on public assets. **a.** Create awareness of secondary salinity processes, location, impacts and treatment options among public land managers at policy and field-management levels. **b.** Provide technical expertise to landholders/managers in localities where secondary salinity impacts on or threatens assets. **c.** Create funding opportunities and options to provide greater incentive for public and private land managers to increase the rate of adoption of treatments for secondary salinity.	Lismore, Stony Rises, Woady Yaloak, Murdeduke
5.2: *Investment partner:* VicRoads. *Objective:* In conjunction with the SAP, minimise the impacts of secondary salinity on roads managed by VicRoads. **a.** Inform VicRoads of the location of secondary salinity in the landscape, for appropriate planning and construction of roads. **b.** Ensure VicRoads' adherence to best management practises in road design, construction and drainage with respect to secondary salinity.	Lismore, Stony Rises, Woady Yaloak, Murdeduke

Table 5.1: (Cont.)

5.2 Other investment opportunities

Relative Risk Values that fell below the highest 20 are not listed in Section 5.1. However, this omission does not imply nor mean that this strategy fails to recognise their significance or importance to the region, the community, individuals or groups.

Their omission simply reflects the fact that on the basis of the Relative Risk Value demonstrated from the analysis methods used in this strategy, these threats to assets fall outside the initial priorities for investment by the Victorian and Australian governments and the various public and private sector partners in those investments.

However, investments to support various actions against these lower-ranked threats will almost certainly fall within the criteria of a range of other investors.

There will most certainly be potential investors in programs that will assist private landowners and managers to change soil-based farm practises to improve agricultural production on private land. Best Management Practice to address threats to soil health in agriculture is outlined in *Appendix F*. These practises have been proven through research and demonstrated practically on farms to have either low impacts on soil health, maintain soil health or in some cases, to contribute positively towards improved soil health.

The Corangamite CMA would provide support to facilitate potential industry-based investors towards improving soil health on private land in the Corangamite region.

6 Aspirations for Soil Health; Resource Condition and Management Action Targets

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

The Corangamite Regional Catchment Strategy, individual sub-strategies and action plans are required to comply with the National Framework for Natural Resource Management Standards and Targets.

The National Framework requires three tiers of targets to be set: *aspirational targets, resource condition targets and management action targets.* These three categories of targets have been set in the Corangamite Soil Health Strategy.

Targets should enable the effectiveness of implementing the SHS to be quantified over a period of time. Monitoring actions are required by the National Framework to enable assessment of progress towards meeting these targets. These monitoring actions have also been set in this Soil Health Strategy.

Importantly, the framework requires that the targets set in regional strategies – such as the Corangamite Soil Health Strategy – should help guide investment towards reducing the impact of soil-related threatening processes on regional assets. The framework also gives direction on which regional targets are required, with guidelines and protocols for target setting, monitoring and reporting.

The framework contains aspirational statements about 'national outcomes' expressed in terms of outcomes for natural resource management. This Soil Health Strategy will make a significant contribution to meeting some of these national outcomes, including:

- the impact of salinity on land and water resources is minimised, avoided or reduced
- the impact of threatening processes on locations and systems, which are critical for the conservation of biodiversity, agricultural production, towns, infrastructure and cultural and social values, are avoided or minimised
- sustainable production systems are developed and management practices are in place, which maintain or rehabilitate biodiversity and ecosystems services, maintain or enhance resource quality, maintain productive capacity and prevent and manage degradation.

The National Framework also outlines a number of 'standard' resource condition and management action targets which regional strategies and sub-strategies must address. From these standard targets, this Soil Health Strategy has developed resource condition targets for '*soil conditions*' and management action targets for '*improved land and water management practices adopted*'.

6.1 Aspirational target

This is a vision for desired conditions of the Corangamite region's natural resources and assets in the longer term (50+ years). It is intended to guide regional planning and set a context for measurable and achievable targets required under the National Framework.

The aspirational target was developed by the Corangamite Sustainable Agriculture and Land Management Implementation Committee (SALMIC) in November 2003 as the community's aspiration for soil health in the region:

'Bring about an improvement in the health and protection of soil resources and regional assets through positive processes and partnerships that allow individuals, communities and organisations to sustainably manage their soils.'

6.2 Resource condition targets

Resource condition targets (RCTs) are specific, time-bound and measurable targets relating to the resource condition over a timeframe of 10 to 20 years. The targets must be pragmatic and achievable. An example may be: *average soil loss of (X) t/ha at a specific catchment health site (Z) by a specific year.*

Resource condition targets *(Table 6.1)* have been developed for the SHS that relate to and are dependent on the management action targets (MATs) described in the next section. However, these RCTs are forecast for revision in coming years of the strategy's implementation.

The key reason for this forecast is that the strategy is not yet informed by a time series of data in regard to the trends of the various threats to assets. A key component of the strategy's R&D plan is the development of such a time series.

Consequently, the RCTs that are listed should be recognised and accepted at the present time for their central characteristics – although specific and time bound, they are more general than particular.

Resource Condition	Target
1: All new urban or infrastructure developments in priority landscape zones will be planned and designed to reduce landslide risks.	2011-2012
2: No net gain in area affected by sheet or rill erosion in priority landscape zones from 2005 erosion levels.	2011-2012
3: No net gain in area affected by gully or tunnel erosion in priority landscape zones from 2005 erosion levels.	2011-2012
4: No potential acid sulphate soils will be disturbed and become acid sulphate soils in the Corangamite region.	2008-2012
5: In conjunction with the Corangamite Salinity Action Plan, no net gain in area affected by secondary salinity in priority landscape zones from 2005 salinity levels.	2010-2012

Table 6.1: Resource condition targets for the Corangamite Soil Health Strategy

6.3 Management action targets

Management action targets (MATs) are short-term targets (one to five years), relating to management actions or capacity building. Ideally, these targets contribute progress towards the resource condition targets. An example may be: *X hectares of waterlogged areas within cropping region Y to be converted to bed farming by year Z*.

MATs for the Soil Heath Strategy are outlined in *Table 6.2* and correspond with the actions detailed in Section 5.1.

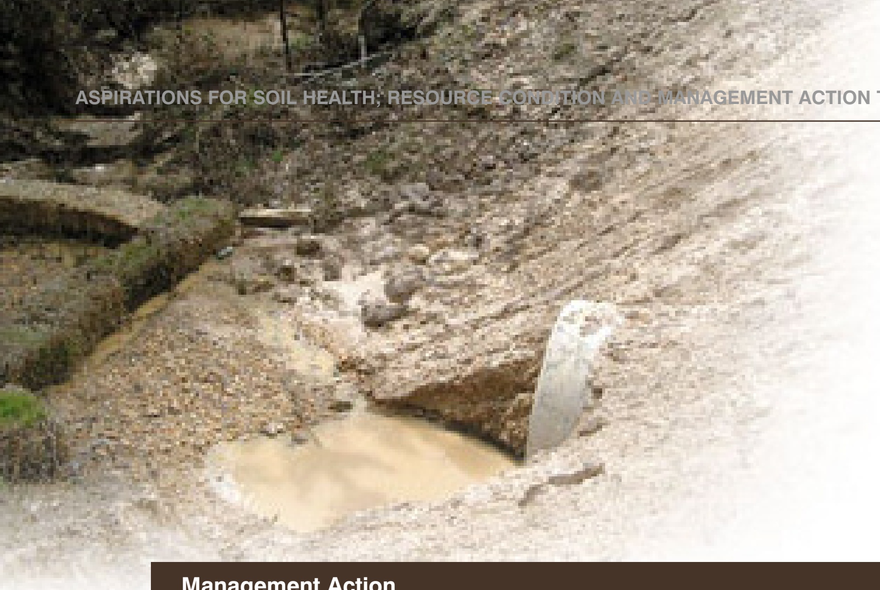
The management action targets listed are believed to be valid and realistic, given the current state of knowledge and understanding of threats and the various risks to assets. However, as for the resource condition targets, these MATs are forecast to change in line with the evolution of the RCTs.

Currently, the foundations of these MATS are:

- validated investment priorities – where there is community capacity to address threatening processes posing risk to its assets
- community engagement and what was learnt
- knowledge and understanding of the Corangamite community's tendencies to adopt various practises and incorporate them into land management activities over a longer term
- where risk to asset(s) is high and therefore there is urgency for the community to adopt appropriate management actions.

Implicit in this approach are several weaknesses in the MATs. The MATs were developed from limited community engagement processes. There is an assumption that many asset managers in priority areas will be willing to partner with the Corangamite CMA in addressing threats posing risk to their assets. Factors such as drought, fire and market values may also adversely impact on the adoption of actions outlined in the SHS.

Refinement of MATs can be made throughout the life of the strategy. Experience gained from the implementation of the strategy and the implementation of research and development actions will make significant contributions to knowledge and understanding of the trends in the threats, providing confidence for resetting RCTs and MATs.



Management Action	Target
1: Engage and communicate with all relevant asset managers on their current knowledge and skills in addressing priority risks to assets. Inform asset managers of the outcomes of relevant research and development projects and work with them to use this information to help reduce risk.	2006-2012
2. Extension and education programs to be delivered to asset managers responsible for assets at risk from landslides, erosion, ASS and secondary salinity in priority landscape zones. The objective is to stimulate demand for services – to create a platform of awareness and understanding of the threats and the options for their amelioration so that asset managers will actively seek assistance through the Corangamite CMA.	2006-2012
3. 20 landslide sites stabilised per year in either the Gellibrand, Curdies, Otway Coast, Upper Barwon and Aire landscape zones (may change subject to trend data still to be completed). The objective is to reduce the risk to the subject sites and flow-on effects to other assets.	2006-2012
4. 40 sheet or rill erosion sites stabilised per year in either the Woady Yaloak, Thompsons, Moorabool, Upper Barwon and Leigh landscape zones (may change subject to trend data still to be completed). The objective is to reduce the risk to the subject sites and flow-on effects to other assets.	2006-2012
5. 25 gully or tunnel erosion sites stabilised per year in either the Woady Yaloak, Moorabool, Upper Barwon and Leigh Landscape Zones (may change subject to trend data still to be completed). The objective is to reduce the risk to the subject sites and flow-on effects to other assets.	2006-2012
6. Co-invest with those municipalities whose boundaries fall within the location of the validated investment priorities in regard to landslides, erosion and ASS. The objective will be to develop and implement appropriate policies and asset management tools, within the framework of local planning schemes, that will enable a reduction in risk of these threats to new urban and infrastructure developments.	2006-2012
7. 90% adherence to the Forest Code of Practices in forestry plantation establishment and harvesting by private and public operators with the objective of reducing the risks of landslides and erosion. The objective is to reduce the risk to the subject sites and flow-on effects to other assets.	2009-2012
8. Trials established that investigate alternative, more cost-effective treatment options for addressing the risk caused by landslides, sheet/rill erosion and gully/tunnel erosion. The objective is to expand the number of treatment options, and thus costs for the asset manager, thereby growing the number of potential adopters.	2007-2010
9. Municipalities, water authorities, VicRoads, Parks Victoria and other key asset managers are made aware of the location of high risks for landslides, erosion, potential ASS and secondary salinity and provided with advice on appropriate actions. The objective is to provide evidence-based stimulation for action to selected asset managers on a site-specific basis. Action taken will reduce the risk to the subject sites and flow-on effects to other assets.	2006-2008
10. Corangamite Soil Health Strategy adapted to changing guiding principles and policies and improved information when applicable. The objective is to keep the strategy in line with current knowledge, enabling RCTs, MATs and investment partnerships to be aligned with the full state of knowledge and understanding of threats to assets.	2006-2012

Table 6.2: Management action targets for the Corangamite Soil Health Strategy

6.4 Monitoring progress and achievements

Ongoing, periodic monitoring of progress towards the achievement of resource condition targets and the adoption of management action targets is essential for assessing the Soil Health Strategy.

The resource condition and management action targets in this strategy provide realistic benchmarks to work towards throughout its implementation.

Monitoring of progressive achievements and the results of the strategy will help develop and build confidence among investors that funds are being spent wisely and are providing positive outcomes in line with the national, state and regional frameworks. Building confidence among investors will help secure ongoing investment.

Monitoring activities have been defined to measure the effectiveness of implementation. These activities are outlined in *Table 6.3.* Monitoring activities will become progressively more specific throughout the implementation of the strategy as targets become more specific.

Monitoring sites will be established in target areas. These monitoring sites will help measure the changes in resource conditions as a result of the adoption of best management practices. For example, monitoring water quality in a selected area of a river will help indicate whether the stabilisation of active erosion sites upstream has reduced the sediment loads in the waterway.

Monitoring Activity	MAT being monitored	RCT being monitored
1. Develop a database and record all training, workshops and field days that aim to promote the adoption of various practises that will reduce the risk to assets *(Appendix G)*.	1, 9	1-5
2. Develop a database that records categories of information, tools and policies that asset managers are using to reduce the risk of landslides, erosion, ASS and secondary salinity.	1, 9	1-5
3. Use the Catchment Activity Management System (CAMS) database to record the distribution and use of incentive payments for the amelioration of high-risk landslide, erosion, ASS and secondary salinity sites.	2	1-5
4. Develop and implement tools that monitor the effectiveness of on-ground treatment works in protecting and enhancing assets from landslides, erosion, ASS and secondary salinity threats.	3, 4, 5, 8	1-5
5. Determine the trends of landslides, erosion, ASS and secondary salinity in target areas. Continue to measure the trends of these threats throughout the implementation of the strategy.	3, 4, 5, 8	1-5
6. Develop a database of the major impacts on high-value assets from landslides, erosion, ASS and secondary salinity.	9	1-5
7. Monitor the changes in guiding principles and policies set by investors, Corangamite CMA, state and Australian governments and adapt them to the SHS if applicable.	10	N/A
8. Monitor the outcomes of soil-based research and make appropriate changes to the SHS with new research findings that are available.	10	N/A

Table 6.3: Monitoring activities to measure progress towards and achievement of resource condition targets (Table 6.1) and management action targets (Table 6.2)

7. Regional Research and Development and Ongoing Monitoring Activities

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

There is limited knowledge about soil health in the Corangamite region. Therefore, research and development (R&D) and ongoing monitoring are essential for the success of the SHS. Many on-ground amelioration actions require R&D and monitoring actions to be completed first before they can be successfully and strategically implemented.

Four main components for R&D and monitoring have been identified as important for the success of the strategy *(Fig. 7.1):*

1. **Determine the trends of threats** – This determines the rate of change of the various threats in the region over time, providing data on the location of increasing or decreasing threats and the implications for assets. Once trends are known and understood, investment can be targeted to those locations where assets are coming under greatest threat.
2. **Identify and understand causal factors** – This identifies causal factors and will establish which of them can be influenced by various kinds of intervention and which of them cannot. A better understanding of causal factors will help define more appropriate options for intervention and treatment.
3. **Understand the consequences for threatened assets** – Understanding the consequences of events for threatened assets enables more informative assessments of risk, evaluation of options for intervention and treatment, and helps to improve prioritisation of investment.
4. **Assess the effectiveness of treatment techniques** – Understanding the effectiveness of treatments to address risk helps identify what treatment types are most cost-effective. The benefit-cost ratio of implementing various actions is highly important to investors. Further, benefit-cost ratios help all parties identify the effectiveness of treatments in protecting or enhancing the asset or the current resource condition.

R&D and ongoing monitoring actions are outlined in *Table 7.1.* They aim to address the four main components of R&D and monitoring for the strategy.

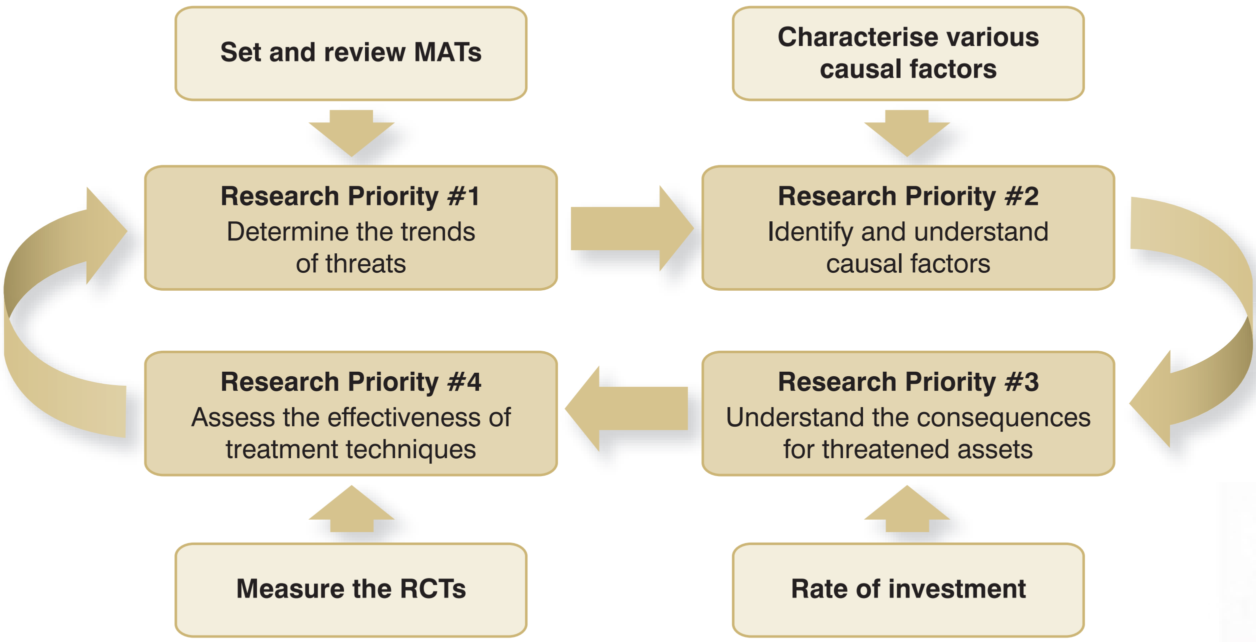


Figure 7.1: Key research components of the Soil Health Strategy

Research and development, and ongoing monitoring actions	Timeline
1. Map the location of landslides, sheet/rill erosion and gully/tunnel erosion sites in the Corangamite region.	2005-2006
2. Develop 1:25 000 susceptibility maps for landslides, sheet/rill erosion and gully/tunnel erosion in the Corangamite region.	2005-2007
3. Investigate and define the trend of landslide, sheet/rill and gully/tunnel incidents from 1950 to 2005 in specified targeted areas and develop RCTs from this data.	2006-2008
4. Investigate, characterise and quantify the impacts caused by all soil health threats on priority assets in the Corangamite region.	2006-2012
5. Map the locations of potential acid sulphate soils in the Corangamite region.	2006-2007
6. Investigate the relationship between climate change and erosion, landslide and acid sulphate soil risk throughout the Corangamite region.	2007-2009
7. Investigate the establishment and deployment of a data repository, as a mechanism to store and display soil-health information needed by the wider community.	2007-2009
8. Improve the susceptibility mapping for all other soil threats and threatening processes, i.e. wind erosion, soil structure decline, soil nutrient decline, soil acidification, organic carbon decline and soil biota decline.	2006-2009
9. Map all contaminated soil sites in the Corangamite region.	2009-2010
10. Improve the information and modelling needed to determine risk to assets for all threats identified in the SHS.	2009-2010
11. Assess novel research of treatment options for threats and soil-threatening processes, identify and characterise options suited for use in the Corangamite region.	2006-2009
12. Develop, adapt or adopt from other CMAs, suitable performance indicators for monitoring the changes to soil health in the region.	2007-2010
13. Develop, adapt or adopt from other CMAs, suitable soil-health assessment tools for use by agricultural and forestry industry groups, enabling them to monitor soil health properties and trends in respect to various management practices.	2009-2012
14. Investigate the impact of land-use change on soil health and the potential consequences caused by soil-threatening processes on high-value public assets.	2010-2012

Table 7.1: Research and development actions for the Corangamite Soil Health Strategy

8 Implementation Structure, Mechanisms and Principles

The SHS aims to guide investment in a range of actions that will enhance natural and built assets in the Corangamite region and protect them from a number of soil-based threats or threatening processes.

8.1 Understanding the implementation structure

The Soil Health Strategy sits within a context of regional, state and national frameworks (Section 1.4). The link between soil health and catchment health provides great potential to develop synergistic relationships between the Soil Health Strategy and programs from other Corangamite CMA strategies concerning the region's water, landscapes, plants and animals.

Within the region, many different aspects of the natural and built environment are linked to each other. A change to one may have impacts on others. For this reason alone, this Soil Health Strategy should not, and in any case cannot, be implemented in isolation.

It is therefore both appropriate and essential for those implementing this strategy to understand and take account of other current catchment programs and to identify those topics and activities where mutually beneficial outcomes may be created through close cooperation and support of one for the other.

Role of the Corangamite Catchment Management Authority

The Corangamite CMA recognises that a diverse range of asset managers and other stakeholders influence soil management practices, and therefore soil health, in the region. These same individuals and entities also provide significant inputs into other aspects of natural resource management.

The Corangamite CMA is an active facilitator of strategic communication and cooperation between the diversity of asset managers and other stakeholders, helping to ensure that potentially complementary projects addressing a range of NRM threats are implemented in collaboration, enabling the achievement of multiple outcomes.

As part of this facilitation and communication, the authority has a central role in ensuring that multi-agency or multi-asset manager-based projects are proposed, developed, implemented and reported to investors in common.

Importantly, the Soil Heath Strategy is just one sub-strategy in the implementation of the Corangamite Regional Catchment Strategy which provides the framework for the Corangamite CMA to address the full breadth of natural resource management issues in the region.

Operational Portfolio Groups have been created by the authority to provide input into and support the implementation of each of the sub-strategies.

The Soils and Salinity Operational Portfolio Group will be responsible for providing advice on investments in soil health projects, using the Soil Heath Strategy as a key guide.

The Regional Implementation Committee (RIC) makes investment decisions based on received advice and recommendations from various Operational Portfolio Groups, and provides these decisions and recommendations to the Corangamite CMA Board. The board approves appropriate investment proposals from the RIC and nominates these to the investors for final approval *(Fig. 8.1).*

Funding mechanisms for implementation

Action plans will be developed for one to three-year periods and will reflect the priority actions for investment as outlined in Section 5.1. Action plans will be written specifically, detailing the 'who, how, when and where' of implementation, describing:

- How do the projects proposed in the action plan fit under the priorities of the Soil Health Strategy?
- What assets are being protected or enhanced by addressing which types of threats?
- Where within the priority landscape zones will treatments be carried out?
- What types of treatments will be used?
- Who are the asset managers and collaborators that will be involved and in what capacity will they be involved with implementation?
- What community engagement processes were conducted with the relevant asset managers while developing the action plan?
- What are the co-investment arrangements between asset managers and investment partners/collaborators for each of the projects outlined in the action plan?
- How will the projects within the action plan integrate with existing projects or other proposed projects?
- What are the targets of the projects outlined in the action plans and how do they contribute to meeting the MATs and RCTs outlined in the Soil Health Strategy?
- How will the outcomes of each of the projects outlined in the action plan be monitored and reported back to the investors?

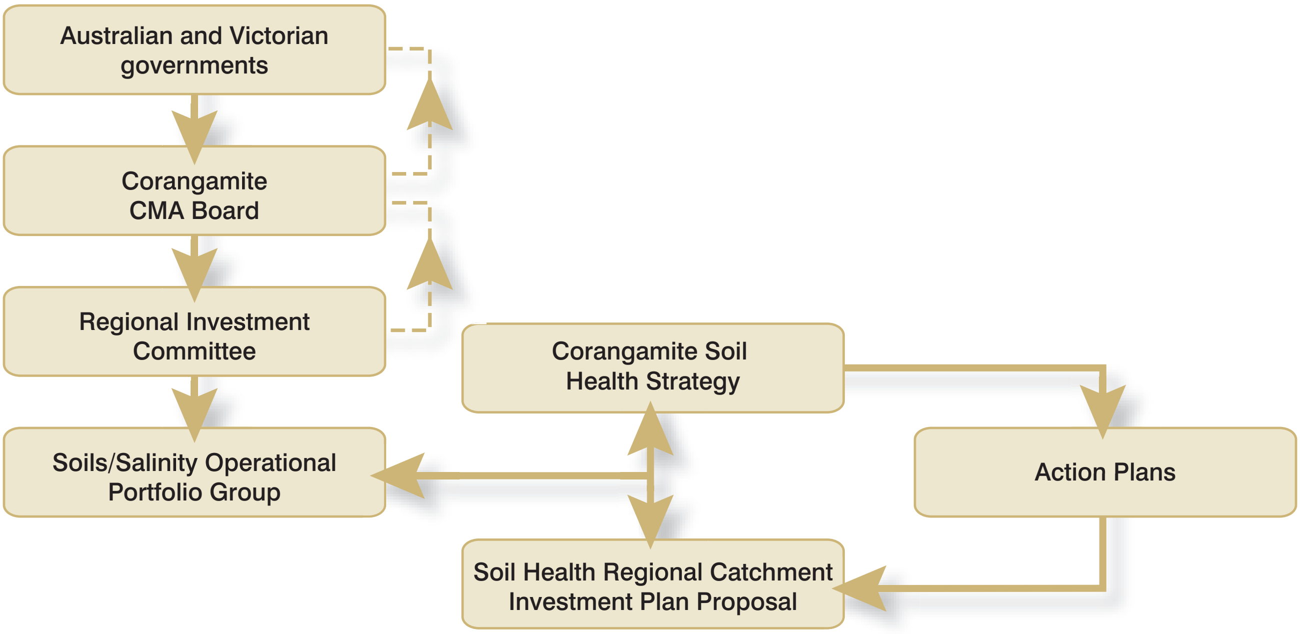


Figure 8.1: The flow diagram shows the framework for investment for the Soil Health Strategy through the Corangamite Catchment Management Authority investment process. Dashed lines indicate reporting back to investors.

The SHS will be implemented predominantly by the Corangamite CMA and will guide investment according to the criteria set by the Regional Catchment Investment Plan and Victorian and Australian government agencies as 'investors'.

The over-arching goal of these investors is mostly to protect and enhance high-value public assets. This is reflected in the selection of specific target areas found within the priority areas as outlined in Section 3.6. Target areas may be specific to the sites or areas where threats pose high risk to assets. There may be a number of target areas in a priority area. 'Target area' describes the specific location of investment within the priority area. For example, investment may be targeted to address gully erosion in the Rokewood area, with gully and tunnel erosion identified as a priority area for the Woady Yaloak Landscape Zone. Target areas have not been defined in this strategy, but will be detailed in action plans. The current investors likely to invest into priorities outlined in the SHS through the Corangamite CMA investment process are outlined in *Table 8.1.*

The SHS identifies 12 separate soil-based threats. As a result, a number of these threats have not been identified as priorities in this document. This does not mean that they are unimportant, because they all impact on important assets throughout the region. The SHS aims to improve the understanding of these soil-related threatening processes and with additional information there may be justification for the Corangamite CMA to invest in addressing them sometime in the future.

There are investors currently operating outside the Corangamite CMA investment process who may be interested in investing in actions to reduce the impact of threatening processes identified in this strategy *(Table 8.2).* For example, investors may wish to help address soil acidification as it is significantly impacting on high-value agricultural land and productivity. The Corangamite CMA will help investigate and coordinate potential investment opportunities to address these other important soil-related threatening processes and engage with the relevant asset managers.

The Corangamite CMA encourages asset managers to use the SHS for guidance and support for any soil-based funding applications. The Corangamite CMA is receptive to co-investing in projects that have some private benefits, but these will be assessed case by case.

Investor	Investor's Criteria	Examples of potential soil health projects
National Action Plan (NAP)	Benefits water quality and manages secondary salinity.	Develop an Erosion Management Overlay with Golden Plains Shire Council for the local planning scheme to help reduce the risk of water erosion threatening water quality.
Natural Heritage Trust (NHT)	Benefits to coast, river and native vegetation assets.	Work with the community to revegetate and stabilise bare soil with native vegetation to control active wind erosion in the Bellarine Landscape Zone.
National Landcare Program (NLP)	Improve profitability, competitiveness and sustainability for primary industries.	Work with the Heytesbury Landcare Network to monitor soil health and to develop more sustainable management practises that help improve various aspects of soil health and sustain long-term agricultural productivity.
EnviroFund	Small community projects with environmental outcomes.	Work with the Leigh Landcare Group to implement on-ground works to control soil erosion that is threatening the habitat of significant AROT species.

Table 8.1: Current investment opportunities for the Soil Health Strategy through the Corangamite CMA (2006/08)

Investor	Investor's Criteria	Examples of potential soil health projects
Victorian Department of Sustainability & Environment	Address threats impacting on environmental and natural resources (public assets).	To develop a project that involves controlling soil erosion and other threats impacting on Lake Corangamite (public asset) to achieve multiple outcomes.
Victorian Department of Primary Industries	Improve primary production and sustainability.	To assist broadacre grain growers to apply appropriate amounts of agricultural lime to acidic soils to combat the loss of productivity through soil acidification.
Water authorities	Protect and enhance their water reservoirs and associated infrastructure.	Through the Corangamite CMA, provide funding to private landholders, helping them stabilise active erosion sites upstream, which add sediments to water reservoirs.
Local municipalities	Protect and enhance public assets and the local community.	Develop and implement an Erosion Management Overlay to reduce the risk of landslides and erosion through local planning schemes.
Private landholders	Protect and enhance private and public assets.	Co-investing in on-ground works to stabilise active erosion sites located on private property which contribute sediments to the Barwon River.
Land and Water Australia	Encourage sustainable agricultural practices.	Develop soil health indicators across SW Victoria to monitor and assess the condition of soil health.
Industry investment groups	Improve sustainable productivity in the grains and livestock industries.	Work with the Southern Farming Systems members in SW Victoria to develop trials that investigate the effects of various cultivation methods on structure decline, helping to ensure long-term soil health and agricultural productivity.
WestVic Dairy	Benefits to the dairy industry's profitability and sustainability.	Work with dairy farmers in the Heytesbury district to develop trials to investigate practises that help reduce the impact of waterlogging on productivity.
National Disaster Mitigation Plan	Addresses natural disaster relief or risk management.	Map the high-risk landslide areas, which may be triggered by storm events, throughout the Corangamite region.
Universities and educational institutions	Building the capacity of communities to undertake soil health programs through education, training, investigation, research and development.	Develop and deliver soil health education programs, undertake or participate in soil investigation and research projects, develop soil health monitoring tools and programs, undertake soil health monitoring programs and maintain soil knowledge databases.
Research institutions such as CSIRO	Discovery of regional soil information through investigation, research and development programs.	Undertake or participate in soil investigation and research projects and disseminate the knowledge to rural communities.

Table 8.2: Other investors who support soil health activities across south-west Victoria

8.2 Predicted costs for implementing the Corangamite Soil Health Strategy

The Soil Health Program has been delivered throughout the Corangamite region since 2000. During this time, the Victorian and Australian governments have supported this program financially through the Corangamite CMA. *Table 8.3* outlines the investments implemented through the Soil Health Program from 2003 until present.

Over the past few years, research and development projects have helped further understanding of the risks associated with the deterioration of soil health in the Corangamite region. This information indicates that far greater investment is needed to address soil-threatening processes and to maintain soil health. The predicted costs for implementing the SHS from 2007 to 2012, which meets existing targets, are outlined in *Table 8.4* and illustrated in *Figure 8.2.* These costs will change as information comes to hand on trends, risk to assets and treatment technologies.

Action Type	2003/04	2004/05	2005/06	2006/07
1. Strategy development	$0	$50,000	$50,000	$60,000
2. Communication of information to asset managers	$35,000	$60,000	$60,000	$55,000
3. Education and extension activities	$70,000	$80,000	$80,000	$70,000
4. Developing planning tools to prevent risk through municipal planning schemes	$0	$80,000	$80,000	$30,000
5. On-ground incentives for remedial works	$0	$0	$0	$80,000
6. Research and development	$0	$60,000	$60,000	$90,000
7. Monitor the adoption of best management practises and its impact in changing resource conditions	$0	$0	$0	$15,000
Total	**$105,000**	**$330,000**	**$330,000**	**$400,000**

Table 8.3: Investment provided by the Australian and Victorian governments through the Corangamite CMA for all soil health-based activities 2003 to 2007

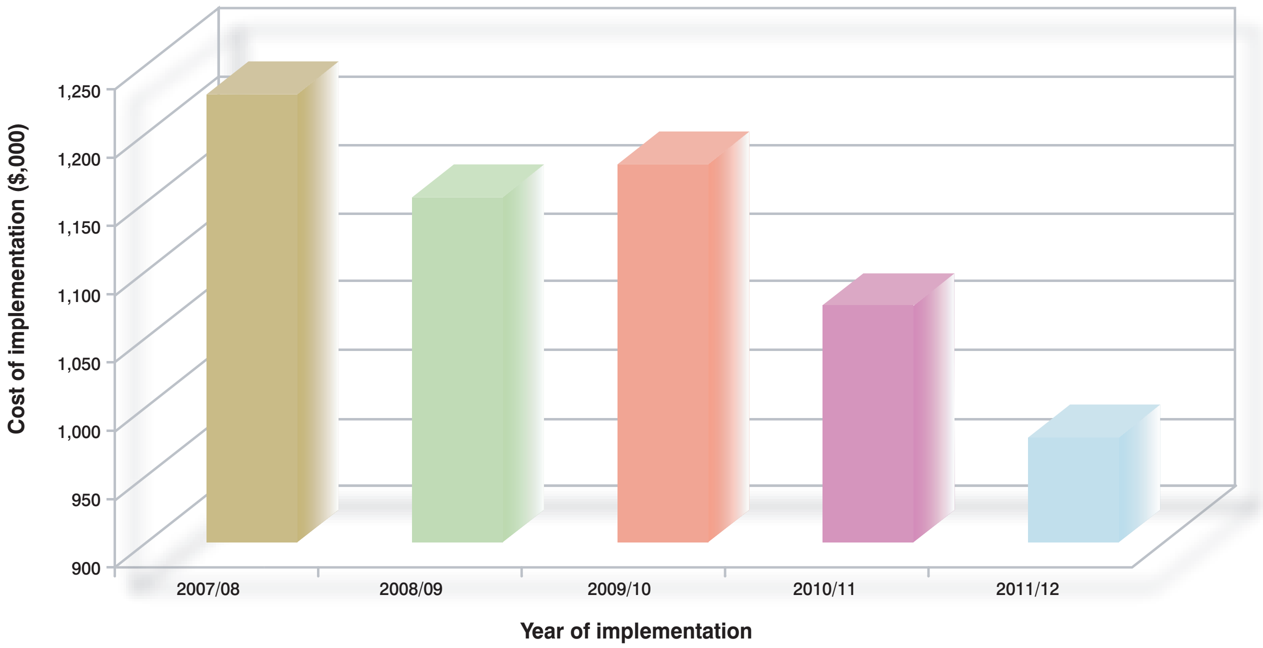


Figure 8.2: Predicted annual costs of implementing the Corangamite Soil Health Strategy from 2007 to 2012

Action Type	Funding required per year
Communication program – Indirect contact with public and private sector asset managers via e.g. direct mail, using the summary document, print media, electronic media (interviews etc) seeking managers to contact CCMA for information or assistance. A communication program is needed to: • improve awareness and information about the core of the Soil Health Strategy, especially about the impacts and need for action by all asset managers in the region • create interest and provide information about how to take action and incentives/support that may be available • provide references/testimonials in regard to practical experience of others taking action • secure on-ground works and promote in media and via field days, workshops, conference papers etc • inform asset managers of relevant research and development findings.	Year 1 (2007/08) $180,000 Year 2 (2008/09) $150,000 Year 3 (2009/10) $140,000 Year 4 (2010/11) $110,000 Year 5 (2011/12) $110,000
Extension/education with private and public sector. This would involve: • direct unsolicited contact with asset managers at known 'hot spots' • supporting the communication program by providing a 'face' or point of contact to would-be participants in the actions • direct face-to-face contact with public and private sector asset managers to demonstrate the situation and highlight alternative actions, funding and implementation • delivery of targeted training courses, field days and presentations.	Year 1 (2007/08) $250,000 Year 2 (2008/09) $250,000 Year 3 (2009/10) $250,000 Year 4 (2010/11) $250,000 Year 5 (2011/12) $250,000
Planning tools to prevent risk (municipalities) – especially EMOs, landslide overlays etc. A pilot program has resulted in the production of Erosion Management Overlays for the City of Greater Geelong and Colac Otway Shire. These overlays address landslide risk through the municipal planning schemes. A priority task is to assist these shires to use the Erosion Management Overlay provided (or equivalent) by securing an amendment to their planning scheme that adequately addresses the risk of landslides and erosion. It is also a priority to engage with all other municipalities within the Corangamite region and assist them to address landslide and erosion risk through their planning schemes by using the Erosion Management Overlay or other tools and policies.	Year 1 (2007/08) $100,000 Year 2 (2008/09) $50,000 Year 3 (2009/10) $50,000 Year 4 (2010/11) $40,000 Year 5 (2011/12) $40,000
On-ground incentives for remedial works – Investment in on-ground activities will help asset managers pay for materials, contractors and technical expertise to reduce the impact of threats that are located on private or public land, but which impact on high-value public assets. Costs include marketing of incentives, delivery of incentive payments, risk assessment, work design and supervision, materials, contractors and monitoring. Erosion and landslide works could range from $2,000 to $50,000 per site depending on magnitude and risk.	Year 1 (2007/08) $420,000 Year 2 (2008/09) $500,000 Year 3 (2009/10) $530,000 Year 4 (2010/11) $560,000 Year 5 (2011/12) $500,000
Research and development – This involves implementing research projects that improve understanding of the nature of the threats and their impact on assets. This knowledge will help to improve targeting of high-risk areas. It also includes project management of research projects (0.5 person), technical experts, data collection, analysis and report write up.	Year 1 (2007/08) $200,000 Year 2 (2008/09) $160,000 Year 3 (2009/10) $160,000 Year 4 (2010/11) $80,000 Year 5 (2011/12) $50,000
Monitoring of adoption and resource conditions – Ongoing monitoring is required to assess 1) the impact of high-risk degradation sites on public assets 2) the adoption of best management practises 3) the changes in resource conditions. Costs include monitoring equipment, data collection and analysis, conducting interviews and report writing.	Year 1 (2007/08) $60,000 Year 2 (2008/09) $20,000 Year 3 (2009/10) $20,000 Year 4 (2010/11) $20,000 Year 5 (2011/12) $60,000
Total	**$5,560,000**

Table 8.4: Estimated strategy implementation costs characterised by resource condition targets and management action targets

8.3 Principles of implementation

The principles for implementing this Soil Health Strategy are consistent with those of other sub-strategies within the Corangamite region, especially those of the overlapping Salinity Action Plan. This ensures that implementation across the two sub-strategies follows the same principles and is as complementary and consistent as possible.

Overseeing the implementation of both sub-strategies are the strategy project managers with assistance from the Soils and Salinity Operational Portfolio Group of the Corangamite CMA.

The Terms of Reference for the Operational Portfolio Groups (OPG) states:

"The broad function of the OPG is to provide additional strategic direction for, and monitoring of, the implementation of the particular Corangamite CMA portfolio area, in line with the RCS and associated sub-strategy(s). The OPG will undertake the role in light of the existing Corangamite CMA management structures, investors' policies and associated priorities for investment."

Integrated delivery

It is important that soil health projects which are implemented on-ground, integrate with other relevant land and water on-ground projects being carried out in the same locality or region. Soil health and its related threatening processes link strongly with many other natural resource management issues. For example, the degradation of soil health can lead to water or wind erosion, which may destroy significant biodiversity areas, and add sediments to watercourses, cause secondary soil salinity and nutrient leaching or deposition to waterways and wetlands. For integration between natural resource management projects to be effective, there must be synergy between different sub-strategies under the RCS.

Customised delivery to each location

There is a temptation to standardise delivery of soils projects across all targeted landscape zones in the Corangamite region. However, community engagement conducted through the Soil Health Strategy development phase, and other sub-strategy development, has identified that asset managers have diverse attitudes to and capabilities for the implementation of treatments.

The individual or group capability and attitudes of asset managers should be considered when developing appropriate action plans.

Use existing delivery mechanisms where appropriate

Before establishing new mechanisms or channels to the community, the Soil Health Strategy should consider the use of existing community groups, programs or mechanisms as opportunities for the delivery of soil health projects. In some instances, new partnerships will be required.

Community engagement and partnerships

Community engagement and partnerships are vital for the successful implementation of the Soil Health Strategy. Community engagement has been a feature of the development of the strategy and will be continued in the development of detailed action plans.

Community partnerships are mechanisms for coordinated and effective engagement of key stakeholders. Partnerships provide mutual benefits and opportunities to greatly enhance the effectiveness of individual actions.

The relevant Victorian Government departments, such as DPI, DSE and EPA, have vital roles in the implementation of this Soil Health Strategy.

Likewise, municipalities and built infrastructure/utility asset managers will be able to make a large contribution to the effectiveness and success of many of the strategy's actions. Relationships established between the steering committee and during the development of this strategy should be consolidated and supported during its implementation.

Ultimately, it is the active, supportive and co-operative participation of public and private landholders in the Corangamite region that will determine the success of the implementation of this strategy. It is they who will have the final 'say' in regard to on-ground works and thus achievement of the desired improvements in soil health.

Especially important are the private landholders – broadacre farmers and graziers in particular – since they control the largest proportion of land in the region. Strong partnerships must be developed and nurtured with these landholders as individuals or within groups such as Landcare and/or agricultural industry networks.

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Appendix A: Threats to be addressed by the strategy

A.1 Landslides

Processes

A landslide is the movement of soil or rock down a slope. Landslides occur episodically, driven by gravitational forces. Understanding the timeframes for the geomorphic development of a landscape provides a maximum range for the likelihood of a landslide event (Dahlhaus & Miner 2002). However, the individual site conditions and local triggering factors need to be considered to refine the estimate of occurrence. For any given site, the evidence of current or past slope movement, slope angles, slope aspect, geological structures, vegetation, drainage and experience of the assessor will all influence the final estimate of likelihood of a landslide occurring within a particular timeframe.

The steepness of the slope is a causal factor in landslides, since gravitational force acts on all slope materials. In the Corangamite region, previous studies (e.g. Cooney 1980, 1982; Wood 1981; Buenen 1995) have related landslide activity to angle of slope based on field observation. However, when these relationships were tested by GIS analysis, the correlation between landslide occurrence and slope angle could not be seen, even in the areas with significant quantities of data. Similarly, no relationship to slope aspect could be established, indicating that other site-specific factors must equally contribute to failures (Dahlhaus & Miner 2000).

Extreme rainfall is the dominant trigger for landslides in south-west Victoria. The previous work by Cooney (1980) provides the most convincing data, using the 1952 Lake Elizabeth landslide and the 1952 Wild Dog Creek landslide as examples. Landslide studies from elsewhere in Australia and the world (e.g. Cruden & Fell 1997) confirm high-intensity and/or prolonged rainfall as the most common landslide triggering factor (Dahlhaus 2003).

Anthropogenic factors must also be considered when assessing the likelihood of landslides. As more urban and infrastructure development proceeds in the region the chance of a catastrophic failure is substantially increased since more weight is added to a slope (buildings, roads, cars), more intensive infiltration occurs (septic tank effluent, gardens, roof and road run-off) and changes are made to slope morphology (roads, embankments, cuts). The combined effect may act to destabilise the slopes, putting property and lives at risk (Dahlhaus 2003). *Figure A1* shows an example of damage caused to a road by a landslide in the Corangamite region.

Figure A1: A landslide that has destroyed a road in the Corangamite region Photograph: A. Miner 2006

In many cases, agricultural practices or environmental works being undertaken may increase landslide risk. If inappropriately considered, investments in environmental works may become liabilities if they result in landslide damage to property or life.

Condition

The landscapes of the Corangamite region are among the most landslide-prone in Australia. Over 2252 (1924 certain) landslides have been mapped in various studies within the Corangamite region *(Fig. A2)*.

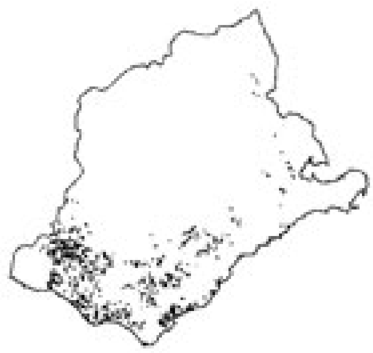


Figure A2: The location of landslides in the Corangamite region

Landslides vary in surface area from a few square metres to more than 120 ha, and in volume from a few cubic metres to over 10 million cubic metres. They are triggered by prolonged and/or high intensity rainfall, man-made changes to the landscape and rare earthquake events. The vast majority of landslides occur in two rock types, the Otway Group rocks and the Gellibrand Marl (Dahlhaus 2003).

Within the Corangamite region over the past 50 years, landslides have caused deaths and destroyed urban and rural infrastructure. The Lake Elizabeth landslide (1952) blocked the east branch of the Barwon River for a year and cost $10 million to repair the damage (URS 2005). Other examples include the Windy Point landslide (1970) which closed the Great Ocean Road for 10 months; the Wongarra landslide (1953) and Princetown landslide (1980) (both of which destroyed dairy farms); and the current Clifton Springs landslide (2001). The cost of these and other landslides has amounted to tens of millions of dollars (Dahlhaus 2003).

Management

Landslide risk management in the Corangamite region has been of growing importance, particularly since the further development of landslide prone areas has coincided with a greater tendency to seek remedy through litigation in our society. These actions have provided the impetus for a review of risk-management practice by local government and professional societies.

Effective management of landslide risk usually requires a site-specific engineering plan designed to reduce or minimise the risk to assets. The management options may include: slope stabilisation works (such as installation of anchors and/or drainage; reducing the load on a slope) reducing the angle of slope, construction of engineered retaining structures, removal of trees or planting trees or other vegetation. Alternatively, the design of the asset may be modified to reduce the consequences of impact by landslides (Dahlhaus 2003).

A.2 Water erosion (sheet/rill and gully/tunnel erosion)

Processes

The processes of soil erosion by water are well understood from research, particularly that by the soil conservation authorities in Australia and the USA. Detailed descriptions and information on erosion are found in many texts including McTainsh & Broughton, 1993 and Young & Young, 2001.

Rainfall erosivity is the potential of rain to erode soil, measured as the power exerted on the soil by the falling rain (Young & Young 2001). Erosivity varies according to rainfall intensity, with intensities of <25 mm/hr considered non-erosive (White 1997).

Sheet erosion may develop where relatively smooth landscapes encourage overland water flow. However, water moving across almost all landscapes separates into individual turbulent flows that produce small meandering channels. As the channels cut down the soil profile they form rills, which are defined as channels less than 300 mm deep (Charman & Murphy 2000). Ultimately, the rills deepen and coalesce to form gullies, which aggregate the flow, increasing its erosive power.

Tunnels may be formed when run-off flows through a crack, root hole or animal burrow into the subsoil. In most soils, the subsoil has a lower permeability than the topsoil, resulting in the water moving across the top of the subsoil as through-flow *(Fig. A3).* Where the subsoil is prone to slaking and/or dispersion, fine particles are carried in suspension, resulting in piping, tunnelling and seepage erosion (Young & Young 2001). Ultimately, the tunnels may collapse to form gully channels.

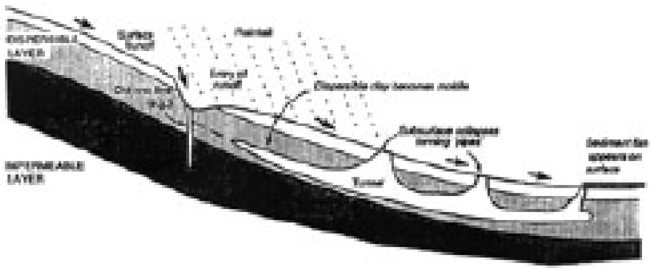


Figure A3: Processes associated with tunnel erosion development

Gullies erode headwards as the concentrated flow of water scours both the channel walls and bed. Eroded sediment is often deposited locally at the mouth of the gully as an alluvial fan. The deepening channel and retreating walls may intercept other sub-surface tunnels and/or the groundwater table, creating additional erosion by sloughing saturated soil into the channel. *Figure A4* illustrates an example of active gully erosion and sedimentation from the erosion site entering a waterway.

Figure A4: The start of an active gully erosion site, which washed sediments into a tributary of the Leigh River

Condition

Sheet/rill and gully/tunnel erosion has recently been mapped for the Corangamite region *(Fig. A5 & A6).* From this study, 1311 (933 certain) sheet/rill sites and 696 (626 certain) gully/tunnel sites have been identified (Feltham 2005). Many of these sites are located near priority waterways and other high-value assets which could be adversely impacted.

Although widespread, sheet/rill erosion is not as visually obvious as other forms of erosion. The most noticeable sheet erosion occurs on slopes where intensive horticulture or cropping is the dominant land use, such as north of Ballarat, where steep slopes are present. Where the slopes are sufficient and the soil properties allow, sheet erosion has developed into rills, which may further develop into gully erosion. Examples include the area near Birregurra, locally known as "the washaways", and in the Murroon district (Dahlhaus 2003).

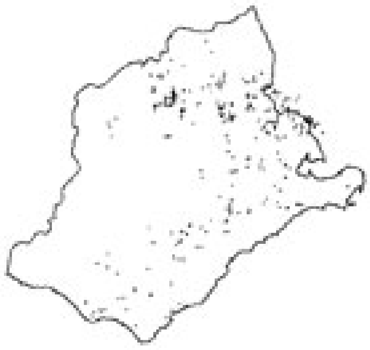


Figure A5: The location of sheet and rill erosion sites in the Corangamite region

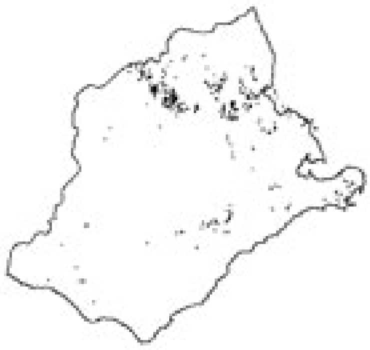


Figure A6: The location of gully and tunnel erosion sites in the Corangamite region

In the Corangamite region, sheet and rill erosion threaten agricultural productivity through the removal of fertile topsoil. Once removed, this topsoil may be deposited in waterways, threatening water quality through sedimentation and nutrient inputs.

Tunnel erosion is particularly prevalent in the weathered Otway Group rocks of lower Cretaceous age (i.e. the Eumeralla Formation). The erosion impacts on agricultural land, water quality and infrastructure associated with residential development. In particular, the residential infrastructure of the townships of Kennett River and Separation Creek has been affected, with tunnel erosion undermining houses and roads. Agricultural land is also affected, with substantial tunnel erosion developing along drainage lines in the steeper, cleared landscapes of Wild Dog Creek valley, Barham River valley, Smythe Creek valley and Wongarra.

Gully erosion is the ultimate result of both tunnel and rill erosion. Gullies are the most visually obvious representation of erosion in the landscape and have been the most common target for rehabilitation in the past. Spectacular examples of gully erosion are found near Elaine and Clifton Springs. Other areas where gully erosion is known to be prevalent include Dereel, Rokewood, Linton, Lismore and Irrewillipe. In many areas, gully erosion is a legacy of past land use, particularly gold mining along creeks and as a result of intense rainfall events after drought. Considerable efforts have been made over the past 60 years to rehabilitate many of these areas, with reasonable success (Dahlhaus 2003).

Management

Maintaining ground cover at 70% throughout the year is the best way to reduce the likelihood of soil erosion. The establishment of perennial pastures and establishing off-stream watering points for livestock also reduces erosion risk. Diverting run-off away from erosion sites, either by using banks or drains, is often used to reduce the impact of water movement in dislodging and transporting soil particles.

Minimal soil disturbance is important in reducing the risk of soil erosion. This includes direct drilling methods to establish crops and pastures. Appropriate cultivation patterns are important on sloping paddocks. Some potato-growing areas encourage winter wheat crops to maintain a ground cover over paddocks to help in reducing rill and sheet erosion during high rainfall months.

Some gully and tunnel erosion sites have been rehabilitated within the Corangamite region. Works conducted have included: the construction of diversion banks and rock chutes, battering of banks and stabilising sites with vegetation. Rabbit control prior to works is essential. Results from erosion remediation in the Corangamite region have been good, if ongoing maintenance has been carried out.

Whole farm planning courses have been conducted for private landholders throughout the Corangamite region over the past 16 years. These courses encouraged landholders to fence paddocks according to land capability. This process decreases the threat of erosion and improves long-term agricultural productivity. Currently, less than 5% of the Corangamite region is fenced according to land classes.

A.3 Acid sulphate soils

Processes

Acid sulphate soils occur naturally in the Corangamite region. These soils have sediments containing iron sulphides below the soil surface. When these naturally occurring sulphides are disturbed and exposed to air, oxidation occurs and sulphuric acid is produced. For every tonne of material that completely oxidises, 1.6 tonnes of pure sulphuric acid can drain into waterways and cause severe short and long-term socio-economic and environmental impacts, such as causing 'fish kills', impacting on aquatic ecosystems, dissolving concrete and therefore impacting on infrastructure (Rampant *et al.* 2003).

The most common activities that disturb acid sulphate soils are:

- agricultural activities that involve land drainage, works to prevent flood and tidal inundation (levees, drains and floodgates) and the use of groundwater. Industry sectors especially implicated are dairying, grazing, cropping and aquaculture
- infrastructure works, especially flood management (levees, floodgates) drainage works, maintenance dredging, laying of utilities (water, sewage, communications) and roads and railways
- urban and tourism development, housing, resorts and marinas
- extractive industries, with sand and gravel extraction from rivers or the floodplain (Rampant *et al.* 2003).

Left undisturbed, potential acid sulphate soils (PASS) cause few or no problems. Urban and regional development is often the main cause of disturbance of potential acid sulphate soils *(Fig. A7).*

Acid sulphate soils are also associated with the mining and processing of brown coal, such as at Anglesea, Lal Lal and Wensleydale. The oxidation of sulphides in the waste dumps associated with these mines results in acid drainage, with the potential for significant impacts on waterways.

Figure A7: Drainage channels contaminated by high levels of acidity leached from disturbed acid sulphate soils

Condition

Potential acid sulphate soils are not found in large areas of the Corangamite region. A study conducted by CSIRO (2005) indicated that there are approximately 54 km^2 of inland and 59 km^2 of coastal potential acid sulphate soils scattered throughout the Corangamite region *(Fig. A8).*

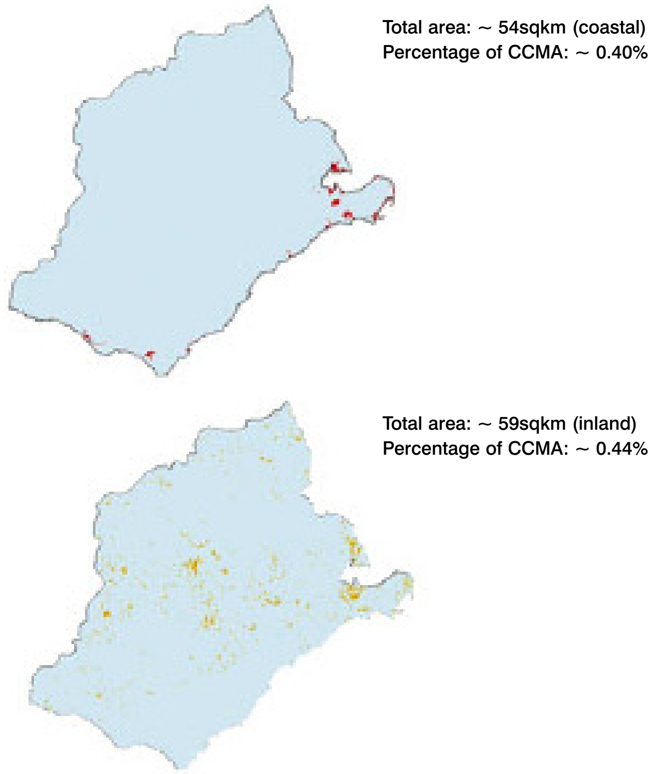


Figure A8: Predicted locations of potential acid sulphate soils in the Corangamite region

Management

The best option for successful management of potential acid sulphate soils is to leave them undisturbed. However, this requires knowledge of their location, followed by protective action to ensure that they are not disturbed. The Corangamite CMA in conjunction with local municipalities, infrastructure and utility managers and EPA Victoria should undertake the management of potential acid sulphate soils.

To improve the base of data, mapping is required to delineate areas of potential acid sulphate soil hazard, particularly in areas more likely to be developed. Once mapped, risk assessment procedures are required to assess the potential for the development of acid drainage and the consequences for regional assets. The risk assessment procedures may ultimately result in changes to municipal planning schemes. Liaison with EPA Victoria is required to manage the potential effects of the off-site impacts of acid mine drainage.

A.4 Secondary salinity

Processes

Secondary salinity in the Corangamite region has been subjected to extensive research over the past 30 years, and has been recently reviewed in the development of the Corangamite Salinity Action Plan (SAP). Primary salinity has been present in the landscape for more than 20,000 years and forms many of the region's environmental assets. However, since the widespread land use changes associated with European settlement, secondary salinity has developed in dryland agricultural areas. The salinity processes are associated with changes to the groundwater and/or soil hydrology (Dahlhaus & MacEwan 1997), which has resulted in an increase in the number and extent of saline water discharge sites in the landscape. The most obvious expression of soil salinity is where salts have accumulated by evaporitic concentration in discharge areas.

Secondary salinity also occurs in areas unrelated to groundwater discharge where salts have accumulated in the soil profile over geological time. In the older landscapes of the region, cyclic salts (present in rainfall) have been accumulating in subsoils through evapotranspiration associated with deeper rooted vegetation *(Fig. A9).* Erosion, soil disturbance and hydrological processes have subsequently brought the salts closer to the surface. This is particularly prevalent where the deeply weathered regolith profiles of the Western Uplands have been exposed relatively recently by erosion or mining disturbance. Changes in the colour of vegetation, pioneering salt tolerant species and bare soil are all indicators of secondary salinity discharge sites.

Figure A9: A secondary salinity discharge site found in the Corangamite region clearly shows bare areas and salt-tolerant species

Condition

Secondary salinity risk, current condition and trends and scenarios in soil and water salinity in the Corangamite region have been described in the background documents to the Corangamite SAP (Heislers & Brewin 2003; Dahlhaus 2003). Although salinity mapping is incomplete and monitoring has been sporadic and inconclusive, there is evidence that secondary salinity has increased alarmingly in some areas *(Fig. A10).* For example, in the Pittong SAP target area, the area of land affected by salinity has grown from 122 ha to 238 ha in the past two decades (Nicholson *et al.* 2003).

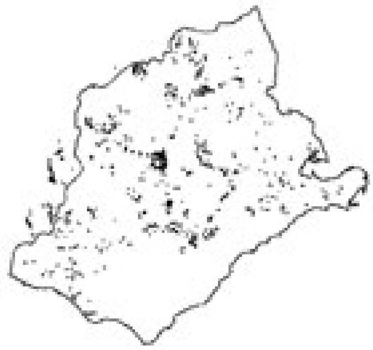


Figure A10: Location of secondary salinity discharge sites in the Corangamite region

Some monitoring was conducted in 2001, when a proportion of mapped salinity sites were revisited. The survey identified an 11% increase in area (Gardiner 2001) and assumed that saline soils sites may have increased by approximately 200 ha in the Corangamite region over the past 10 years.

Assets at risk from secondary salinity have been identified using the Geospatial Salinity Hazard and Asset Risk Prioritisation (GSHARP) model for the Corangamite SAP (Heislers & Brewin 2003). These include the region's Ramsar wetlands, urban water quality for Ballarat and Geelong, the Colac urban area and substantial areas of agricultural land.

Management

The Soil Health Strategy has recognised secondary salinity as a soil-related threatening process in the Corangamite region, and will carry out a risk analysis to determine the locations of the highest risk to assets. It will work with the SAP to address secondary salinity and will focus efforts in areas under high risk that fall outside the SAP target areas.

Detailed management actions have been identified for the SAP target areas, using scenario models, asset manager consultation and benefit-cost analyses. Salinity management using recharge control is recommended for three of the 12 SAP target areas. Discharge management is recommended for all areas, especially those where regional groundwater flow systems are present. Amendments to municipal planning schemes are recommended for all local governments in the Corangamite region. This will ensure that salinity risk posed by new urban and infrastructure developments and the risk of salinity impacting on new developments are considered.

A.5 Waterlogging and soil structure decline

Processes

In waterlogged soils, the lack of oxygen in pore spaces over sustained periods will severely affect plant growth. In wet and compacted soil horizons, where the air porosity is low, poor soil aeration is exacerbated by the production of toxic compounds by soil micro-organisms.

'Soil structure' refers to the arrangement, size and shape and proportion of stable soil aggregates (or peds) in the soil profile. The structure determines soil drainage, porosity, microbial activity, root penetration, aeration, availability of nutrients to plants, water-holding capacity and resistance to erosion and mass movement. Soil structure can be adversely affected by agricultural practises that either breakdown structure or cause soil compaction. The breakdown of soil structure is the cause of:

- restricted root growth, reducing the uptake of water and nutrients by plants
- lower average soil pore size, affecting the water-holding capacity of the soil and the activity levels of soil micro-organisms
- reduced infiltration rates, increasing the likelihood of surface run-off, water erosion and surface ponding.

Soil structure decline can occur through:

- cultivation
- compaction
- aggregate instability.

Cultivation can damage soil aggregates, allowing the organic matter that binds these aggregates together to be consumed by micro-organisms. Inappropriate cultivation may lead to wind or water erosion and soil structure decline, or may have a negative impact on the soil hydrology by altering the drainage of the soil profile (Leeper and Uren 1993).

Compaction of soils generally results from livestock and/or machinery traffic under wet soil conditions. In dairying in particular, the intensity of treading, particularly in moist or wet conditions, leads to compaction, surface roughening and impedance of water and air movement. Organic inputs are high in well-maintained dairy pastures, especially ryegrass pastures, which are strongly mycorrhizal and encourage stable aggregate formation.

Compaction of soils by machinery is a significant issue for cropping and forestry industries. The weight of machinery (particularly in wet conditions) compresses the soil, reducing air and water movement in wheel tracks.

Dispersion is a physico-chemical process observed when a soil aggregate placed in water breaks down to form a milky cloud around it. Dispersive soils are characterised by a high Exchangeable Sodium Percentage (ESP), where excessive sodium forces the clay particles apart in water. The dispersed clay particles can block the pores in the soil, resulting in impeded passage of air and water into the soil profile. Dispersed clays carried across the soil surface can form hard crusts and clods, presenting a barrier to infiltration and root development (McGuiness 1991).

Pugging, a form of compaction, is a significant issue where animals are grazed on landscapes with wet or waterlogged *(Fig. A11)* soils. Severe pugging can occur on the clay soils in dairy country found in the south-west areas of the Corangamite region. A study by MacEwan (1998) confirmed the susceptibility of the region's soils to pugging, especially in landscapes where the soils are saturated or where the watertable is within 20cm of the surface soil.

Figure A11: Pugging in waterlogged soils caused by dairy cattle, leading to soil structure decline

Compaction of surface and sub-surface soils threatens agricultural production as it degrades the productivity of most cropping soils. In addition, compaction caused by machinery can reduce the productivity of the land and increase run-off rates, which may increase the likelihood of water erosion and threaten water quality.

In drier parts of the Corangamite region, compaction of the surface soil as a result of intensive treading of hard-hoofed animals also causes significant soil structure decline, particularly on fine sandy loam soils. Pugging and hoof compaction significantly impact soil health and threaten agricultural productivity.

Soil structure decline is often associated with cultivation in dry conditions, particularly on loam topsoils in the region. These soils are particularly vulnerable to over-tillage, which under dry conditions breaks down the soil aggregates to a 'flour' easily blown by wind or washed by excessive rainfall. This problem is more likely to occur prior to crop or pasture establishment and can threaten water quality by adding suspended sediments to waterways (turbidity).

Dispersive soils occur extensively across the region, particularly in subsoils. The breakdown of soil structure caused by dispersion not only threatens agricultural production, but can also lead to severe erosion that threatens water quality.

Condition

Waterlogging may be a natural condition of the soil, but can worsen with deterioration in soil structure. There is a strong relationship between high likelihood of soil structure deterioration and a high susceptibility to waterlogging. Susceptibility maps indicate that waterlogging is high to very high over more than 50% of the Corangamite region *(Fig. A12).* These susceptible areas are generally located on low-lying heavy duplex soils in higher rainfall areas. High to very high susceptibility to soil structure decline covers similar areas to that of waterlogging, predominant in the south-west section of the region *(Fig. A13).*

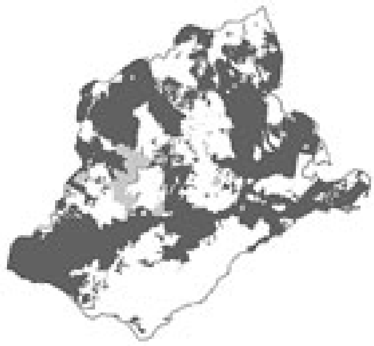


Figure A12: Areas of high to very high waterlogging susceptibility in the Corangamite region

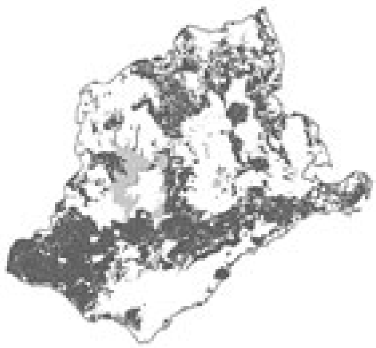


Figure A13: Areas of high to very high soil structure decline susceptibility in the Corangamite region

Management

The dairy industry has long recognised pugging as a significant issue, resulting in the development of the 'Wet Soil Management Initiative' (MacEwan 1998). Grazing practices have been developed that focus on the timely removal of livestock from wet soils and include off-site agistment, restricting livestock access and calving over a longer period.

Surface and sub-surface drainage are commonly used to rehabilitate waterlogged land and improve soil structure. Currently, over 80% of dairy land has some form of surface drainage and up to 20% has sub-surface drainage (MacEwan 1998).

'Graze and spell' rotation has been identified as an effective method of reducing hoof compaction on broadacre grazing land as it maintains good ground cover and higher organic carbon levels. This practice is currently being adopted over 30% of broadacre grazing land in the region (MacEwan 1998).

Compaction of wet forest soils by machinery while establishing or harvesting productive forests is a significant issue in the region. According to the 'Forestry Code of Practices', forestry activities should cease during wet periods to ensure that soil structure is maintained. Currently, most forestry activity on public land stops when soils are too wet. The adoption rates of this Code of Practice on private land are not known.

Over the past decade, extensive research efforts have been directed towards the factors that contribute to waterlogging and soil structure decline under broadacre cropping regimes. The biggest development has probably been with raised bed techniques, which currently cover about 10% of the annual crop area in the Corangamite region. Raised beds aim to reduce machinery compaction by using controlled traffic and to reduce waterlogging by lifting the soil above the saturated zone. Where used, raised beds have significantly improved soil structure and reduced waterlogging on cropping land, while significantly increasing agricultural productivity in high-rainfall areas. The construction of surface drains on crop land is also used to reduce waterlogging and improve agricultural production. It is recognised that the proper installation and maintenance of surface drainage (including raised beds) is critical in minimising off-site impacts, especially where sediments and nutrients may enter waterways and threaten water quality.

The adoption of minimum tillage practices can lessen and even reverse soil structure decline by maintaining organic carbon and limiting soil disturbance. Using tyned implements for crop sowing in preference to disc cultivators can also cut soil disturbance. Currently, about 60% of cropping land is minimal tilled and 30% conducted under 'no till' in the Corangamite region (Ward pers. comm. 2003). Reduction in tillage will help preserve soil structure and further sustain agricultural productivity.

In areas where dispersive soils are present, gypsum may be applied to help maintain aggregate stability, ultimately improving soil structure. In the Corangamite region, 10% of cropped and less than 5% of dairy and broadacre grazing land has gypsum applied. The costs of transporting and spreading gypsum inhibit wider adoption by broadacre grazing and cropping farmers in the region.

A.6 Wind erosion

Processes

The process of saltation (whereby fine sand particles bounce across the ground hitting and detaching other particles) dominates wind erosion. The finer particles are lifted in suspension and carried great distances. Coarser particles are bumped by other particles, resulting in the coarser particles 'creeping' along the surface. The mechanics of wind erosion are fully described in the scientific literature (e.g. McTainsh & Leys 1993).

Studies in Australia have revealed that the wind-blown fraction contained 16 times as much nitrogen, and twice the cation exchange and water-holding capacity of the original soil (Young & Young 2001). Therefore, wind erosion has the potential to threaten agricultural production due to the removal of fertile topsoil, which may end up in waterways and cause water pollution. Wind erosion also threatens air quality.

By nature, coastal dunes are originally and intermittently mobile and are a dynamic and natural feature of the landscape. Dunes become immobilised when some agent binds the surface. This may be a mineral material such as salt or calcareous cement, or sand-binding grasses and shrubs. All coastal dunes should be regarded as potentially unstable and prone to movement as environmental conditions change.

Condition

Wind erosion is mostly seen across the Basalt Plains, the Central Highlands and at points along the coastline. Wind erosion generally occurs on fallowed areas in cropping country and exposed sand dunes along the coast *(Fig. A14).*

Figure A14: Wind erosion in fallowed paddock

Wind erosion of sand dunes is most dynamic along south-west to south-facing shorelines in response to prevailing and strong winds. However, detailed dune position, extent and dynamics are determined by several variables including the beach slope and offshore profile, the geometry of the coastline and the availability of sand (partly a function of shoreline geology). High to very high susceptibility areas for wind erosion are illustrated in *Figure A15.*

The susceptibility of coastal dune movement along the Corangamite coast has not been accurately mapped. Managers in coastal areas suggest that the susceptibility of dunes to movement will vary depending on infrastructure, tides and ground cover protection.

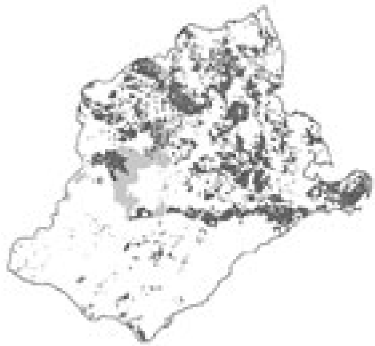


Figure A15: Areas of high to very high wind erosion susceptibility in the Corangamite region

Management

In agricultural areas, wind erosion has been managed by maintaining ground cover throughout the year. Strategically located windbreaks can be effective in reducing wind velocity and therefore risk of soil movement.

Dunes have been revegetated and stabilised by tussocky species such as marram grass. Community groups along much of the Corangamite coastline have been actively involved with DSE in programs to revegetate sand dunes susceptible to wind erosion.

A.7 Soil nutrient decline

Processes

Maintaining a cost-effective balance of available plant nutrients is an important component of farm management. Sustainable land use requires the replacement of extracted nutrients. Nutrients can also be lost from the soil through leaching into the deeper soil profile, in run-off or through soil movement.

In some cases, nutrient extraction or deficiencies may be over-corrected through excessive fertiliser or trace element application leading to off-site impacts including an increased risk of algal blooms and eutrophication processes.

Condition

In their natural, virgin state, soil nutrients are naturally deficient for the levels of agricultural production required of most soils throughout the Corangamite region. As a result dairy, cropping and broadacre grazing managers apply fertilisers to improve productivity. Nutrients are replaced as they are removed from the soil by pastures and crops. The greatest susceptibility to soil nutrient decline is found along the ranges of the Otways *(Fig. A16).*

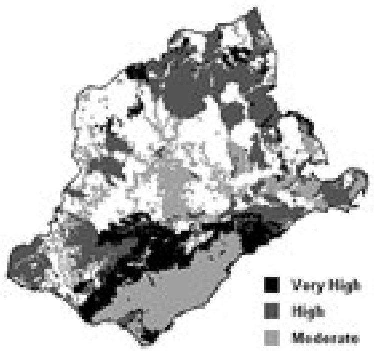


Figure A16: Areas of moderate, high and very high soil nutrient decline susceptibility in the Corangamite region

Management

Approximately 10% of agricultural land managers in the Corangamite region regularly conduct soil tests to determine the nutrient input requirements for the soils. Many land managers could potentially be applying insufficient or excessive amounts and/or the incorrect type of fertilisers to their soils.

'Nutrient budgets', together with soil tests, are recognised as prime indicators for improved nutrient management. Soil tests should be used to identify whether topsoil nutrient levels are at, above or below the target ranges. On areas that are below the target levels, capital applications of nutrients are required. Once target levels are reached, maintenance fertiliser rates should be applied. The aim of nutrient budgeting is to balance inputs and outputs, so that levels are maintained at the optimum for production.

A.8 Soil acidification

Process

Soil pH is used as an indicator of soil acidity or alkalinity. This is based on a numerical scale of 0 to 14 where pH below 7 is acid and pH above 7 is alkaline. The pH scale is logarithmic, meaning that a soil of pH 8 is 10 times more alkaline than a soil of pH 7.

The pH of soil falls as a result of *(Fig. A17):*

- leaching of soil water containing nitrogen, in the form of nitrate from either legumes (e.g. clover) or applied fertiliser nitrogen, which leaches the alkaline-based elements leaving behind the acidic-based elements
- removal of alkaline agricultural products such as hay, wool, meat, and milk
- accumulation of soil organic matter, which breaks down to release acidic elements.

Low soil pH reduces the availability of essential nutrients such as phosphorus and molybdenum, and increases the availability of toxic elements such as aluminium and manganese. Low pH also makes the environment unsuitable for many soil microbes.

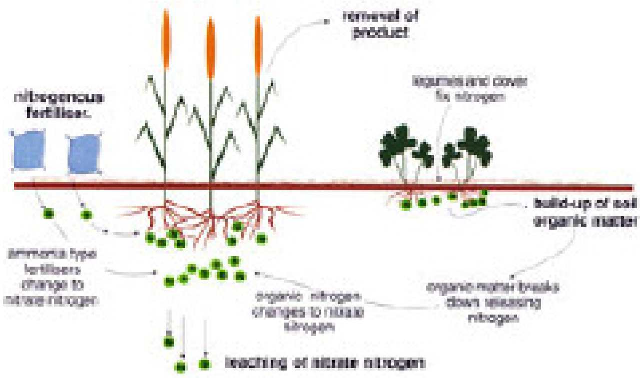


Figure A17: Processes associated with acidification through nitrate leaching

Condition

Soil acidification is a process that is more common in sandier soils, where nitrogen/nitrate leaching occurs more readily. Soil acidification is found throughout the Corangamite region, but appears to be most prevalent in areas of higher agricultural production *(Fig. A18).* These areas have high levels of agriculture-related inputs and outputs, which also increase the likelihood of soil acidification.

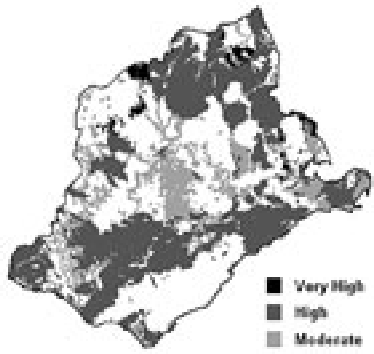


Figure A18: Areas of moderate, high and very high soil acidification susceptibility in the Corangamite region

Management

The only way to reverse soil acidification is to raise the pH through the application of alkaline minerals such as agricultural lime to the soil. The effectiveness of an application of lime will depend on the relationship between pH, soil type, buffering capacity and enterprise. Lime can be incorporated into the soil or simply top-dressed and left to leach into the soil with subsequent rainfall.

In the Corangamite region, more than half the cropping and dairy land is subjected to regular applications of agricultural lime (Bluett and Ward pers. comms. 2003). On broadacre grazing, less than 10% of land has lime applied regularly, because it is generally not cost-effective. As an alternative, land managers may grow more acid-tolerant pasture species. Soil aluminium concentration ultimately determines which pasture species will be productive on more acidic soils. Acid-tolerant species such as cocksfoot, and legumes such as Serradella, help maintain pasture productivity in the face of falling soil pH.

Deep-rooted perennial pastures such as phalaris and cocksfoot can use water from deeper in the soil profile, reducing the potential for nitrate leaching and, therefore, soil acidification. Phalaris retains some deeper roots over the summer and can quickly grow new roots following autumn rains. In the Corangamite region, about 20% of pastures in broadacre areas have a sufficient proportion of perennial species to minimise acidification rates.

Soil testing ensures that excess nitrogen is not being applied through fertilisers; unused nitrogen may leach and cause soil acidification. Within the region, only about 10% of landholders regularly conduct soil tests. Therefore nitrogen leaching could be significant, particularly on sandy soils.

A.9 Soil contamination

Processes

The physical and chemical contamination of soil is largely a legacy of past practices. These commonly include heavy metal contamination from mining, hydrocarbon contamination from leaking fuel tanks and organochlorine and other pesticides from agriculture.

At the time of the development of the SHS, the status of soil contamination in the region could not be readily determined. EPA Victoria has no published study on regional soil contamination sites. However, there are 15 sites in the region where the EPA has issued a notice to the occupier because of pollution or potential for pollution of groundwater, surface water and/or land. These sites are in highly developed industrial areas.

Condition

Heavy metals, particularly arsenic, are associated with past mining activities around Ballarat (Lamb *et al.* 1993; Harvey, 2003), although these sites have not been recognised by the EPA as a significant contamination threat. Dieldrin insecticide was used extensively in the 1950s, 60s and 70s for the control of insect pests in potato crops. This type of pesticide is persistent in the soil and can take up to 200 years to break down by biological processes. Dieldrin contamination sites are mostly found in the Bellarine Peninsula area, east of Lake Connewarre. The use of dieldrin is now prohibited.

The presence of contaminants can restrict the options for land use. At worst, contaminated sites can be declared unsuitable for any use, as the contaminants may cause death or illness of humans and livestock. In other cases, contaminants may limit the productive use of the soil, such as when animals grazed on contaminated soils are declared unfit for human consumption. The mobilisation of contaminants from the soil has the potential to cause severe impacts to the environment.

Management

Contaminated sites usually require individually tailored management solutions, which must comply with EPA regulations. For instance, all sites contaminated by dieldrin have been identified. At these sites, landholders develop property management plans to ensure that dieldrin does not spread off-site and that any livestock grazed in these paddocks spend time on uncontaminated paddocks prior to sale.

A.10 Soil organic carbon (matter) decline

Processes

Organic matter is any material that contains carbon compounds that were formed by living organisms, covering a wide range including: leaves, stems, branches, moss, algae, lichens, decaying animals, manure, droppings, sewage sludge, sawdust, insects, earthworms and microbes.

There are three main components of organic matter in soils:

- dead forms of organic material – mostly dead plant parts
- living parts of plants – mostly roots
- living microbes and soil animals.

The breakdown of organic matter is a complex process that involves chemical alteration of organic matter, physical fragmentation and finally, release of mineral nutrients. Organic matter breakdown is a biological process. Soil organisms (micro-organisms, earthworms, micro-arthropods, ants, beetles, etc), perform the chemical and physical changes. Each type of organism plays a different role in the breakdown.

Breakdown starts almost immediately after the organism, or part of it, dies. The organic material is first colonised by micro-organisms using enzymes to oxidise the organic matter and obtain energy. In the case of leaves and roots, their surfaces are colonised by micro-organisms even before they die. Soil animals such as earthworms assist in the decomposition of organic matter by incorporating it into the soil where conditions are generally more favourable for decomposition than on the surface. Earthworms and other larger soil animals, such as mites, collembola and ants, fragment organic material, increasing the surface area and allowing more micro-organisms to colonise the organic matter and decompose it.

During decomposition, complex organic chemical molecules progressively break down into simpler organic molecules. These undergo further decomposition into mineralised nutrients. The first organic compounds to be broken down include simpler amino acids and sugars. Cellulose is broken down more slowly. Complex molecules such as phenols, waxes and lignins remain in the soil for the longest time (Abbott 2002).

High levels of organic carbon are essential for good soil health, improving soil structure, raising fertility, reducing erosion and encouraging soil biota. Soil organic carbon also helps maintain agricultural production and reduces potential off-site risks, such as sediments entering waterways as a consequence of soil erosion.

Condition

Although there is little or no information available on soil organic carbon levels in the Corangamite region, it can be assumed that higher organic carbon levels are likely in higher rainfall areas featuring long-standing perennial vegetation, with minimal agricultural land use. *Figure A19* illustrates the difference in soil organic carbon levels at a farm scale under different management practises.

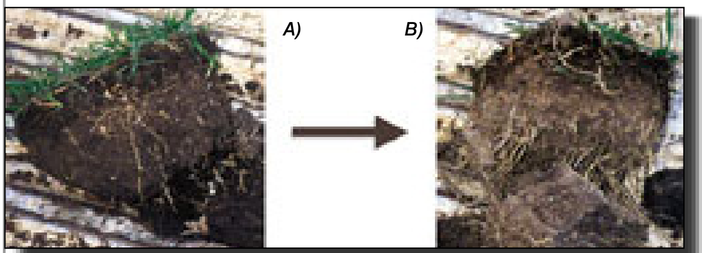


Figure A19: Two soils from neighbouring paddocks, soil 'A' has high organic carbon levels, while soil 'B' has lower carbon levels due to poor land management practises

Management

Within the Corangamite region, only a minority of pastures are predominantly perennial species. Increasing the proportion of perennial species in pastures will increase organic carbon in soils at depth. Perennial species have a much higher biomass and therefore provide greater amounts of organic carbon to the soil. Grazing regimes that encourage pasture regeneration, such as 'graze and spell rotation', are effective contributors to the maintenance of higher organic carbon levels.

Maintaining soil organic carbon levels is as important in cropping paddocks as it is in pasture paddocks. Stubble retention contributes to the maintenance of higher carbon levels in soils. Incorporating pasture phases into the rotations also helps maintain higher organic carbon levels.

A.11 Soil biota decline

Processes

Soil biota, or organisms, are extremely diverse and abundant. It is believed that there are twice as many species of organisms alive in the soil than in tropical rainforest canopies. Soil biota are grouped into three categories according to their size. The first group is the microfauna, which are the smallest of the soil animals and range from 20 – 200µm (e.g. protozoa). The mesofauna is the next largest group and range in size from 200µm – 10mm (e.g. mites, collembola and nematodes). Macrofauna is the largest soil biota, and includes earthworms, beetles and termites.

Associations between bacteria and plants that fix atmospheric nitrogen include species of Frankia bacteria and certain tree species such as those of the genera Casuarina and Allocasuarina. Another example is between that of Azospirillum and certain grass species. The most well-known plant-bacteria association that fixes atmospheric nitrogen is the symbiotic relationship between rhizobia and legume plants (Abbott 2002).

Biological fertility of soils, while hard to quantify, provides great opportunities for land management and monitoring because of its dynamic nature. Understanding the biological state of soils may provide early warning of land degradation, thereby enabling the employment of more sustainable land management practises (Abbott 2002).

Figure A20: A Soil Mite commonly found in soils
Photograph: B. Marcot

Condition

Little is known about soil biota conditions in the Corangamite region. Soil biology is complex and a better understanding of the mediatory effect the biological components have on chemical and physical fertility needs to be identified. In the region, it is most likely that high biota numbers will be found in soils that are well structured, have high organic carbon levels and a neutral pH.

Management

Soil biota play an important role in the breakdown of organic matter, improving soil structure and releasing nutrients for plants. The level of soil biota is an excellent indicator of soil health and is vital in maintaining agricultural productivity.

To make the soil environment more favourable for soil biota, Abbott (2002) believes the following best-management practices should be followed:

- conduct appropriate crop rotations (especially legume-based), that improve nutrient and organic matter levels, break disease cycles and provide more diverse nutrient sources for soil biota
- maintain soil fertility by conducting regular soil tests and applying fertiliser according to crop and paddock needs. Most biota are sensitive to soil acidity, therefore adding agricultural lime will raise the pH to foster biological activity.
- retain crop stubble to encourage higher levels of organic matter as a food source for soil organisms
- reduce soil structure decline to maintain pore spaces and drainage
- reduce waterlogging because many soil microbes do not adapt to anaerobic environments.

In the Corangamite region, stubble is burnt on 60% of crop land (Bluett pers. comm. 2003), potentially impacting on organic matter and biota in the soil. Other stubble management practices used in the region include retention, incorporation and grazing. Burning stubble exposes surface soils to wind and water erosion. Retaining stubbles is one alternative, but may require investment in seeders capable of handling larger volumes of crop trash.

Appendix B: Processes, examples and results for prioritising investment

B.1 Data sources, types and quality

The data used in the GIS analysis was obtained from the Corangamite Catchment Management Authority, Department of Sustainability and Environment, Department of Primary Industries and the University of Ballarat.

The data are three distinct types: factual data, derived data and interpretive data.

Factual data includes the located polygons, lines and points representing an asset (lake, road or stream) or threatening process (landslide or gully). This data provides the highest resolution data for targeting the exact intersection of the asset and threat.

Derived data is either interpolated or classified from factual data, such as land-use polygons classified from satellite imagery or aerial photographs. Derived data is useful for determining areas of interest, but cannot generally be used to specify locations.

Interpretive data layers are those where a value is assigned to a particular landscape parameter, usually delineated as a polygon, to represent the data value. As an example, landform units are assigned a number to indicate their susceptibility to soil waterlogging, soil structure decline or soil acidification. Interpretive data provides a much broader intersection of threats and assets, compared to factual or derived data.

Intersecting assets and potential soil-threatening processes

The intersection of assets with soil-related threatening processes was undertaken using MapInfo GIS (version 8), with Vertical Mapper (version 3.1) and Encom Discover (version 7.1) as additional tools. The Spatial Query Language (SQL) tool in MapInfo allows for three main types of queries:

- contains (object A contains object B if B's centroid is anywhere within A's boundary)
- within (object A is within object B if its centroid is within B's boundary)
- intersects (object A intersects object B if they have at least one point in common).

An SQL query can be written to instruct the program to count objects, sum the area or perimeter of objects (and other functions), and report the results in a particular order.

Care was taken to ensure that the SQL queries did not misrepresent the data by reporting a misleading result. For example, where two polygons – gully erosion polygon and native vegetation with very high conservation significance potential – intersected, the area of native vegetation potentially threatened by the gully was reported as the overlapping area of the polygons. Whereas, if the gully intersected the 50-metre buffer zone alongside a waterway, then the area of the entire gully was counted as the threat to the waterway. The results are outlined in the next section of this Appendix.

In the GIS analysis, it was recognised that each process may not potentially threaten each asset. For example, soil waterlogging may not be a threat to a wetland and it could be argued that a loss of soil waterlogging would be more threatening. The relationship of assets to potential threatening processes was determined at a meeting of the Corangamite SHS Steering Committee.

B.2 Relative severity of threats

The relative severity of threatening processes has a greater range to account for the variation in the types of data used. Some threats, such as a landslide or gully erosion sites, have been mapped to a high resolution and are represented by discrete polygons which have a relatively small area of intersection with an asset, such as a road or stream. By contrast, the area of land with a high susceptibility to soil structure decline is mapped at a very coarse scale (i.e. a large polygon), and the area of intersection with an asset such as the land used for cropping is generally quite a large number. To adjust for the different data sets, threats with high resolution (e.g. gully erosion), have been assigned a Relative Severity Factor (RSF) of 5, whereas the high threat of soil structure decline has been assigned an RSF of 100 *(Table B1)*. Because division was used in the calculations, the lower the RSF for a threat, the higher was the resolution and confidence in the data. Conversely the higher the RSF for a threat, the lower was the resolution and confidence in the data.

Factual Data	
Threat	**Relative Severity Factor (RSF)**
Gully erosion	5
Sheet/rill erosion	5
Landslides	3
Secondary salinity	10

Table B1: Relative Severity Factor (RSF) assigned to threatening processes

Factual Data		
Threat	**Relative Severity Factor (RSF)**	
Susceptibility to soil structure decline	Very High High Moderate	50 100 150
Susceptibility to soil waterlogging	Very High High Moderate	50 100 150
Susceptibility to soil nutrient decline	Very High High Moderate	50 100 150
Susceptibility to soil acidification	Very High High Moderate	50 100 150
Susceptibility to soil erosion by wind	Very High High Moderate	50 100 150
Potential acid sulphate soils		25

B.3 Example calculation of relative risk

As an example, the relative risk to assets for the threatening process of soil waterlogging in the Upper Barwon Landscape Zone was calculated using the interpretive data, as tabulated in *Table B2*.

Waterlogging only impacts on agricultural production, therefore other asset classes in which waterlogging does not have an impact was given an RSF of zero. This means that all waterlogged areas that overlap with conservation, urban and peri-urban areas were not included in the final Relative Risk Value. The RSF for very high waterlogging susceptibility was 50 and is the highest likelihood of risk to agricultural production. The RSF for high waterlogging susceptibility was 100 and moderate waterlogging was 150 as the likelihood of risk is lower. The RSF is divided in the calculations, therefore the lower the RSF number, the higher the risk value.

The totals for all asset classes were added to determine the overall risk value for waterlogging in the Upper Barwon, which in this case was 233. However, because landscape zones vary in size, larger landscape zones are likely to have higher Relative Risk Values than smaller landscape zones, as there is more land area to be susceptible. To measure waterlogging and other soil-threatening processes amongst landscape zones, the total risk values were multiplied by the percentage of area they cover within the Corangamite region. This standardised the values in a fair way. However, with landslides and erosion, because actual sites were used in the analysis these were not standardised according to the size of the landscape zone *(Table B2)*.

Asset	RAV	Very high susceptibility (hectares)	RSF	High susceptibility (hectares)	RSF	Moderate susceptibility (hectares)	RSF	Total Relative Risk
Land use								
Conservation	0	966	50	1903	100	2926	150	0
Urban	0	19	50	167	100	66	150	0
Peri-urban	0	0	50	96	100	14	150	0
Horticulture	5	0	50	141	100	0	150	7
Dairy	4	0	50	1903	100	2926	150	154
Cropping	3	0	50	3035	100	563	150	102
Grazing	2	4755	50	33255	100	15865	150	1067
Forestry	3	200	50	1741	100	15367	150	372
Animal Production	7	0	50	0	100	0	150	0
Raw Total								**1702**
Normalised to CCMA region (the raw total is multiplied by 7.3%, which is the proportional area of the Corangamite CMA region covered by the Upper Barwon Landscape Zone)							**Final total**	**233**

Table B2: Calculation of relative risk from soil waterlogging in the Upper Barwon Landscape Zone

By contrast, the relative risk to assets for the threatening process of gully erosion in the Upper Barwon Landscape Zone was calculated using the factual data, as shown in *Table B3.* The main difference between gully/tunnel erosion and waterlogging, is that gully/tunnel erosion has the potential to impact on all asset classes. Therefore, if there was an overlap of erosion with any asset class, the figure was included in the final Relative Risk Value.

The other difference is that actual mapped gully erosion sites were used in this calculation, therefore a much lower RSF number was used to produce a high Relative Risk Value. Unlike waterlogging, because actual gully sites were used, no standardised processes were needed to make the results consistent amongst the varying sizes of landscape zones *(Table B3).*

Asset	RAV	Actual area under threat (hectares)	RSF	Relative Risk Value
Land use				
Water Supply	10	0	5	0
Conservation	10	7	5	13
Urban	9	0	5	0
Peri-urban	7	0	5	0
Infrastructure	10	0	5	0
Horticulture	5	0	5	0
Dairy	4	0	5	0
Cropping	3	0	5	0
Grazing	2	68	5	27
Forestry	3	40	5	24
Animal Production	7	0	5	0
Mining	8	0	5	0
Public Land	7	82	5	114
Conservation	10	31	5	62
Wetlands	10	85	5	170
Waterways	10	124	5	249
Roads	10	42	5	85
				Total 743

Table B3: Calculation of relative risk from gully erosion in the Upper Barwon Landscape Zone

The combined relative risk for each threatening process is illustrated in *Figure B1*, showing that landslides present the greatest relative risk to assets, and wind erosion the least relative risk. It is stressed that the risk values are relative, and not absolute values.

B.4 Sensitivity analysis

Since the ranking of the relative risk is dependent on both the RAV chosen for assets and the RSF assigned to the soil-threatening processes, an analysis was undertaken to determine the sensitivity of the calculations. A series of tests were conducted where the RAV and/or the RSF were significantly changed (e.g. doubled) and the final results compared.

Overall, the outcomes were much the same, indicating the relative insensitivity of the calculations to the RAV and RSF. Even though the values were significantly changed in the sensitivity analysis, the final ranking of the soil-threatening processes within a landscape zone and between the landscape zones remained virtually unchanged.

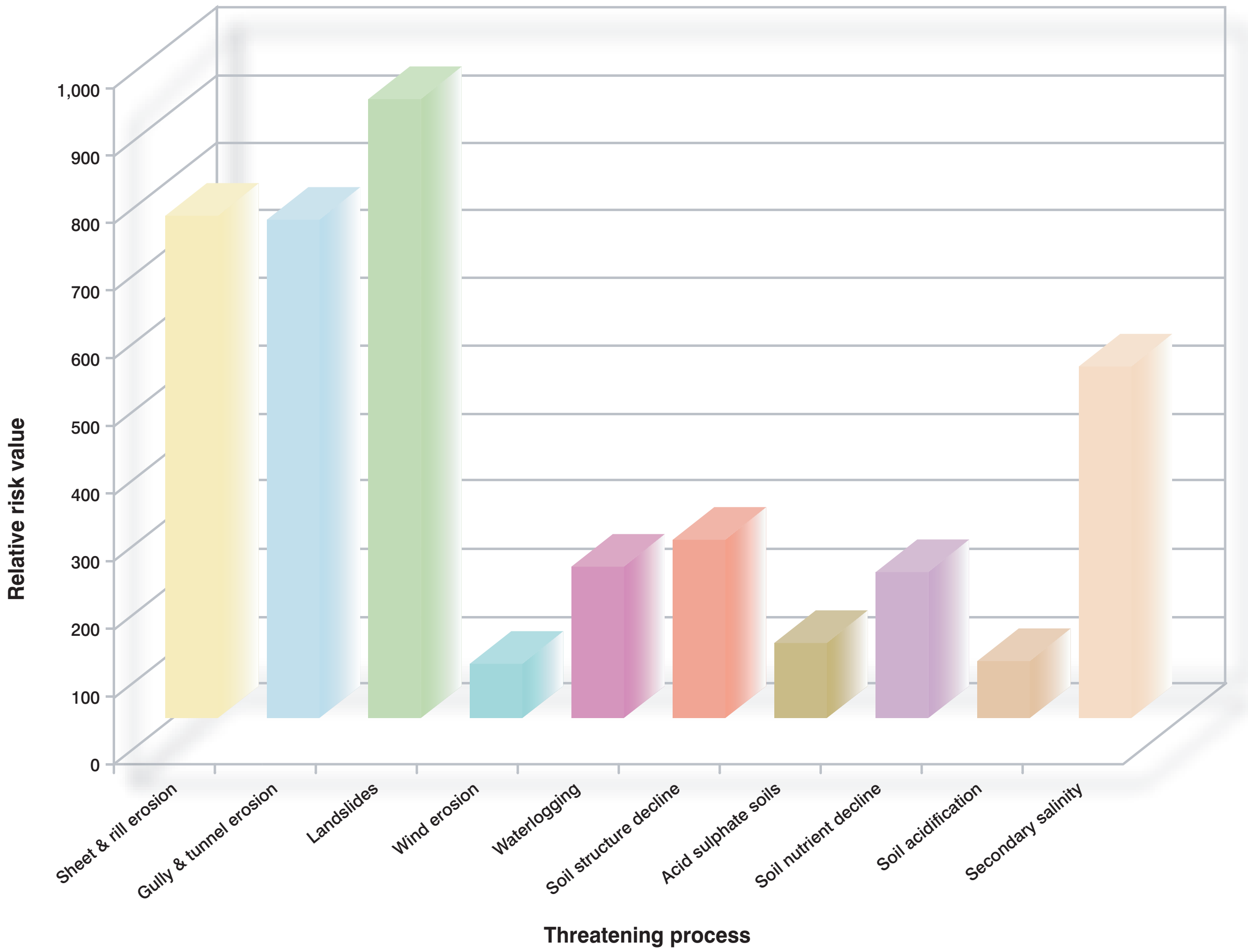


Figure B1: Relative Risk Values for the Upper Barwon Landscape Zone

B.5 Relative Risk Values for all threats across all landscape zones

Rank	Threat	Landscape Zone	Relative Risk Value	Rank	Threat	Landscape Zone	Relative Risk Value
1	Landslides	Gellibrand	3167	=38	Soil Nutrient Decline	Gellibrand	270
2	Secondary Salinity	Lismore	2886	=40	Soil Structure Decline	Upper Barwon	268
3	Acid Sulphate Soils	Bellarine	2748	=40	Soil Structure Decline	Middle Barwon	268
4	Gully/tunnel Erosion	Woady Yaloak	2501	42	Waterlogging	Middle Barwon	257
5	Sheet/rill Erosion	Woady Yaloak	2317	43	Soil Structure Decline	Stony Rises	256
6	Secondary Salinity	Stony Rises	1925	44	Waterlogging	Stony Rises	254
7	Landslides	Curdies	1903	45	Acid Sulphate Soils	Woady Yaloak	246
8	Landslides	Otway Coast	1872	46	Soil Structure Decline	Hovells	244
9	Sheet/rill Erosion	Thompsons	1804	47	Secondary Salinity	Hovells	243
10	Secondary Salinity	Woady Yaloak	1646	48	Gully/tunnel Erosion	Hovells	236
11	Sheet/rill Erosion	Moorabool	1154	49	Secondary Salinity	Thompsons	233
12	Secondary Salinity	Murdeduke	1090	=50	Waterlogging	Upper Barwon	232
13	Gully/tunnel Erosion	Leigh	938	=50	Waterlogging	Woady Yaloak	232
14	Landslides	Upper Barwon	917	52	Waterlogging	Moorabool	230
15	Gully/tunnel Erosion	Moorabool	893	53	Waterlogging	Lismore	228
16	Sheet/rill Erosion	Upper Barwon	752	54	Soil Structure Decline	Woady Yaloak	227
17	Gully/tunnel Erosion	Upper Barwon	743	=55	Soil Structure Decline	Otway Coast	225
18	Sheet/rill Erosion	Leigh	734	=55	Acid Sulphate Soils	Lismore	225
19	Acid Sulphate Soils	Thompsons	557	57	Soil Structure Decline	Moorabool	219
20	Landslides	Aire	548	58	Waterlogging	Murdeduke	218
21	Secondary Salinity	Upper Barwon	525	59	Soil Nutrient Decline	Upper Barwon	217
22	Landslides	Thompsons	518	60	Soil Nutrient Decline	Stony Rises	211
23	Acid Sulphate Soils	Hovells	506	61	Soil Nutrient Decline	Otway Coast	197
24	Secondary Salinity	Leigh	502	=62	Soil Structure Decline	Murdeduke	196
25	Secondary Salinity	Bellarine	485	=62	Waterlogging	Leigh	196
26	Waterlogging	Curdies	482	64	Wind Erosion	Thompsons	195
27	Sheet/rill Erosion	Hovells	444	65	Soil Structure Decline	Leigh	192
28	Secondary Salinity	Gellibrand	424	=66	Soil Structure Decline	Thompsons	184
29	Soil Structure Decline	Curdies	416	=66	Soil Nutrient Decline	Aire	184
30	Acid Sulphate Soils	Aire	402	68	Soil Nutrient Decline	Curdies	175
31	Secondary Salinity	Curdies	399	69	Soil Acidification	Curdies	173
32	Acid Sulphate Soils	Gellibrand	398	=70	Soil Structure Decline	Bellarine	167
33	Sheet/rill Erosion	Gellibrand	336	=70	Soil Acidification	Bellarine	167
34	Gully/tunnel Erosion	Bellarine	317	72	Soil Structure Decline	Lismore	165
35	Secondary Salinity	Middle Barwon	296	73	Soil Nutrient Decline	Thompsons	164
36	Sheet/rill Erosion	Middle Barwon	294	=74	Waterlogging	Thompsons	160
37	Soil Structure Decline	Gellibrand	273	=74	Waterlogging	Bellarine	160
=38	Waterlogging	Gellibrand	270	76	Waterlogging	Otway Coast	149

Table B4: Ranking of soil-based threats for each landscape zone according to calculated Relative Risk Values (continued next page)

Rank	Threat	Landscape Zone	Relative Risk Value
77	Waterlogging	Hovells	146
=78	Wind Erosion	Bellarine	145
=78	Soil Structure Decline	Aire	145
80	Soil Acidification	Stony Rises	144
81	Acid Sulphate Soils	Curdies	141
82	Landslides	Moorabool	136
83	Soil Nutrient Decline	Moorabool	135
84	Soil Acidification	Leigh	134
85	Soil Nutrient Decline	Leigh	133
86	Soil Acidification	Moorabool	132
87	Soil Nutrient Decline	Woady Yaloak	131
=88	Soil Acidification	Woady Yaloak	130
=88	Acid Sulphate Soils	Moorabool	130
90	Soil Acidification	Thompsons	127
91	Sheet/rill Erosion	Bellarine	120
92	Landslides	Bellarine	119
93	Wind Erosion	Aire	118
=94	Acid Sulphate Soils	Upper Barwon	113
=94	Soil Nutrient Decline	Bellarine	113
96	Wind Erosion	Woady Yaloak	109
97	Landslides	Middle Barwon	107
98	Wind Erosion	Stony Rises	105
99	Wind Erosion	Gellibrand	102
100	Secondary Salinity	Moorabool	101
=101	Soil Acidification	Upper Barwon	99
=101	Wind Erosion	Leigh	99
103	Acid Sulphate Soils	Middle Barwon	95
=104	Wind Erosion	Murdeduke	93
=104	Acid Sulphate Soils	Murdeduke	93
=104	Wind Erosion	Middle Barwon	93
107	Acid Sulphate Soils	Stony Rises	88
=108	Acid Sulphate Soils	Otway Coast	81
=108	Soil Acidification	Gellibrand	81
110	Soil Nutrient Decline	Middle Barwon	80
111	Wind Erosion	Moorabool	79
112	Wind Erosion	Lismore	78
=113	Wind Erosion	Upper Barwon	72

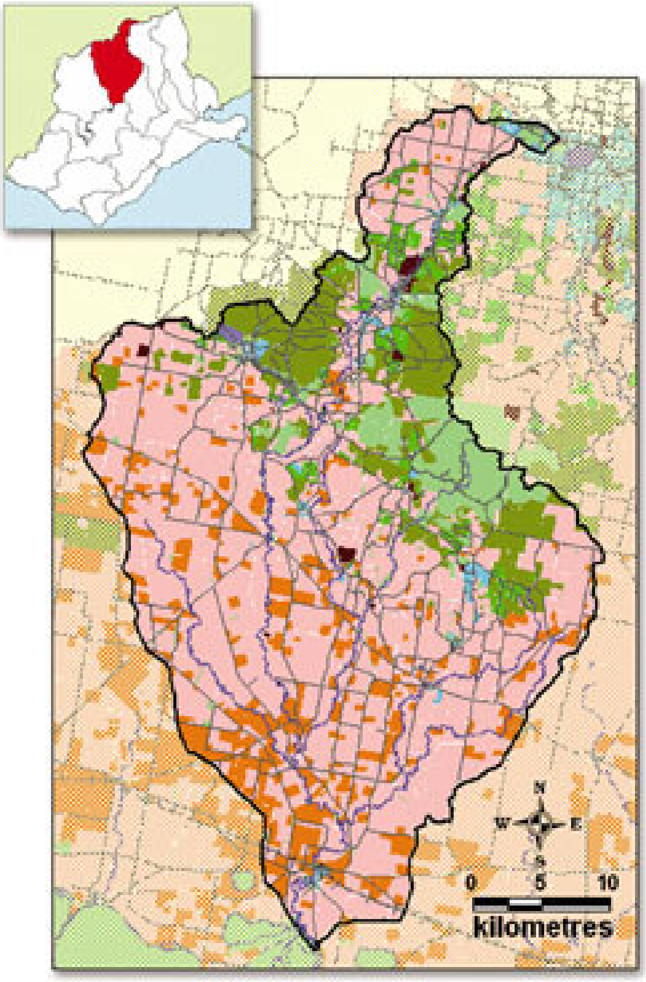
Rank	Threat	Landscape Zone	Relative Risk Value
=113	Soil Acidification	Middle Barwon	72
115	Acid Sulphate Soils	Leigh	70
116	Gully/tunnel Erosion	Middle Barwon	66
117	Wind Erosion	Curdies	65
118	Waterlogging	Aire	58
119	Gully/tunnel Erosion	Curdies	54
=120	Soil Nutrient Decline	Lismore	49
=120	Soil Acidification	Lismore	49
=122	Sheet/rill Erosion	Otway Coast	43
=122	Wind Erosion	Hovells	43
=122	Soil Nutrient Decline	Hovells	43
=122	Soil Acidification	Hovells	43
126	Soil Acidification	Aire	38
127	Sheet/rill Erosion	Murdeduke	35
128	Gully/tunnel Erosion	Gellibrand	31
129	Gully/tunnel Erosion	Thompsons	28
130	Gully/tunnel Erosion	Lismore	27
131	Sheet/rill Erosion	Aire	26
132	Sheet/rill Erosion	Lismore	24
=133	Landslides	Leigh	20
=133	Landslides	Hovells	20
=135	Soil Nutrient Decline	Murdeduke	19
=135	Soil Acidification	Murdeduke	19
137	Landslides	Stony Rises	16
138	Sheet/rill Erosion	Curdies	13
139	Wind Erosion	Otway Coast	12
140	Sheet/rill Erosion	Stony Rises	10
141	Gully/tunnel Erosion	Stony Rises	6
142	Soil Acidification	Otway Coast	3
=143	Landslides	Woady Yaloak	0
=143	Gully/tunnel Erosion	Otway Coast	0
=143	Secondary Salinity	Otway Coast	0
=143	Gully/tunnel Erosion	Murdeduke	0
=143	Landslides	Murdeduke	0
=143	Landslides	Lismore	0
=143	Gully/tunnel Erosion	Aire	0
=143	Secondary Salinity	Aire	0

Table B4: (Cont.)

Appendix C: Land use, assets, threats and Relative Risk Values for landscape zones

C.1 Woady Yaloak

- **122,943 hectares or 9.2% of Corangamite CMA region**
- **11.3% public land**



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	415	9566.9	7.8
Cropping	260	15437.3	12.6
Forestry	201	13214.5	10.7
Grazing	830	73887.9	60.1
Horticulture	1	1.6	0.0
Infrastructure	30	74.1	0.1
Mining	36	629.9	0.5
Peri-urban	143	3757.2	3.1
Urban	274	1560.2	1.3
Water	22	414.2	0.3
Total	**2212**	**118543.0**	**96.5**

Figure C1: Land use in the Woady Yaloak Landscape Zone in 2000-2002

Assets

- 2,117 km of waterways including the Woady Yaloak River, Naringhil Creek, Misery and Moonlight creeks, Kuruc-a-ruc Creek and Ferrars Creek.
- 91 wetlands (0.8% of area)
- Native vegetation conservation significance potential: 5.5% of total landscape zone is very high, 6.7% of total landscape zone is high.
- 1,000 km of roads, excluding the more recently subdivided areas west of Ballarat.

Threats

To public assets

- *Erosion by water.* There are 320 (637 ha) gully erosion sites and 166 (526 ha) sheet/rill erosion sites within 50 m of waterways, with Mount Misery Creek, Moonlight Creek and the Woady Yaloak River recording the most. Thirty-two mapped gully erosion sites (69 ha) and 25 mapped sheet/rill erosion sites (50 ha) intersect with native vegetation of very high conservation significance, and 34 gully erosion (82 ha) and 20 sheet/rill erosion sites (64 ha) intersect with native vegetation of high conservation significance potential.

The vast majority of these intersections occur along the waterways and drainage lines along a broad zone from Mount Mercer to Pittong. There are 48 gully erosion sites and 32 sheet/rill erosion sites within 50 m of roads, mostly on minor rural roads north of the Rokewood – Skipton Road. Ninety-seven gully erosion sites (330 ha) and 79 sheet/rill erosion sites (329 ha) are mapped on public land.

- *Salinity.* Secondary salinity occurs along waterways and drainage lines contributing salt loads to the Woady Yaloak River, with 1,237 ha of secondary salinity mapped in the landscape zone. Sixty-four hectares of secondary salinity occurs on public land, 702 ha within 50 m of waterways, 60 ha within 50 m of roads, and 171 ha within 50 m of wetlands. Over 170 ha of very high and 150 ha of high conservation significance potential native vegetation are also intersected. Although secondary salinity is widespread, there are much larger areas in the granitic landscapes south of Pittong and on the sand soils from Mt Mercer to Cape Clear.

To private assets

- *Susceptibility to soil structure decline.* About 52% (7,992 ha) of cropping land, 98% (13,000 ha) of forestry land and 67% (49,626 ha) of grazing land is highly susceptible to soil structure decline. This constitutes almost all the north and east sections of the landscape zone.
- *Susceptibility to soil waterlogging.* Around 14% (2,133 ha) of cropping land and 10% (7,298 ha) of grazing land has a very high susceptibility to waterlogging in the southern portion of the landscape zone along the Woady Yaloak River floodplain and in the Rokewood area. Another 42% (6,441 ha) of cropping land and 50% (37,293 ha) of grazing land has a high susceptibility to waterlogging. This constitutes almost all of the volcanic landscapes in the southern half of the landscape zone and the area around Haddon.
- *Susceptibility to soil nutrient decline.* Soils of the granitic landscapes south of Pittong and in the Mount Kinross locality are very highly susceptible to soil nutrient decline. These include 4,156 ha of grazing land, 804 ha of forestry land and 459 ha of cropping land. Another 21,347 ha of grazing land, 9,478 ha of forest land and 2,030 ha of cropping land are highly susceptible to soil nutrient decline. This includes the majority of the highlands from Rokewood to Pittong and north to Haddon.
- *Susceptibility to soil acidification.* The same area that is susceptible to soil nutrient decline is also susceptible to soil acidification, with 3,985 ha of grazing land, 746 ha of forestry land and 459 ha of cropping land very highly susceptible. Another 21,518 ha of grazing country, 9,536 ha of forestry country and 2,030 ha of cropping country are highly susceptible.
- *Susceptibility to soil erosion by wind.* About 9,820 ha of grazing land and 1,018 ha of cropping land are highly susceptible to wind erosion in the Mt Mercer – Cape Clear area.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C2)*:

- gully/tunnel erosion and sheet/rill erosion pose the greatest risk in the Woady Yaloak, and overall were ranked 4 and 5 respectively in the Corangamite region
- secondary salinity also poses very high risk to assets, being ranked number 10 in the Corangamite region
- other soil threatening processes that pose a potential risk to assets in the Woady Yaloak include acid sulphate soils, waterlogging and soil structure decline
- soil-related threatening processes not posing significant risk to assets in the area include soil nutrient decline, soil acidification and wind erosion
- no landslides are present in the Woady Yaloak Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Gully/tunnel erosion	4	2501
2. Sheet/rill erosion	5	2317
3. Secondary salinity	10	1646
4. Acid sulphate soils	45	246
5. Waterlogging	=50	232
6. Soil structure decline	54	227
7. Soil nutrient decline	87	131
8. Soil acidification	=88	130
9. Wind erosion	96	109
10. Landslides	=143	0

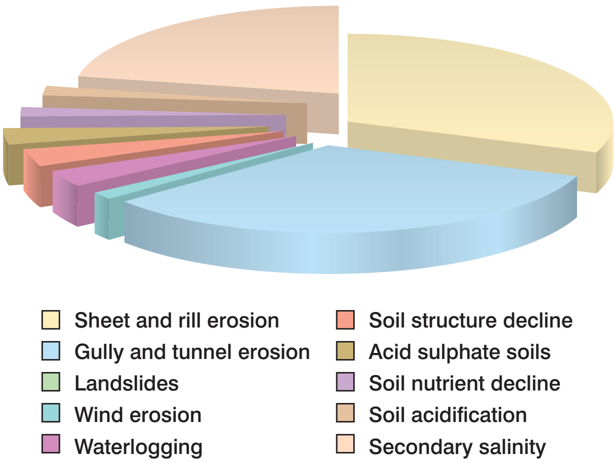


Figure C2: The rank and Relative Risk Values for soil-threatening processes in the Woady Yaloak Landscape Zone

C.2 Gellibrand

- 122,943 hectares or 9.2% of Corangamite CMA region
- 50.2% public land

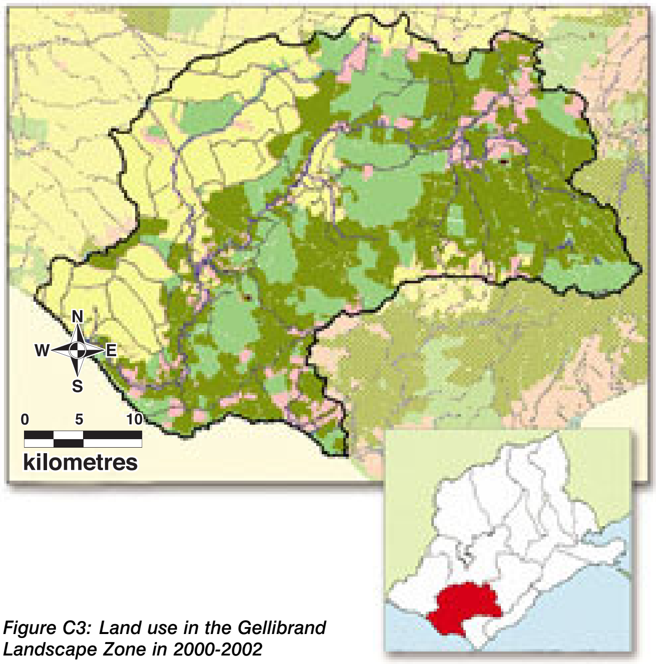


Figure C3: Land use in the Gellibrand Landscape Zone in 2000-2002

Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	476	31704.5	25.8
Dairy	181	29229.3	23.8
Forestry	585	47038.1	38.3
Grazing	460	11750.1	9.6
Infrastructure	6	2.0	0.0
Mining	10	64.6	0.1
Urban	38	86.9	0.1
Water	1	0.7	0.0
Total	**1757**	**119876.2**	**97.7**

Assets

- 3,107 km of waterways including the Gellibrand River and coastal wetlands.
- 47 wetlands (0.3% of area) with the coastal wetlands of the Lower Gellibrand River as significant assets.
- Native vegetation conservation significance potential: 11.0% of total landscape zone is very high, 17.1% of total landscape zone is high. Many of these are included in national parks and state parks.
- 548 km of roads, including part of the Great Ocean Road.
- Coastal assets include beaches, coastal cliffs, sea stacks (i.e. the Twelve Apostles), marine parks and sanctuary, cultural and heritage assets, including Aboriginal archaeological sites, shipwrecks and buildings.

Threats

To public assets

- *Landslides*. There are 392 intersections (at least 3308 ha) of mapped landslides within 50 m of waterways, especially the Lower Gellibrand River tributaries (LaTrobe Creek, Boggy Creek), Johanna River and Stafford Creek, and the headwaters of the Kennedy Creek system. Roads are known to be at risk (e.g. Princetown – Simpson Road) and considerable efforts have been made for stabilisation. There are 242 landslides mapped on public land.
- *Soil erosion by water.* Three gullies and 26 sheet/rill erosion sites are mapped within 50 m of a waterway, as relatively small-sized incidences in the tributaries to Kennedys Creek and the Gellibrand River. Sediment and nutrient export to the Kennedys Creek system and the Lower Gellibrand River tributaries (LaTrobe Creek, Boggy Creek) is of some concern, with the likely sources being run-off from fertilised pastures and farm tracks and dairy effluent.

- *Potential acid sulphate soils.* Potential coastal and inland sites are mapped on 172 ha of public land, and intersect around 350 ha of native vegetation with very high or high conservation significance potential, 220 ha of wetlands, 28 km of waterways and 20 km of roads. The vast majority occur along the Lower Gellibrand River and associated coastal wetlands.
- *Secondary salinity.* Secondary salinity affects 35 ha of public land in the Lower Gellibrand River, and 103 ha of native vegetation with very high or high conservation significance potential, 105 ha of wetlands, 114 ha within 50 m of a waterway and 6.6 ha within 50 m of a road. The majority occurs along the Lower Gellibrand River, north of Princetown and as small outbreaks in the Kennedys Creek catchment.

To private assets

- *Susceptibility to soil structure decline.* Approximately 86% (25,066 ha) of dairy land and 63% (7,370 ha) of grazing land is highly susceptible to soil structure decline, mostly by soil pugging of wet soils in the Heytesbury Settlement.
- *Susceptibility to soil waterlogging.* Around 37% (10,920 ha) of dairy land is very highly susceptible to waterlogging, and 30% (8,792 ha) is highly susceptible to waterlogging; 16% (1,891 ha) of grazing land is very highly susceptible to waterlogging, and 15% (1,761 ha) is highly susceptible to waterlogging. The most severe threats are in the areas east of Simpson, north of Kennedys Creek and around Princetown.
- *Landslides.* On land used for dairying, 129 landslides have been mapped, up to 200 ha in size. Most occur east of Simpson around Kennedys Creek and in the Princetown area. One dairy farm (house, dairy, sheds) is known to have been destroyed by a landslide. There are 80 landslides mapped on grazing land.
- *Soil erosion by water.* A few gully erosion sites and 11 sheet/rill sites have been mapped on dairy land, and 21 sheet/rill sites on grazing land. Although they cover a relatively small total area (~ 100 ha), they may be underestimated by the mapping techniques.
- *Secondary salinity.* Approximately 60 ha of dairy and 60 ha of grazing land are affected on the eastern side of the landscape zone, bordering the Heytesbury Settlement.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C4):*

- landslides poses the greatest risk to assets in the Gellibrand Landscape Zone and is ranked number one for all soil-related threatening processes in the Corangamite region
- secondary salinity, acid sulphate soils, sheet/rill erosion, soil structure decline, waterlogging and nutrient decline all pose moderate to high risk to assets in the Gellibrand Landscape Zone
- wind erosion, soil acidification and gully/tunnel erosion pose little risk in the Gellibrand Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Landslides	1	3167
2. Secondary salinity	28	424
3. Acid sulphate soils	32	398
4. Sheet/rill erosion	33	336
5. Soil structure decline	37	273
6. Waterlogging	=38	270
7. Soil nutrient decline	=38	270
8. Wind erosion	99	102
9. Soil acidification	=108	81
10. Gully/tunnel erosion	128	31

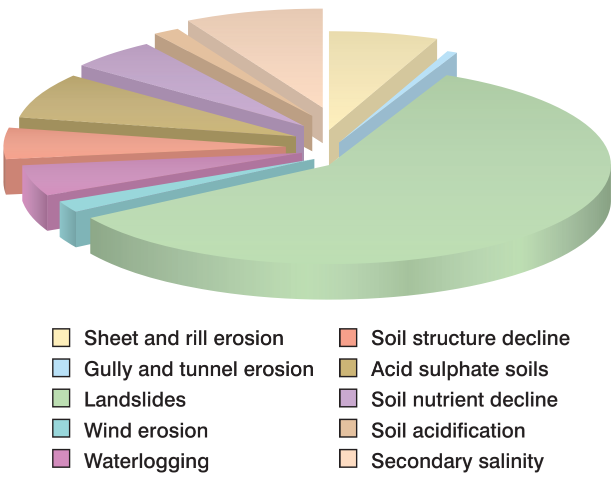


Figure C4: The rank and Relative Risk Values for soil-threatening processes in the Gellibrand Landscape Zone

C.3 Bellarine

- **53,625 hectares or 4.0% of Corangamite CMA region**
- **11% public land**

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	20	290.8	0.5
Conservation	429	5378.3	10.0
Cropping	128	3856.2	7.2
Forestry	18	357.8	0.7
Grazing	339	28004.7	52.2
Horticulture	42	449.7	0.8
Infrastructure	147	663.6	1.2
Mining	12	741.8	1.4
Peri-urban	180	2462.4	4.6
Urban	2412	7754.2	14.5
Water	11	196.8	0.4
Total	**3738**	**50156.3**	**93.5**

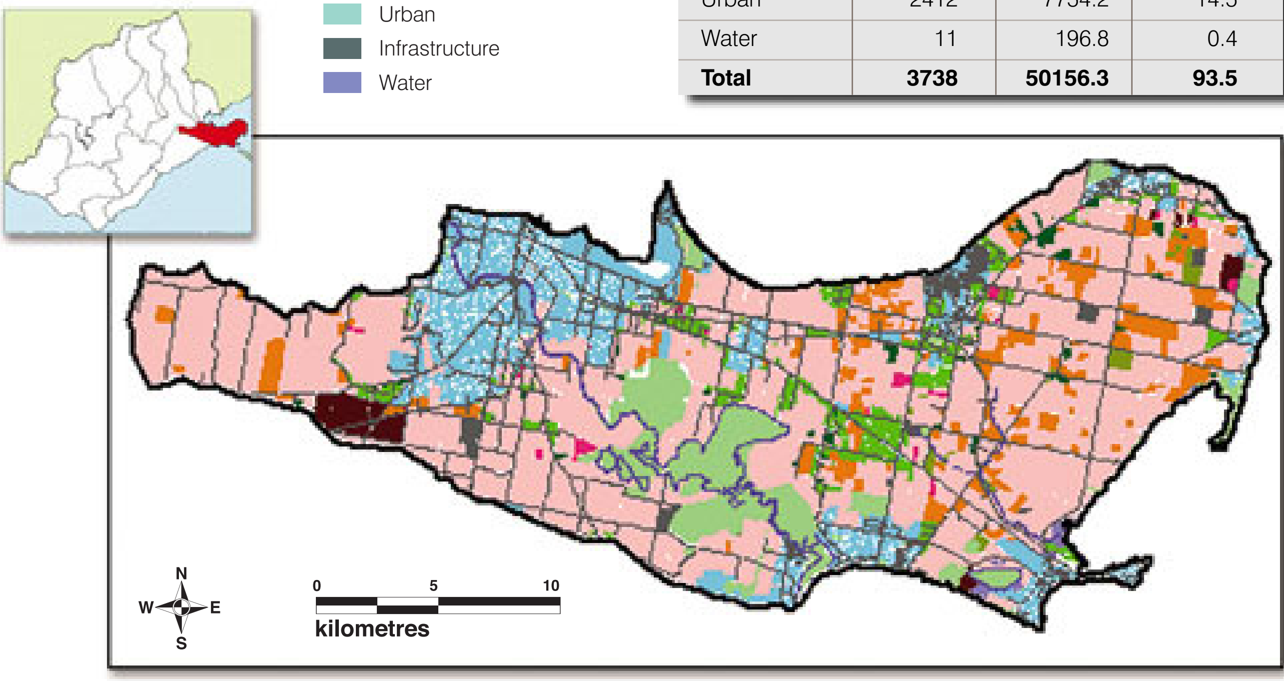


Figure C5: Land use in the Bellarine Landscape Zone in 2000-2002

Assets

- 425 km of waterways, including the Lower Barwon River in Geelong.
- 139 wetlands (9.6% of area), including wetlands of international, national, State and local significance. The Lake Connewarre State Game Reserve is highly ranked.
- Native vegetation conservation significance potential: 9% of total landscape zone is rated as very high, 14% of total landscape zone is rated as high.
- At least 1,243 km of roads, not including many of the urban roads in more recent subdivisions.
- City of Greater Geelong, including industrial and port facilities.
- Cultural and heritage assets include many Aboriginal archaeological sites and Victoria's early pastoral settlement history. Coastline and marine parks.

Threats

To public assets

- *Landslides.* Nine landslide intersections with waterways and five landslides occur on public land. Infrastructure and coastal assets are threatened along the northern coast of the Bellarine Peninsula east of Point Henry (i.e. the Curlewis Monocline), especially at Clifton Springs. Landslides also threaten infrastructure and waterways at Waurn Ponds, and rockfalls are prevalent along the coast at Point Lonsdale and Barwon Heads.
- *Soil erosion by water.* Sediments and nutrients are contributed to Lake Connewarre and Lower Barwon River wetlands by stormwater run-off and erosion in the higher catchment areas. Twenty-seven gullies (76.4 ha) and seven sheet erosion sites (26 ha) occur within a 50 m buffer of waterways.

- *Secondary salinity.* Approximately 300 ha of secondary salinity have been mapped. Secondary salinity threatens 42 ha of native vegetation with very high conservation significance potential and 119 ha of native vegetation with high conservation significance potential, as well as 3 km of waterways and 2.5 km of roads. The majority of the secondary salinity fringes the primary salinity sites, especially the wetlands.
- *Potential acid sulphate soils.* Sixty-eight polygons of potential acid sulphate soils have been mapped, totalling 4,112 ha (7.7% of area), mostly in coastal and estuarine wetlands of the Lower Barwon River and estuary. Potential for disturbance is highest in the Point Henry environs. Over 2,000 ha of native vegetation with high or very high conservation significance potential are intersected, along with 2,170 ha of wetlands, 46.5 km of waterways (465 ha within a 50 m buffer) and 57 km of roads (571 ha within a 50 m buffer).

To private assets

- *Susceptibility to soil erosion by wind.* Over 10,000 ha of the landscape zone are highly susceptible to wind erosion, mostly in the Wallington, Drysdale, Bellarine, Indented Head and St Leonards areas. Coastal dune movement is prevalent in the Queenscliff, Point Lonsdale, Ocean Grove and Barwon Heads areas.
- *Susceptibility to soil nutrient decline.* Over 8,000 ha of grazing land and 1,400 ha of cropping land with sandy soils (developed on the marine sands of Pliocene age) on the Bellarine Peninsula (Bellarine Horst) are highly susceptible to nutrient decline under agricultural production.
- *Susceptibility to soil acidification.* The same sandy soils that are susceptible to soil nutrient decline are also susceptible to soil acidification.
- *Contaminants.* At least 41 known sites scattered across the Bellarine Peninsula, east of an arc through Point Henry – Moolap – Barwon Heads.
- *Susceptibility to soil structure decline.* Nearly all of the land used for agriculture is highly susceptible to soil structure decline (23,000 ha), with the exception of the soils developed on the elevated volcanic landscapes around Mount Drysdale.
- *Susceptibility to soil waterlogging.* Approximately 1,435 ha of agricultural land are very highly susceptible and 18,875 ha are highly susceptible to soil waterlogging. The vast majority are the grazing lands in the low elevation landscapes of the Moolap Sunkland, along the Lower Barwon River estuary.
- *Soil erosion by water.* Twenty-seven gullies (76 ha) and seven sheet erosion sites (24 ha) occur on agricultural land, almost all of which are on the grazing land on the edges of the elevated part of the Bellarine Peninsula (i.e. the Bellarine Horst).

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C6):*

- acid sulphate soils pose the greatest potential risk to assets in the Bellarine Landscape Zone and the third greatest of all soil threatening processes in the Corangamite region
- secondary salinity and gully/tunnel erosion also pose a high risk to assets in the Bellarine Landscape Zone
- soil structure decline, soil acidification, waterlogging, wind erosion, sheet/rill erosion, landslides and soil nutrient decline all pose low to moderate risk to assets.

Soil threatening process	Rank across entire region	Relative risk values
1. Acid sulphate soils	3	2748
2. Secondary salinity	25	485
3. Gully/tunnel erosion	34	317
4. Soil structure decline	=70	167
5. Soil acidification	=70	167
6. Waterlogging	=74	160
7. Wind erosion	=78	145
8. Sheet/rill erosion	91	120
9. Landslides	92	119
10. Soil nutrient decline	=94	113

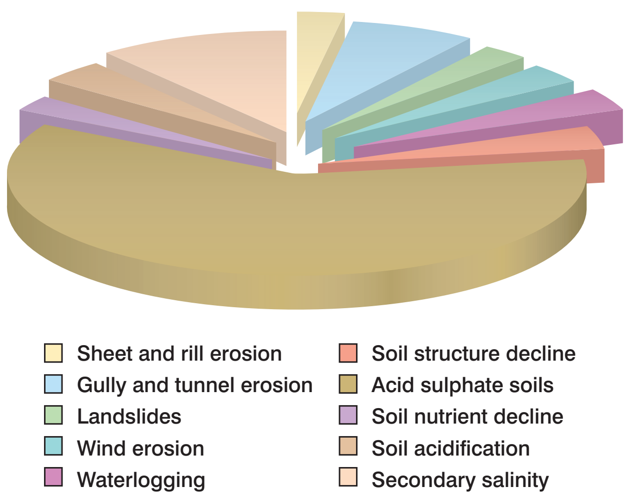
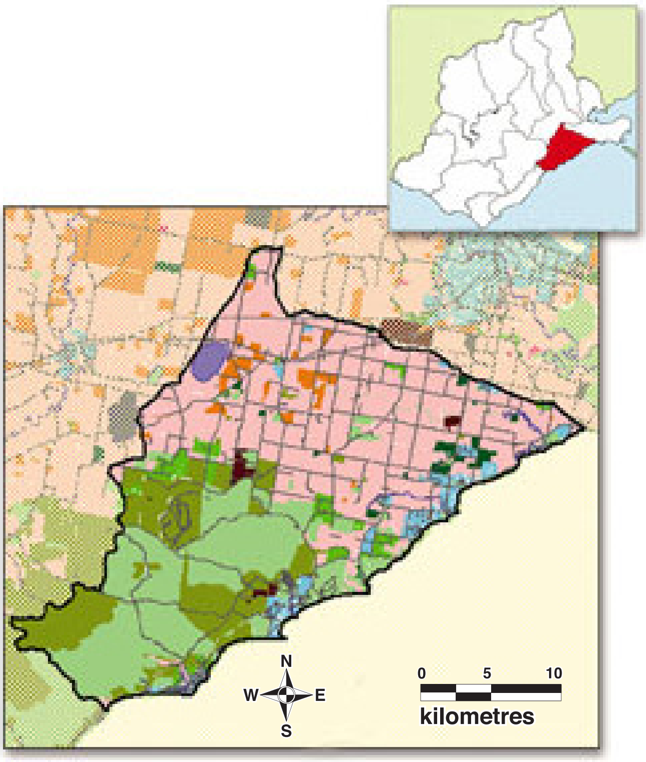


Figure C6: The rank and Relative Risk Values for soil-threatening processes in the Bellarine Landscape Zone

C.4 Thompsons

- 62,626 hectares or 4.7% of Corangamite CMA region
- 33.3% public land



Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	174	16334.9	26.1
Cropping	41	1326.0	2.1
Forestry	68	9348.2	14.9
Grazing	185	27499.9	43.9
Horticulture	27	771.3	1.2
Infrastructure	29	182.0	0.3
Mining	7	455.8	0.7
Peri-urban	59	2049.2	3.3
Urban	381	2258.2	3.6
Water	1	532.6	0.9
Total	**972**	**60758.1**	**97.0**

Figure C7: Land use in the Thompsons Landscape Zone in 2000-2002

Assets

- 1,048 km of waterways and 56 wetlands (1.9% of area).
- Native vegetation conservation significance potential: 4.6% of total is very high and 25.6% of total is high in the landscape zone.
- 713 km of roads, not including the more recently subdivided areas of Torquay and other coastal towns.
- Coastal assets including beaches, cliffs and shore platforms, which are highly valued as tourist assets. Cultural and heritage assets including Aboriginal archaeological sites are associated with the coast.

Threats

To public assets

- *Potential acid sulphate soils.* In both inland and coastal locations, the mapped potential for acid sulphate soils intersects with nearly 36 km of waterways and 13 km of roads. About 470 ha of native vegetation with high or very high conservation significance potential is intersected, along with 277 ha of public land and 243 ha of wetlands. The largest sites are the Breamlea wetlands and Lower Thompson Creek, followed by the wetlands of Marshy Creek and Salt Creek (Lower Anglesea River), and Lower Painkalac Creek.
- *Landslides.* There are 17 intersections of landslides and waterways, and 129 landslides on public land. Almost all occur along the coastline south of Jan Juc, with Point Addis and Eastern View areas recording the most.

- *Erosion by water.* Nine gully erosion sites (10 ha) and 46 (34 ha) sheet/rill erosion sites occur within 50 m of waterways, with Thompson Creek and Spring Creek recording the most. Approximately 25 ha of native vegetation of very high and high conservation significance is threatened by erosion, along the coast and along waterways. There are 11 intersections of roads with erosion, mostly sheet/rill erosion (57 ha) and 51 sheet/rill erosion sites (1,075 ha) are mapped on public land.

To private assets

- *Susceptibility to soil waterlogging.* Alluvial soils in the low-lying poorly-drained landscape positions are very highly susceptible to waterlogging and include 1,037 ha of grazing land. Around 76% (20,948 ha) of grazing land, 47% (4,400 ha) of forest land and 73% (973 ha) of cropping land is highly susceptible. These occur in widespread areas across the northern portion of the landscape zone.
- *Susceptibility to soil structure decline.* Almost all of the agricultural land (95%) is highly susceptible to soil structure decline. This includes 26,061 ha of grazing land and 1,127 ha of cropping land. Similarly, 77% (7,168 ha) of forest land is highly susceptible to soil structure decline.
- *Susceptibility to soil nutrient decline.* Around 4,100 ha of forest country and 755 ha of grazing country is very highly susceptible to soil nutrient decline. This includes the sandy and gravelly soils of the Anglesea hinterland in the southern portion of the landscape zone. The sandy soils of the northern portion (i.e. north of Point Addis to Moriac) include 14,268 ha of grazing country, 2,595 ha of forest country and 495 ha of cropping country which are highly susceptible to soil nutrient decline.
- *Susceptibility to soil acidification.* The areas described above as susceptible to nutrient deficiency are also susceptible to soil acidification. These include around 15,000 ha of grazing land, 6,700 ha of forest land and 500 ha of cropping land.
- *Susceptibility to soil erosion by wind.* The soils of around 4,365 ha of grazing land east of Paraparap and in the area west of Mt Moriac are highly susceptible to wind erosion.
- *Erosion by water.* There are 28 sheet/rill erosion sites (28 ha) and eight gully erosion sites (10 ha) mapped on grazing land, mostly south of Connewarre and north of Torquay.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C8):*

- Sheet/rill erosion poses the greatest risk to assets in the Thompsons Landscape Zone, which is the ninth highest risk to assets across all soil-threatening processes in the Corangamite region
- acid sulphate soils pose the second greatest risk to assets in the Thompsons Landscape Zone, which is ranked number 19 out of all soil-threatening processes in the Corangamite region
- landslides also pose a high risk to assets in the Thompsons Landscape Zone
- secondary salinity, wind erosion, soil structure decline, soil nutrient decline and waterlogging pose a moderate risk to assets in the Thompsons Landscape Zone
- soil acidification and gully/tunnel erosion pose a low risk to assets in the Thompsons Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Sheet/rill erosion	9	1804
2. Acid sulphate soils	19	557
3. Landslides	22	518
4. Secondary salinity	49	233
5. Wind erosion	64	195
6. Soil structure decline	=66	184
7. Soil nutrient decline	73	164
8. Waterlogging	=74	160
9. Soil acidification	90	127
10. Gully/tunnel erosion	129	28

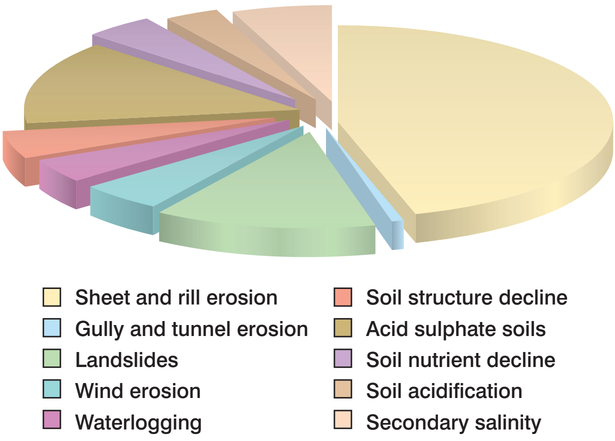


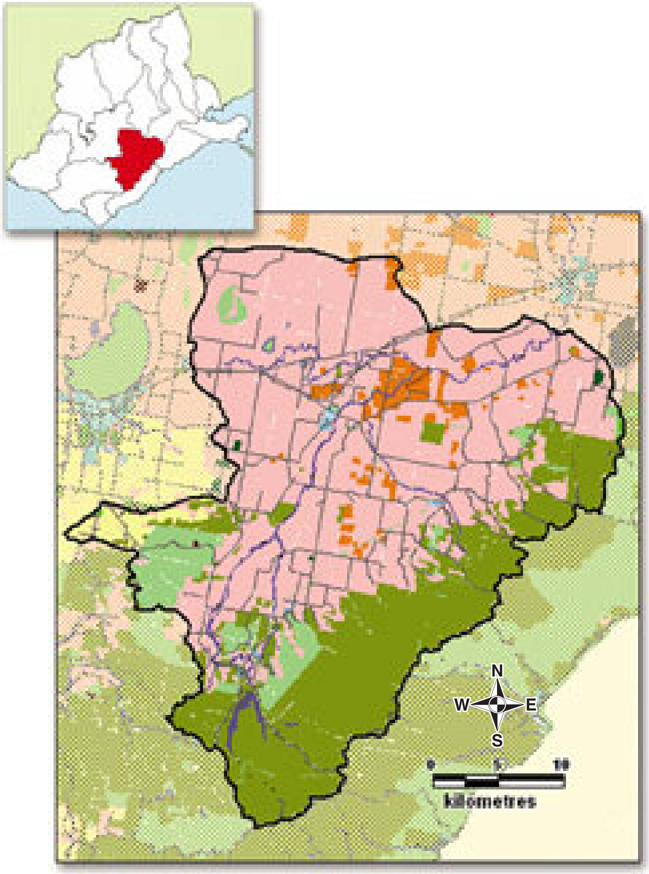
Figure C8: The rank and Relative Risk Values for soil-threatening processes in the Thompsons Landscape Zone

C.5 Upper Barwon

- 97,590 hectares or 7.3% of Corangamite CMA region
- 28.1% public land.

Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	212	6546.8	6.7
Cropping	59	3602.2	3.7
Dairy	24	1614.5	1.7
Forestry	248	27590.1	28.3
Grazing	369	55200.9	56.6
Horticulture	6	141.0	0.1
Infrastructure	24	397.4	0.4
Mining	4	16.0	0.0
Peri-urban	5	111.3	0.1
Urban	68	253.1	0.3
Water	3	22.6	0.0
Total	**1022**	**95495.9**	**97.9**

Figure C9: Land use in the Upper Barwon Landscape Zone in 2000-2002

Assets

- 1,822 km of waterways including the Barwon River.
- 53 wetlands (1.0% of area) including The Sanctuary (Lake Thurrumbong).
- Native vegetation conservation significance potential: 3.2% of total landscape zone is very high, 15.9% of total landscape zone is high. Most are included in the Otway Ranges.
- 533 km of roads and rural infrastructure. Birregurra is the main urban centre.

Threats

To public assets

- *Erosion by water.* There are 28 (124 ha) gully erosion sites and 40 (141 ha) sheet/rill erosion sites mapped within 50 m of waterways, with Wormbete Creek, Yan Yan Gurt Creek and the Barwon River recording the most. Approximately 43 ha of native vegetation of high conservation significance are threatened by erosion, mostly along the waterways. There are 10 intersections of roads with erosion, with gully sites and sheet/rill sites covering approximately 43 ha each. Examples occur along Cape Otway Road and Coalmine Road. Eight erosion sites (163 ha) are mapped on public land.

- *Landslides.* There are 148 landslides mapped within 50 m of a waterway, including several larger slides which have occurred along the western flanks of the Barwon River valley, south of Birregurra. Around 34 landslides intersect with high-value native vegetation and 56 occur on public land, and almost all are on the flanks of the Otway Ranges.
- *Secondary salinity.* Around 265 ha of secondary salinity have been mapped within 50 m of a waterway and 46 ha within 50 m of a road. Most occurs in a widespread distribution along drainage lines and landscape depressions from Gerangamete in the south to Warncoort in the west to near Bambra in the east.

To private assets

- *Susceptibility to soil waterlogging.* Around 9% (4,755 ha) of grazing land has a very high susceptibility to waterlogging, mostly occurring in the Gerangamete – Barwon Downs area. Approximately 60% (33,256 ha) of grazing land, 84% (3,035 ha) of cropping land and 39% (623 ha) of dairy land has a high susceptibility to waterlogging. This constitutes almost all of the landscapes north of the Otway Ranges to Birregurra Creek and the Barwon River.
- *Erosion by water.* There are 23 gully erosion sites (68 ha) and 42 sheet/rill erosion sites (99 ha) mapped on grazing land, mostly in the Bambra, Wensleydale and Wormbete areas. Some relatively small-scale sheet/rill erosion sites are mapped on cropping land and dairy land.
- *Susceptibility to soil structure decline.* Nearly 83% (45,617 ha) of grazing land, 89% (24,577 ha) of forest land, 84% (3,013 ha) of cropping land and 39% (622.8 ha) of dairy land is highly susceptible to soil structure decline.
- *Susceptibility to soil nutrient decline.* About 20% (11,284 ha) of grazing land, 68% (1,095 ha) of dairy land and 13% (3,537 ha) of forestry land is very highly susceptible to soil nutrient decline. The area occurs as a broad band of sandy soils from north of the West Barwon Reservoir to Barongarook and across to Whoorel, excluding the river flats of the Barwon River valley. Smaller scattered areas of sandy soil (4,856 ha grazing, 596 ha forest, 272 ha cropping) are highly susceptible.
- *Susceptibility to soil acidification.* The soils susceptible to nutrient deficiency are also highly susceptible to acidification. These include 16,139 ha of grazing land, 4,132 ha of forestry land and 1,095 ha of dairy land.
- *Susceptibility to soil erosion by wind.* Around 5,400 ha of grazing land and 973 ha of dairy land are highly susceptible to wind erosion. These areas are north-west of Warncoort and include the general area from Yeodene to Barongarook.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C10):*

- landslides, sheet/rill erosion and gully/tunnel erosion pose the greatest risk to assets in the Upper Barwon Landscape Zone, being ranked 14, 16 and 17 respectively
- secondary salinity also poses a high risk to assets in the Upper Barwon Landscape Zone
- soil structure decline, waterlogging and soil nutrient decline pose a moderate risk to assets, while acid sulphate soils, soil acidification and wind erosion pose the lowest risk to assets in the Upper Barwon Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Landslides	14	917
2. Sheet/rill erosion	16	752
3. Gully/tunnel erosion	17	743
4. Secondary salinity	21	525
5. Soil structure decline	=40	268
6. Waterlogging	=50	232
7. Soil nutrient decline	59	217
8. Acid sulphate soils	=94	113
9. Soil acidification	=101	99
10. Wind erosion	=113	72

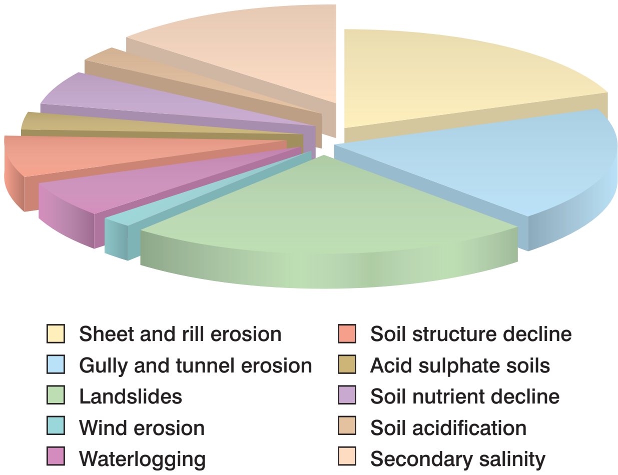


Figure C10: The rank and Relative Risk Values for soil-threatening processes in the Upper Barwon Landscape Zone

C.6 Curdies

- 119,393 hectares or 9.0% of the Corangamite CMA region
- 6.6% public land

Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	144	4969.2	4.2
Cropping	7	47.0	0.0
Dairy	449	97040.0	81.3
Forestry	13	2379.0	2.0
Grazing	586	13263.1	11.1
Infrastructure	4	20.7	0.0
Mining	12	118.0	0.1
Urban	150	437.8	0.4
Water	1	2.0	0.0
Total	**1366**	**118276.8**	**99.1**

Figure C11: Land use in the Curdies Landscape Zone in 2000-2002

Assets

- 1,891 km of waterways including the Curdies River and estuary.
- 93 wetlands (1.3% of area) including Lake Purrumbete.
- Native vegetation conservation significance potential: 6.6% of total landscape zone is rated as very high, 10.2% of total landscape zone is rated as high.
- 876 km roads, including a section of the Great Ocean Road.
- Coastline including beaches, coastal cliffs and sea stacks (e.g. Bay of Islands), marine sanctuary and marine parks which include significant cultural and heritage assets.

Threats

To public assets

- *Landslides.* At least 287 landslides occur within a 50 m buffer of waterways, especially along Scotts Creek, Curdies River, Cowley Creek and Port Campbell Creek (at least 4,895 ha). Roads are known to be at risk (e.g. Port Campbell – Cobden Road, Williams Road) and 46 landslides are mapped on public land. Rockfalls and landslides threaten coastal assets including the sea cliffs and areas of high scenic and recreational value.

- *Soil erosion by water.* There are 13 intersections of mapped gullies within 50 m of a waterway, especially in tributaries of the upper catchment of the Curdies River and Scotts Creek. Sediment and nutrient export to the Curdies Inlet is of concern, with dairy effluent and run-off from fertilised pastures and farm tracks being targeted as the most likely sources. Stream erosion forms deeply incised gullies along the coastal cliffs near Port Campbell.
- *Potential acid sulphate soils.* These intersect with 68 ha of native vegetation with very high and high conservation significance potential, 32 ha of wetlands, 22 km of waterways (219 ha within a 50 m buffer) and 1.6 km of roads. Most intersections are along the Lower Curdies River and estuary.
- *Secondary salinity.* This affects 4.7 ha of public land near Scotts Creek, 31 ha of native vegetation with very high and high conservation significance potential, 119 ha within 50 m of a waterway and 24 ha within 50 m of a road.

To private assets

- *Susceptibility to soil structure decline.* Nearly 80% (77,087 ha) of dairy land and 49% (6,500 ha) of grazing land is highly susceptible to soil structure decline. Soil pugging (or poaching) by animals is the primary cause of soil structure decline, with the clay soils (Gellibrand Marl) of the Heytesbury Settlement worst affected.
- *Susceptibility to soil waterlogging.* About 12% (11,520 ha) of dairy land is very highly susceptible to waterlogging and 75% (73,049 ha) is highly susceptible to waterlogging. The most severe threat is in the area around Waarre, Cooriemungle and Simpson. Of the grazing lands, 5% (642 ha) is very highly susceptible to waterlogging and 52% (6,861 ha) is highly susceptible to waterlogging.
- *Landslides.* At least 429 landslides have been mapped on dairy land (4,665 ha), ranging up to 150 ha in size. Most occur west of Simpson around Scotts Creek and Cowleys Creek, also Cooriemungle, Newfield and Port Campbell. Eighteen are mapped on grazing land.
- *Susceptibility to soil nutrient decline.* Of the land used for dairy farming, around 300 ha are very highly susceptible and over 30,000 ha are highly susceptible to nutrient decline under agricultural production. These are mostly the sandy loams and coffee-rock soils around Simpson, Jancourt, Timboon, Nirranda, Peterborough and Curdie Vale.
- *Secondary salinity.* This affects around 330 ha of dairy land and 30 ha of grazing land, mostly as small outbreaks in the lower slopes of the Heytesbury Settlement.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C12):*

- landslides pose the greatest risk to assets in the Curdies Landscape Zone, being ranked the 7th highest risk to assets amongst all soil-related threatening processes in the Corangamite region
- waterlogging, soil structure decline and secondary salinity also pose a high risk to assets in the Curdies Landscape Zone
- soil nutrient decline, soil acidification and acid sulphate soils pose a moderate risk to assets in the Curdies Landscape Zone
- wind erosion, sheet/rill erosion and gully/tunnel erosion pose a low risk to assets in the Curdies Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Landslides	7	1903
2. Waterlogging	26	482
3. Soil Structure Decline	29	416
4. Secondary Salinity	31	399
5. Soil Nutrient Decline	68	175
6. Soil Acidification	69	173
7. Acid Sulphate Soils	81	141
8. Wind Erosion	117	65
9. Gully/tunnel erosion	119	54
10. Sheet/rill erosion	138	13

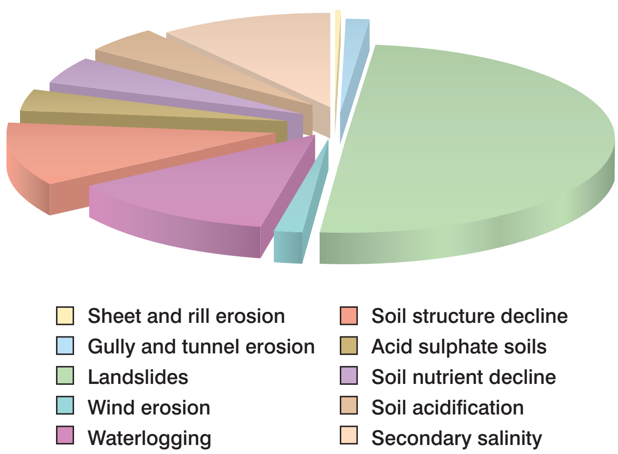
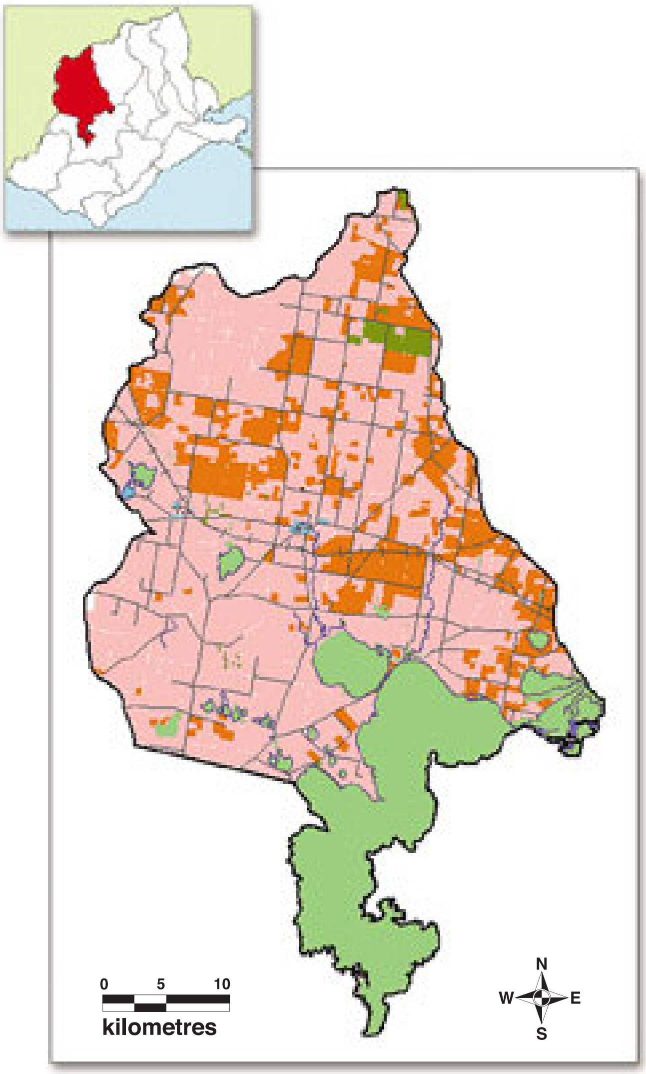


Figure C12: The rank and Relative Risk Values for soil-threatening processes in the Curdies Landscape Zone

C.7 Lismore

- 153,742 hectares or 11.5% of Corangamite CMA region
- 20.9% public land



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	88	31574.5	20.5
Cropping	229	26016.9	16.9
Forestry	24	1530.9	1.0
Grazing	402	90332.4	58.8
Infrastructure	23	163.5	0.1
Mining	1	5.6	0.0
Urban	55	308.3	0.2
Water	2	405.4	0.3
Total	**824**	**150337.4**	**97.8**

Figure C13: Land use in the Lismore Landscape Zone in 2000-2002

Assets

- 736 km of waterways and 187 wetlands (22.5% of area), including Ramsar and significant wetlands, such as Lake Corangamite.
- Native vegetation conservation significance potential: 0.9% of total landscape zone is very high, 3.9% of total landscape zone is high.
- 622 km of roads, including highways. Other infrastructure includes significant railway and power lines.
- Cultural and heritage assets, especially Aboriginal archaeological sites associated with the lakes, waterways and wetlands.

Threats

To public assets

- *Secondary salinity.* Eighty-six sites totalling 1,973 ha of secondary salinity are mapped in the landscape zone. About 580 ha of secondary salinity occur on public land, almost all of which is around Lake Martin. More than 100 ha of native vegetation with very high and 160 ha with high conservation significance potential intersect with secondary salinity, with a scattered distribution. More than 345 ha of land within 50 m of a waterway and 43.5 ha of land within 50 m of a road are affected by secondary salinity.

- *Potential acid sulphate soils.* Potential inland acid sulphate soils intersect 100 ha of high-value native vegetation, 215 ha of wetlands, 18 km of waterways, and 2 km of roads. All areas are associated with the margins of the wetlands in the southern portion of the landscape zone.

To private assets

- *Secondary salinity.* About 983 ha of grazing land and 85 ha of cropping land are affected by secondary salinity. Many areas fringing primary saline areas, including wetlands, are affected, especially around Lake Martin and Derrinallum.
- *Susceptibility to soil structure decline.* About 10% (2,723 ha) of cropping land and 24% (21,750 ha) of grazing land is highly susceptible to soil structure decline, especially around Leslie Manor, Lismore and Derrinallum.
- *Susceptibility to soil waterlogging.* Around 5% (1,379 ha) of cropping land and 12% (11,056 ha) of grazing land is very highly susceptible to waterlogging, mostly south of Lismore, Derrinallum and Cressy. Approximately 69% (17,980 ha) of cropping land and 59% (53,210 ha) of grazing land is highly susceptible to waterlogging, in widespread locations north-west of Berrybank and west of Leslie Manor.
- *Susceptibility to soil nutrient decline.* Approximately 1,133 ha of grazing country, 715 ha of cropping country and 100 ha of forest country are very highly susceptible to soil nutrient decline, being almost all the granitic landscapes around Lismore and north-west of Lismore. The sandy soils around Leslie Manor and Lake Gnarpurt are highly susceptible, including 13,640 ha of grazing land and 2,158 ha of cropping land.
- *Susceptibility to soil acidification.* The soils susceptible to soil nutrient decline are also susceptible to soil acidification, with the same regions and statistics as above.
- *Susceptibility to soil erosion by wind.* The soils of 14,466 ha of grazing country and 1,084 ha of cropping country are highly susceptible to wind erosion. These include the sandy soil plains around Leslie Manor and the alluvial clay pans associated with low-lying poorly-drained areas such as ephemeral wetlands.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C14):*

- secondary salinity poses the greatest risk to assets in the Lismore Landscape Zone, which was ranked the second-greatest relative risk amongst all soil-related threatening processes across the Corangamite region
- waterlogging, acid sulphate soils and soil structure decline all pose a moderate risk to assets in the Lismore Landscape Zone
- wind erosion, soil nutrient decline, soil acidification, gully/tunnel erosion and sheet/rill erosion pose a low risk to assets in the Lismore Landscape Zone
- no landslides are found in the Lismore Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Secondary Salinity	2	2886
2. Waterlogging	53	228
3. Acid Sulphate Soils	=55	225
4. Soil Structure Decline	72	165
5. Wind Erosion	112	78
6. Soil Nutrient Decline	=120	49
7. Soil Acidification	=120	49
8. Gully/tunnel erosion	130	27
9. Sheet/rill erosion	132	24
10. Landslides	=143	0

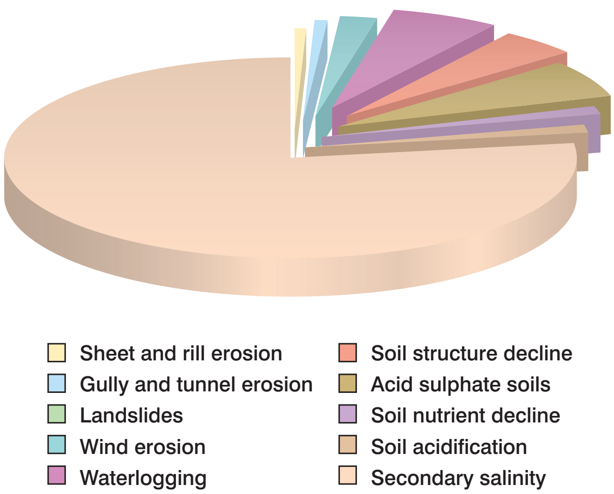


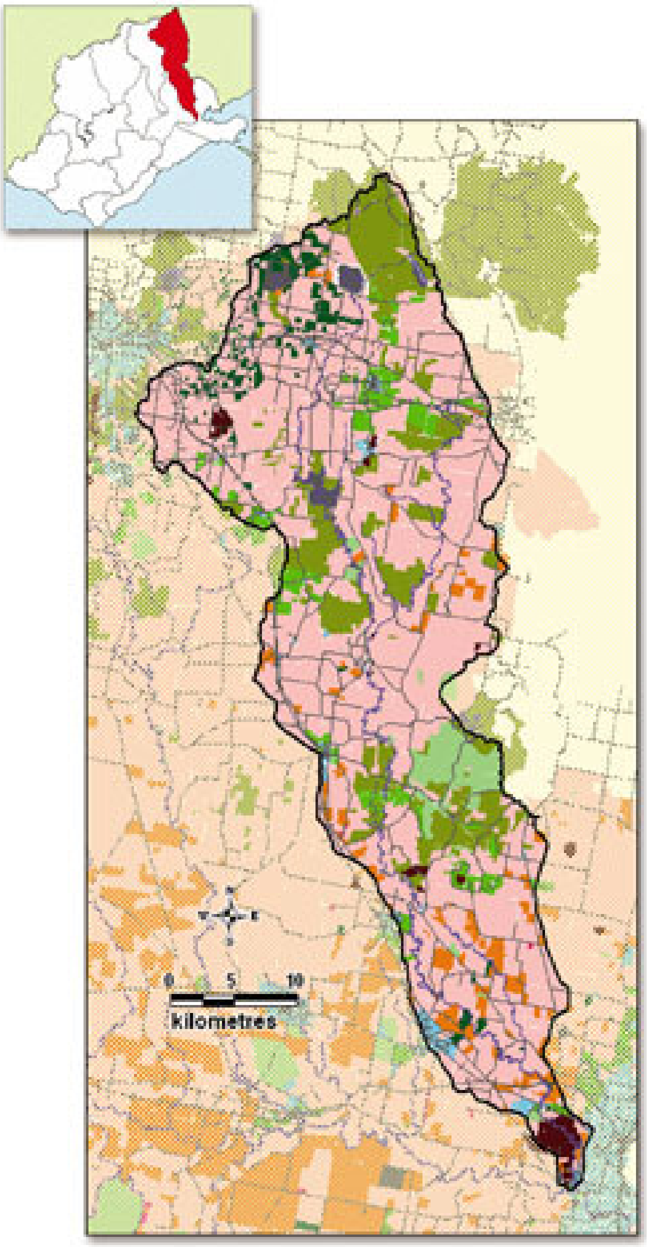
Figure C14: The rank and Relative Risk Values for soil-threatening processes in the Lismore Landscape Zone

C.8 Moorabool

- **115,407 hectares or 8.7% of Corangamite CMA region**
- **13.9% public land**

Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	5	34.4	0.0
Conservation	152	4352.3	3.8
Cropping	97	4808.3	4.2
Forestry	138	15742.6	13.6
Grazing	783	73598.7	63.8
Horticulture	136	2909.5	2.5
Infrastructure	44	1636.5	1.4
Mining	16	1522.1	1.3
Peri-urban	148	4819.1	4.2
Urban	288	1363.3	1.2
Water	4	88.2	0.1
Total	**1811**	**110874.9**	**96.1**

Figure C15: Land use in the Moorabool Landscape Zone in 2000-2002

Assets

- Urban water supply catchments for the City of Ballarat, City of Greater Geelong and other urban centres (e.g. Meredith & Bannockburn).
- 2,151 km of waterways, including the Moorabool River and tributaries. 132 wetlands (1.1% of area). High-value groundwater resources (Bungaree Groundwater Management Area).
- Native vegetation conservation significance potential: 9.3% of total landscape zone is very high, 16.6% of total landscape zone is high.
- 978 km of roads, excluding the more recently constructed urban and peri-urban roads of newer subdivisions around Geelong and Ballarat. Extensive peri-urban development.

Threats

To public assets

- *Soil erosion due to water.* Waterways intersect with 145 mapped gully sites (226 ha) and 169 mapped sheet/rill sites (272 ha). Most severe are Eclipse Creek, Tea Tree Creek, Anakie Creek and Deadman Gully. There are nine intersections (24 ha) of mapped gully erosion with native vegetation of very high conservation significance potential, and 40 intersections (48 ha) with native vegetation of high conservation significance potential. Similarly, there are 18 intersections (22 ha) of mapped sheet/rill erosion with native vegetation of very high conservation significance potential, and 48 intersections (94 ha) with native vegetation of high conservation significance potential. The vast majority of these are associated with drainage lines in the area between Morrisons and Gheringhap. There are 15 intersections of roads with gully erosion and 24 intersections with sheet/rill erosion sites.
- *Landslides.* Eighteen landslides intersect with waterways, mostly along the Moorabool River. Recently, remediation has been necessary to protect a main water supply pipeline.

To private assets

- *Soil erosion due to water.* Around 138 gullies, totalling 216 ha, have been mapped on grazing land, along with 180 sheet/rill erosion sites (206 ha). There are some minor (< 10 ha) occurrences on cropping land and approximately 50 ha of forestry land. The vast majority of the land is in the Morrisons, Durdidwarrah, Sheoaks, Steiglitz, Maude and Anakie areas.
- *Susceptibility to soil waterlogging.* Extensive areas of river flats are very highly susceptible to soil waterlogging, which includes 12,330 ha of grazing land, 1,134 ha of cropping land, 1,358 ha of forestry land and 232 ha of horticultural land. Widespread areas that include 38,137 ha of soils used for grazing, 2,580 ha of soils used for cropping and 2,600 ha of soils used for forestry are highly susceptible to waterlogging.
- *Susceptibility to soil structure decline.* Almost all of the soils with the exception of the volcanic soils (krasnozems) east of Ballarat are highly susceptible to soil structure decline. This includes 50,290 ha of soils used for grazing, 2,568 ha of soils used for cropping, 14,130 ha of soils used for forestry and 400 ha of soils used for horticulture.
- *Susceptibility to soil nutrient decline.* Approximately 4,250 ha of grazing land on soils developed on granitic rocks, and soils developed on sands and gravel caps are very highly susceptible to soil nutrient decline. Widespread areas of non-volcanic soils which includes 21,670 ha of grazing land and 12,480 ha of forestry land are highly susceptible to soil nutrient decline.
- *Susceptibility to soil acidification.* Similar areas to those mentioned above (soil nutrient decline) are susceptible to soil acidification. Around 3,340 ha of grazing land in the granitic soil landscapes are very highly susceptible and 22,585 ha of grazing land on the non-volcanic soils are highly susceptible to soil acidification.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C16):*

- sheet/rill erosion and gully/tunnel erosion pose the greatest risk to assets in the Moorabool Landscape Zone, and according to relative risk were ranked 11th and 15th respectively out of all soil threatening processes in the Corangamite region
- waterlogging and soil structure decline pose a moderate to high risk to assets in the Moorabool Landscape Zone
- landslides, soil nutrient decline, soil acidification, acid sulphate soils, secondary salinity and wind erosion pose a relatively low risk to assets in the Moorabool Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Sheet/rill erosion	11	1154
2. Gully/tunnel erosion	15	893
3. Waterlogging	52	230
4. Soil structure decline	57	219
5. Landslides	82	136
6. Soil nutrient decline	83	135
7. Soil acidification	86	132
8. Acid sulphate soils	=88	130
9. Secondary salinity	100	101
10. Wind erosion	111	79

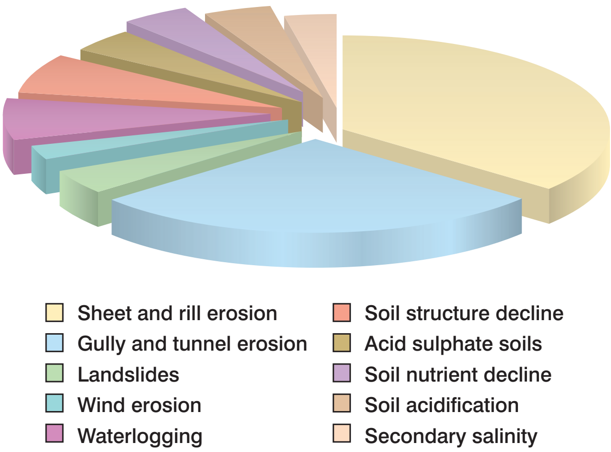


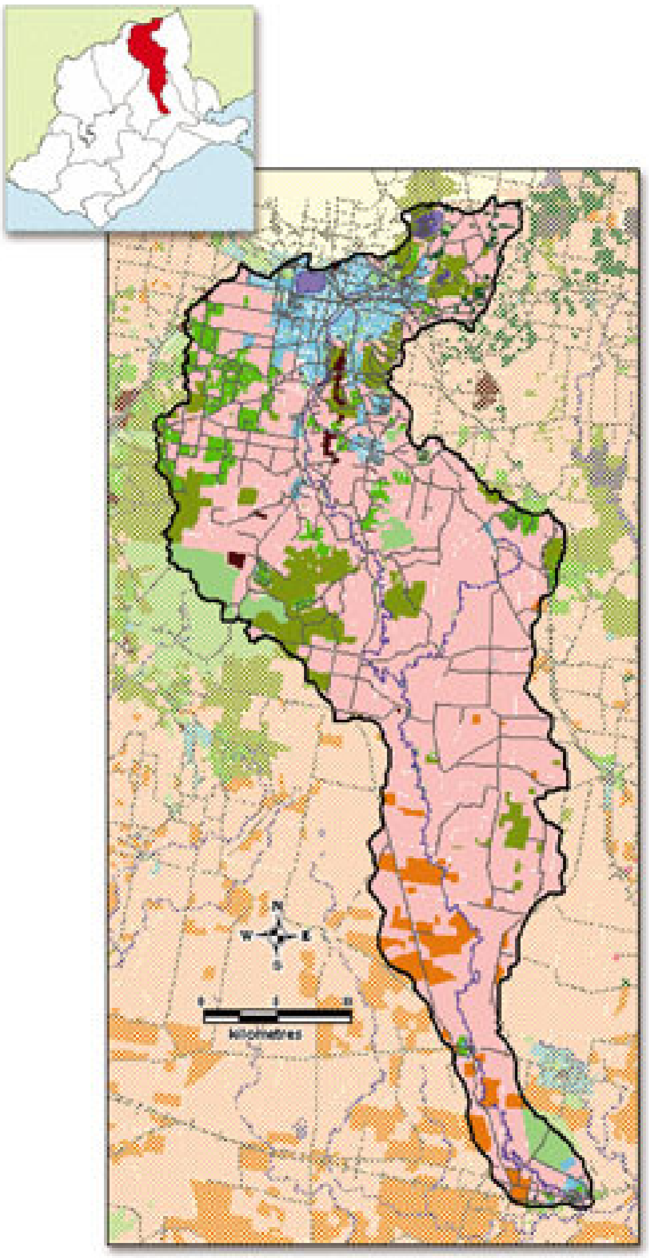
Figure C16: The rank and Relative Risk Values for soil-threatening processes in the Moorabool Landscape Zone

C.9 Leigh

- **88,765 hectares or 6.7% of Corangamite CMA region**
- **16.7% public land**

Land use

Conservation
Forestry
Cropping
Horticulture
Grazing
Dairy
Animal production
Mining
Peri-urban
Urban
Infrastructure
Water



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	352	4685.8	5.3
Cropping	52	3559.5	4.0
Forestry	115	7726.7	8.7
Grazing	779	57326.0	64.6
Horticulture	37	354.0	0.4
Infrastructure	132	517.2	0.6
Mining	29	506.9	0.6
Peri-urban	162	4358.2	4.9
Urban	1276	4779.9	5.4
Water	13	382.1	0.4
Total	**2947**	**84196.2**	**94.9**

Figure C17: Land use in the Leigh Landscape Zone in 2000-2002

Assets

- 1,689 km of waterways, including the Leigh River and Leigh River Gorge.
- 74 wetlands (0.8% of area), including Lake Wendouree which has high recreational value.
- Native vegetation conservation significance potential: 5.2% of total landscape zone is very high, 11.7% of total landscape zone is high.
- 1,224 km of roads, not including the more recently constructed urban roads in Ballarat.
- A portion of the City of Ballarat, which includes significant educational facilities, industry, mining, transport corridors and heritage assets.

Threats

To public assets

- *Soil erosion by water.* There are 178 mapped gullies (260 ha) and 128 mapped sheet/rill erosion sites (197 ha) that intersect with waterways (50 m buffer). The most extensive occurrences are along Woodbourne Creek, Lower Williamson Creek, the Yarrowee River downstream of Grenville and the Leigh River. Fifty-five mapped gully sites (85 ha) and 47 mapped sheet/rill sites (59 ha) intersect with native vegetation with very high and high conservation significance potential.

Thirteen road intersections with gullies (15 ha) and 10 with sheet/rill (12 ha) include the Mount Mercer – Meredith Road at Woodbourne Creek, Bamganie Road and minor rural roads in the Grenville, Bamganie and Woodbourne districts. Fifteen gullies (77 ha) and 27 sheet/rill sites (69 ha) are mapped on public land.

- *Secondary salinity.* Secondary salinity has been mapped on 3.8 ha of public land on or near the Buninyong Dredge Reserve. Nearly 300 ha of land is within 50 m of a waterway, 31 ha of land within 50 m of a road and 66 ha of native vegetation with very high and high conservation significance potential intersect with the mapped secondary salinity.
- *Potential acid sulphate soils.* Potential acid sulphate soils intersect with 9 km of waterways, 2 km of road and 42 ha of high-value native vegetation, mostly along the Yarrowee River.

To private assets

- *Soil erosion by water.* There are 162 gullies (240 ha) mapped on grazing land along with 127 mapped sheet/rill sites (203 ha). Almost all are in the Garabaldi, Grenville, Woodbourne and Bamganie districts. Other land uses (e.g. cropping, peri-urban, urban) record minor incidences (< 5 ha total).
- *Susceptibility to soil waterlogging.* Approximately 3,100 ha of grazing land and 600 ha of cropping land are very highly susceptible to soil waterlogging, all of which occur in the river flats of the Lower Leigh River valley. Approximately 3,600 ha of grazing land, 4,500 ha of forestry land and 650 ha of cropping land are highly susceptible to soil waterlogging.
- *Susceptibility to soil nutrient decline.* The granitic landscapes north of Warrenheip include over 200 ha of grazing land and 145 ha of forestry land which is very highly susceptible to soil nutrient decline. The sedimentary hills and gravel caps in the northern and central eastern parts of the landscape zone comprise over 25,000 ha of grazing land, 8,500 ha of forestry land and 285 ha of cropping land which is highly susceptible to soil nutrient decline.
- *Susceptibility to soil acidification.* Much of the same country which is susceptible to soil nutrient decline is also susceptible to soil acidification. The only variation is that about half the area of soil (181 ha) is very highly susceptible, but the same area is highly susceptible.
- *Susceptibility to soil structure decline.* Nearly all of the agricultural land in the landscape zone – over 42,000 ha of grazing country, 7,000 ha of forest land and 1,000 ha of cropping country – is highly susceptible to soil structure decline.
- *Susceptibility to soil erosion by wind.* About 11,000 ha of grazing land on the sandier soils in the middle of the landscape zone are highly susceptible to wind erosion.

Relative Risk to Assets

According to the relative risk to assets analysis results indicate *(Fig. C18):*

- gully/tunnel erosion and sheet/rill erosion pose the greatest risk to assets in the Leigh Landscape Zone, which were, according to relative risk, ranked 13th and 18th respectively out of all soil-threatening processes in the Corangamite region
- secondary salinity also poses a relatively high risk to assets in the Leigh Landscape Zone
- waterlogging, soil structure decline, soil acidification and soil nutrient decline pose a moderate risk to assets in the Leigh Landscape Zone
- wind erosion, acid sulphate soils and landslides pose a relatively low risk to assets in the Leigh Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Gully/tunnel erosion	13	938
2. Sheet/rill erosion	18	734
3. Secondary Salinity	24	502
4. Waterlogging	=62	196
5. Soil Structure Decline	65	192
6. Soil Acidification	84	134
7. Soil Nutrient Decline	85	133
8. Wind Erosion	=101	99
9. Acid Sulphate Soils	115	70
10. Landslides	=133	20

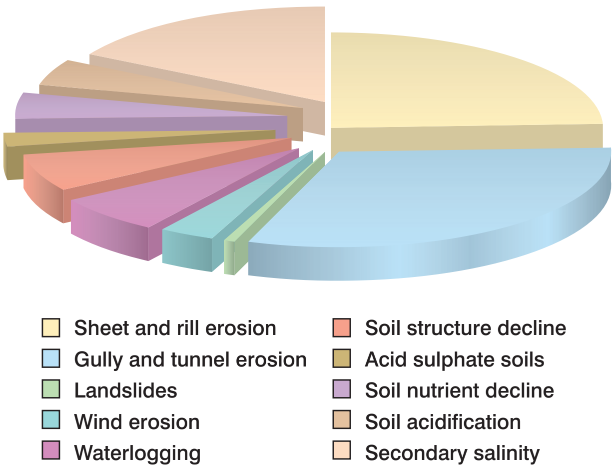
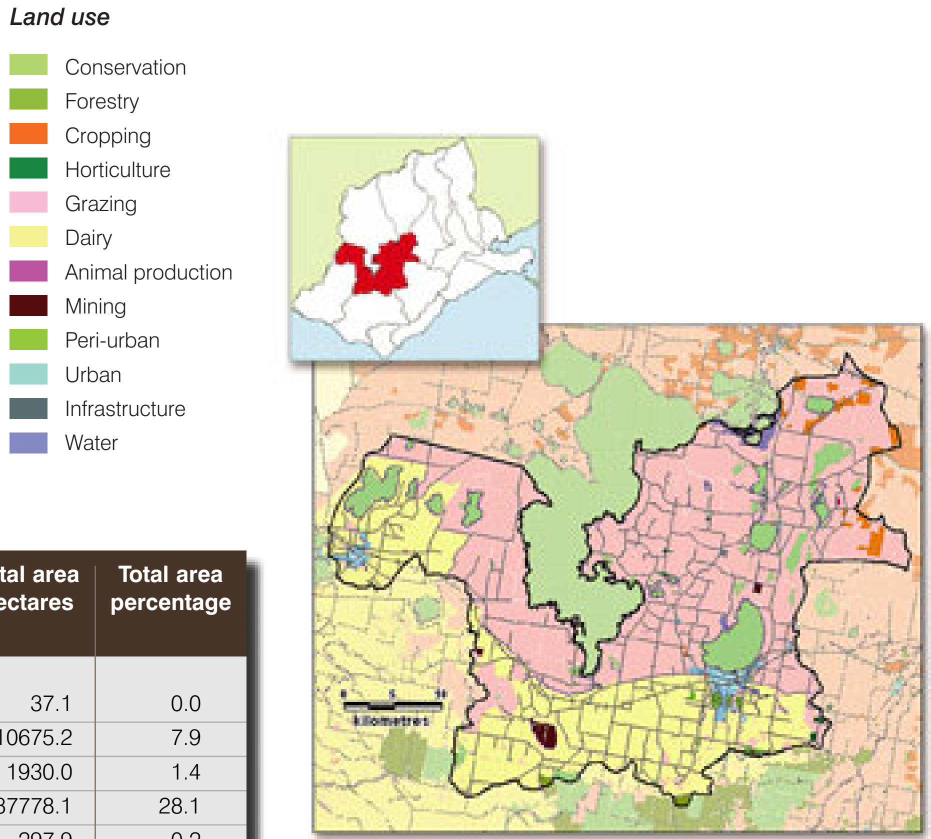


Figure C18: The rank and Relative Risk Values for soil-threatening processes in the Leigh Landscape Zone

C.10 Stony Rises

- **134,466 hectares or 10.1% of Corangamite CMA region**
- **8.6% public land**



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	1	37.1	0.0
Conservation	215	10675.2	7.9
Cropping	24	1930.0	1.4
Dairy	209	37778.1	28.1
Forestry	10	297.9	0.2
Grazing	587	77078.1	57.3
Horticulture	8	155.7	0.1
Infrastructure	44	143.3	0.1
Mining	13	684.2	0.5
Peri-urban	37	436.4	0.3
Urban	363	1684.3	1.3
Water	9	803.7	0.6
Total	**1520**	**131704.1**	**97.9**

Figure C19: Land use in the Stony Rises Landscape Zone in 2000-2002

Assets

- 946 km of waterways and 535 wetlands (9.2% of area), including Ramsar and significant wetlands such as Lake Beeac and Lake Cundare.
- Native vegetation conservation significance potential: 6.4% of total landscape zone is very high, 10.0% of total landscape zone is high.
- 1,054 km of roads, excluding the more recently subdivided areas around Colac and Camperdown.
- Cultural and heritage assets include Aboriginal archaeological sites and buildings associated with the early pastoral settlement.
- Urban centres of Colac and Camperdown, including manufacturing and service industries.

Threats

To public assets

- *Secondary salinity.* Around 1,544 ha of secondary salinity have been mapped in the landscape zone, which includes 235 ha on public land. Within a 50 m buffer of waterways there are 81 sites amounting to 300 ha, within 50 m of wetlands there are nearly 1000 ha, and around 39 ha in 57 sites mapped within 50 m of a road. Although widely scattered, the largest areas are around Lake Martin, The Sanctuary and the upper reaches of Barongarook Creek.
- *Potential acid sulphate soils.* Potential acid sulphate soils have been mapped at 118 sites (124 ha) within 50 m of a waterway and 35 sites (20 ha) within 50 m of a road. About 35 ha of high-value native vegetation and 40 ha of wetlands are also intersected. The sites are very fragmented and scattered, with the majority in low-lying and poorly-drained areas of the volcanic landscapes.

To private assets

- *Susceptibility to soil structure decline.* Around 7% (2,728 ha) of dairy land is very highly susceptible to soil structure decline in the Swan Marsh, Pirron Yallock and Larpent areas. A further 58% (21,951 ha) of dairy land, 34% (651 ha) of cropping land and 60% (46,321 ha) of grazing land is highly susceptible to soil structure decline. The dairy land around Bungador, Swan Marsh and Barongarook; the cropping land around Barpinba; and the grazing land in the Eurack, Lough Calvert, Beeac, Dreeite and Wool Wool areas are mapped in this category.
- *Susceptibility to soil waterlogging.* Soils very highly susceptible to soil waterlogging include 12% (4,609 ha) of dairy land, 32% (623 ha) of cropping land and 25% (18,885 ha) of grazing land. The largest areas are the grazing lands north of Lake Colac through Lough Calvert to Eurack. Around 54% (20,585 ha) of dairy land, and 37% (28,439 ha) of grazing land is highly susceptible to waterlogging, including nearly all the land between the Colac – Cressy Road and Lake Corangamite.
- *Secondary salinity.* Secondary salinity has been mapped on 52 ha of dairy land and 402 ha of grazing land. The largest extents of salt-affected grazing lands are those fringing Lake Martin.
- *Susceptibility to soil nutrient decline.* Soils very highly susceptible to nutrient decline include 13,460 ha of dairy land and 3,876 ha of grazing land. A further 10,829 ha of dairy country, 2,900 ha of grazing country and 292 ha of forestry country are highly susceptible to soil nutrient decline. These include all of the soils developed on the undulating sandy landscapes in the southern section of the landscape zone (i.e. south of the volcanic plains).
- *Susceptibility to soil acidification.* Around 24,289 ha of dairy country, 6,777 ha of grazing country and 300 ha of forest country in the same areas as described above are highly susceptible to soil acidification.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C20):*

- secondary salinity poses the greatest risk to assets in the Stony Rises Landscape Zone, which was ranked the sixth-greatest relative risk amongst all soil-related threatening process across the Corangamite region
- soil structure decline, waterlogging, soil nutrient decline and soil acidification pose a relatively moderate risk to assets in the Stony Rises Landscape Zone
- wind erosion, acid sulphate soils, landslides, sheet/rill erosion and gully/tunnel erosion pose relatively low risk to assets in the Stony Rises Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Secondary salinity	6	1925
2. Soil structure decline	43	256
3. Waterlogging	44	254
4. Soil nutrient decline	60	211
5. Soil acidification	80	144
6. Wind erosion	98	105
7. Acid sulphate soils	107	88
8. Landslides	137	16
9. Sheet/rill erosion	140	10
10. Gully/tunnel erosion	141	6

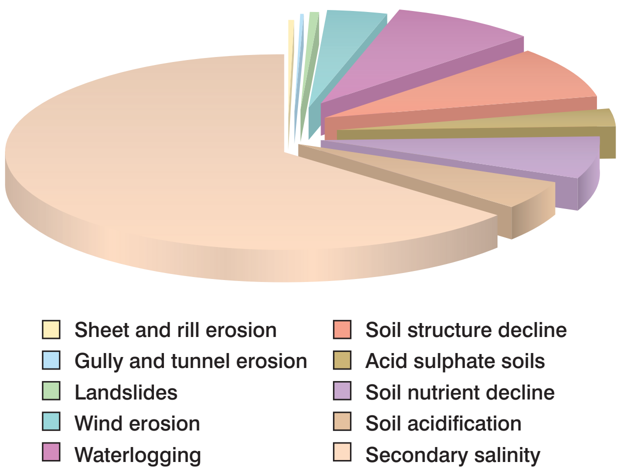
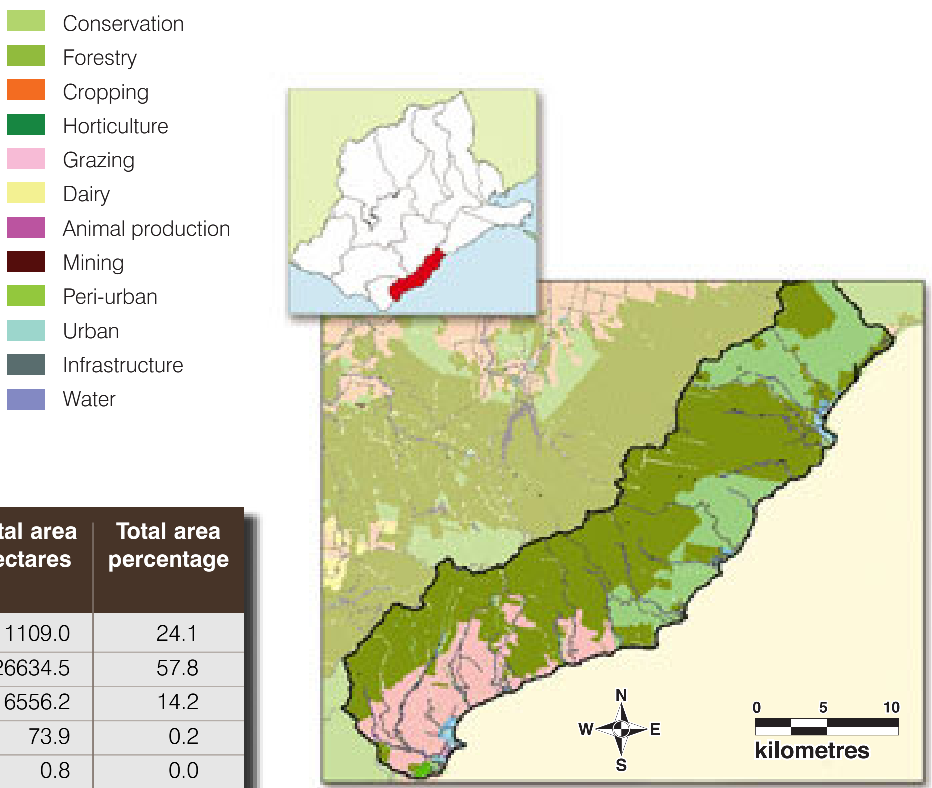


Figure C20: The rank and Relative Risk Values for soil-threatening processes in the Stony Rises Landscape Zone

C.11 Otway Coast

- **46,091 hectares or 3.5% of the Corangamite CMA region**
- **33.5% public land**



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	168	11109.0	24.1
Forestry	98	26634.5	57.8
Grazing	81	6556.2	14.2
Infrastructure	8	73.9	0.2
Mining	1	0.8	0.0
Peri-urban	2	117.3	0.3
Urban	146	481.5	1.0
Total	**504**	**44973.3**	**97.6**

Figure C21: Land use in the Otway Coast Landscape Zone in 2000-2002

Assets

- 1,282 km of waterways, mostly mountain streams. Barham River is the largest catchment.
- 3 wetlands (<0.1% area).
- Native vegetation conservation significance potential: 7.8% of total landscape zone is very high, 2.5% of total landscape zone is high. A significant proportion of the native vegetation is in the Great Otway National Park.
- 284 km of roads including the Great Ocean Road.
- Cultural and heritage assets, and high-value tourism sites.

Threats

To public assets

- *Landslides.* There are 280 landslide intersections mapped within a 50 m buffer of waterways, with Wild Dog Creek, Barham River and Smythe Creek recording the most. Around 109 landslides are mapped on public land, affecting at least 205 ha. Landslides threaten roads, utilities and urban infrastructure of small coastal towns, especially Wye River, Separation Creek, Kennett River, Lorne and the hinterland of Apollo Bay. Landslides have periodically closed the Great Ocean Road, Turtons Track, Wild Dog Road and other scenic tourist routes in recent years.

- *Susceptibility to soil waterlogging.* Waterlogged soils result from high rainfall combined with septic tank effluent disposal in shallow stony soils within coastal towns. The resultant run-off of poorly-treated effluent threatens the ecological integrity of waterways, estuarine and coastal environments.
- *Potential acid sulphate soils.* Approximately 8 km of waterways and 5 km of roads intersect with potential acid sulphate soils. Around 22 ha of high-value native vegetation and 49 ha of public land are also intersected. The most extensive areas are in the coastal plains around Apollo Bay.

To private assets

- *Landslides.* There are 232 landslides mapped on grazing land and 65 on land used for forestry. The areas most affected are Wongarra, Wild Dog Creek valley, Tanybryn, Barham River valley and Paradise.
- *Susceptibility to soil structure decline.* Around 83% (22,000 ha) of land used for forestry and 95% (6,200 ha) of land used for grazing is highly susceptible to soil structure decline. This covers the entire landscape zone with the exception of the gently undulating landscapes near the crest of the Otway Ranges.
- *Susceptibility to soil waterlogging.* Nearly 177 ha of grazing country in the Lower Barham River valley are highly susceptible to soil waterlogging.
- *Susceptibility to soil nutrient decline.* Nearly 200 ha of land used for forestry and over 300 ha of land used for grazing are very highly susceptible to soil nutrient decline, in the area around Lorne.
- *Susceptibility to soil acidification.* The same area as above (i.e. very high nutrient decline) is highly susceptible to soil acidification.
- *Susceptibility to soil erosion by wind.* Around 300 ha of grazing land near Apollo Bay have been identified as highly susceptible to wind erosion.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C22):*

- landslides pose the greatest risk in the Otway Coast, which was ranked eighth-highest relative risk of all soil-related threatening processes across the Corangamite region
- soil structure decline, soil nutrient decline and waterlogging pose a relatively moderate risk to assets in the Otway Coast Landscape Zone
- acid sulphate soils, sheet/rill erosion, wind erosion and soil acidification all pose a relatively low risk to assets in the Otway Coast Landscape Zone
- gully/tunnel erosion and secondary salinity sites have not been located in the Otway Coast Landscape Zone and therefore pose no known risk.

Soil threatening process	Rank across entire region	Relative risk values
1. Landslides	8	1872
2. Soil Structure Decline	=55	225
3. Soil Nutrient Decline	61	197
4. Waterlogging	76	149
5. Acid Sulphate Soils	=108	81
6. Sheet/rill erosion	=122	43
7. Wind Erosion	139	12
8. Soil Acidification	142	3
9. Gully/tunnel erosion	=143	0
10. Secondary Salinity	=143	0

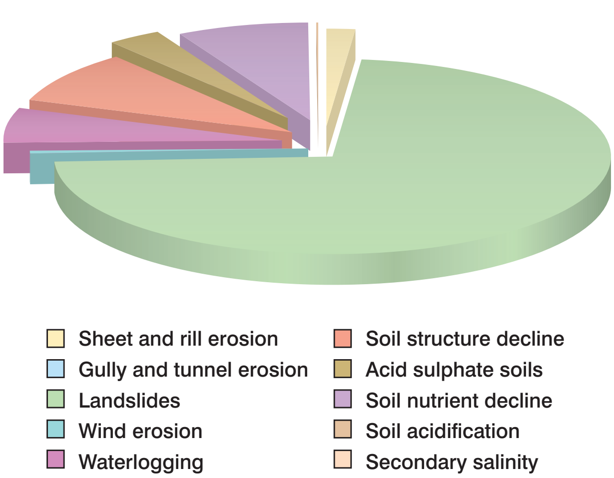


Figure C22: The rank and Relative Risk Values for soil-threatening processes in the Otway Coast Landscape Zone

C.12 Hovells

- **36,480 hectares or 2.7% of Corangamite CMA region**
- **9.6% public land**

Land use

Conservation
Forestry
Cropping
Horticulture
Grazing
Dairy
Animal production
Mining
Peri-urban
Urban
Infrastructure
Water

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	5	63.5	0.2
Conservation	202	3088.4	8.5
Cropping	49	2448.5	6.7
Forestry	2	0.0	0.0
Grazing	145	18442.0	50.6
Horticulture	10	176.4	0.5
Infrastructure	31	1815.3	5.0
Mining	8	972.5	2.7
Peri-urban	98	2730.0	7.5
Urban	1236	4493.0	12.3
Total	**1786**	**34229.6**	**93.8**

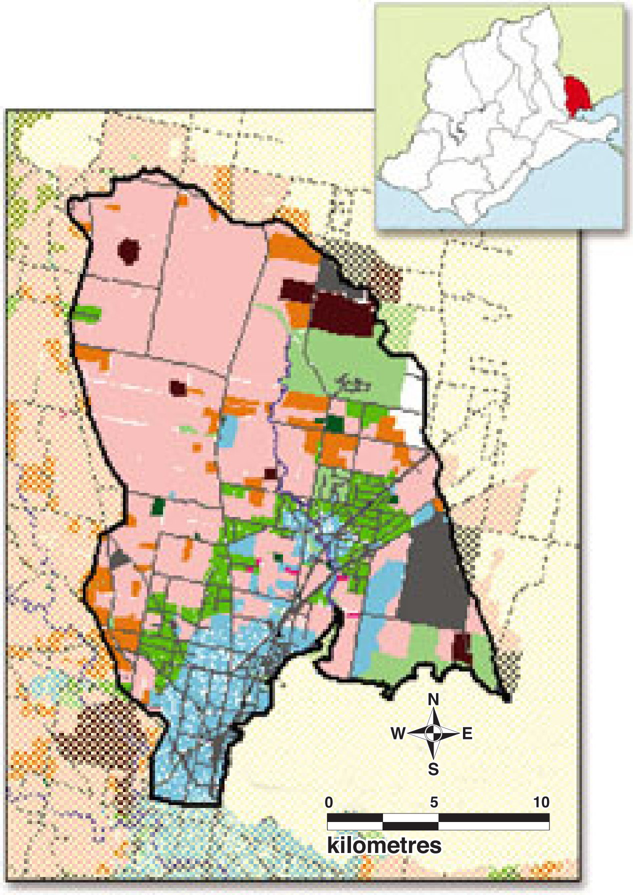


Figure C23: Land use in the Hovells Landscape Zone in 2000-2002

Assets

- 251 km of waterways, with Hovells Creek and Limeburners Bay being the most significant.
- 44 wetlands (3.0% of area), includes Ramsar and significant wetlands around Point Lillias and Point Wilson.
- Native vegetation conservation significance potential: 16.1% of total landscape zone is very high, 10.4% of total landscape zone is high.
- At least 694 km of roads, not including many of the more recent suburban roads in Lara and Geelong.
- Portions of the City of Greater Geelong, including significant urban and industrial infrastructure.
- Cultural and heritage assets include Aboriginal archaeological sites and historical sites associated with the early pastoral settlement of Victoria.

Threats

To public assets

- *Soil erosion by water.* There are 15 intersections (51 ha) of mapped gullies with waterways and 41 intersections (72 ha) of mapped sheet/rill erosion and waterways, all in the headwaters of Hovells Creek, especially on the flanks of the You Yang Ranges. These have the potential for sediment and nutrient export to Limeburners Bay, especially when added to the lower water quality associated with the urban development of Lara (flooding and stormwater disposal). There are eight intersections of mapped gully erosion (22 ha) and 31 intersections of mapped sheet/rill erosion (29 ha) with native vegetation of very high conservation status and two gully intersections and 12 sheet/rill intersections with native vegetation of high conservation status potential. Most occur along the flanks of the You Yang Ranges and along the creeklines of tributaries to Hovells Creek. Roads intersect with seven mapped gully erosion sites and 17 mapped sheet erosion sites with the largest along Sandy Creek Road and Granite Road. Seven sheet erosion sites (6 ha) have been mapped on public land.

- *Secondary salinity.* Secondary salinity has been mapped on 16 ha of public land (Avalon Airport and Serendip Sanctuary). Secondary salinity also intersects with nearly 40 ha of native vegetation with high and very high conservation significance potential, and 46 ha of wetlands. Around 31 ha occur within 50 m of a waterway and 19 ha within 50 m of a road.
- *Potential acid sulphate soils.* Potential acid sulphate soils have been mapped on 202 ha of public land, the vast majority occurring in the coastal and estuarine wetlands around Limeburners Bay, Point Lillias and Point Wilson. Many of these are Ramsar and significant wetlands and rare species habitat (e.g. orange-bellied parrot). Approximately 250 ha of native vegetation with high and very high conservation significance potential, 535 ha of wetlands, 12 km of waterways and 15 km of roads also intersect with potential acid sulphate soils.

To private assets

- *Soil erosion by water.* There are 44 incidences (38 ha) of sheet/rill erosion which have been mapped on grazing land along with five gullies (7 ha). There are 19 ha of gully erosion at five sites threatening cropping land. Eroded mining/quarry land amounts to 29 ha.
- *Susceptibility to soil nutrient decline.* More than 370 ha of grazing land and 125 ha of cropping land are very highly susceptible and nearly 1600 ha of grazing land and 240 ha of cropping land are highly susceptible to soil nutrient decline. Most occurs along the sandy slopes of the granitic landscapes adjacent to the You Yang Ranges, and the sandy coastal plain on the edge of Corio Bay.
- *Susceptibility to soil acidification.* Soils of the sandy slopes of the granitic landscapes adjacent to the You Yang Ranges, and the sandy coastal plain on the edge of Corio Bay are also susceptible to soil acidification.
- *Susceptibility to soil waterlogging.* Approximately 15,846 ha of grazing land, 2,190 ha of cropping land and 164 ha of land used for horticulture are highly susceptible to soil waterlogging. This is nearly all of the volcanic soils in the landscape zone.
- *Susceptibility to soil structure decline.* Around 3,900 ha of grazing land, 1,040 ha of cropping land and 104 ha of land used for horticulture are highly susceptible to soil structure decline. The majority of the land is along the Hovells Creek valley from the You Yang Ranges to Limeburners Bay.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig C24):*

- acid sulphate soils and sheet/rill erosion pose a relatively high risk to assets in the Hovells Landscape Zone
- soil structure decline, secondary salinity, gully/tunnel erosion and waterlogging pose a relatively moderate risk to assets in the Hovells Landscape Zone
- wind erosion, soil nutrient decline, soil acidification and landslides pose a relatively low risk to assets in the Hovells Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Acid sulphate soils	23	506
2. Sheet/rill erosion	27	444
3. Soil structure decline	46	244
4. Secondary salinity	47	243
5. Gully/tunnel erosion	48	240
6. Waterlogging	77	146
7. Wind erosion	=122	43
8. Soil nutrient decline	=122	43
9. Soil acidification	=122	43
10. Landslides	=133	20

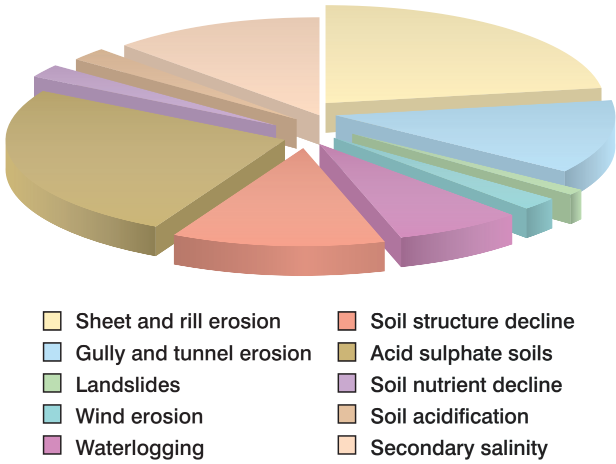


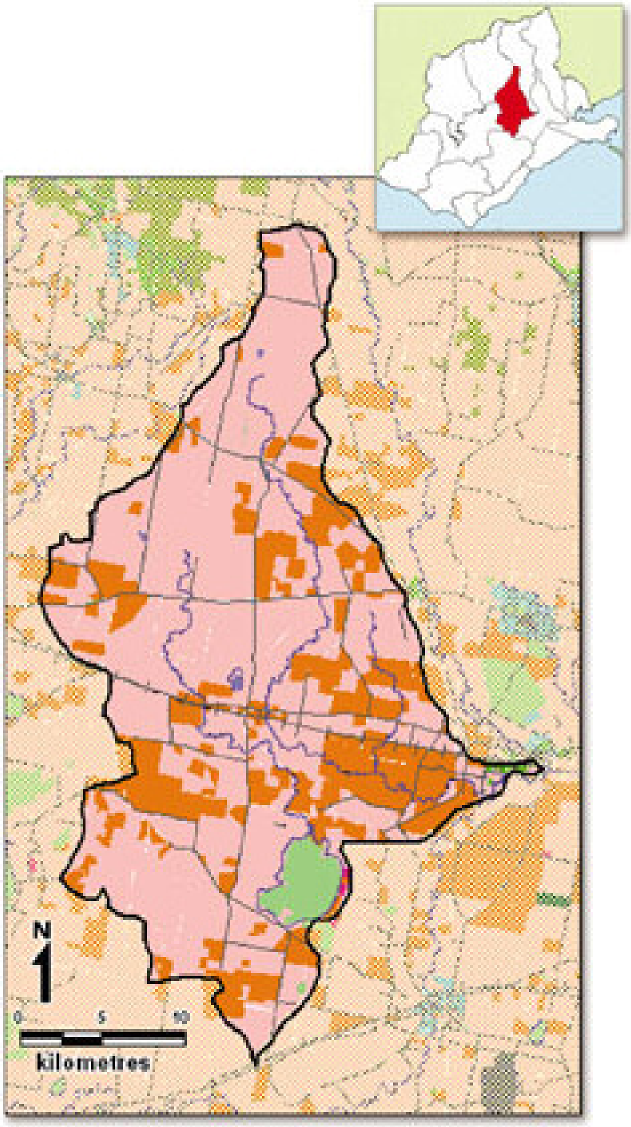
Figure C24: The rank and Relative Risk Values for soil-threatening processes in the Hovells Landscape Zone

C.13 Murdeduke

- **68,316 hectares or 5.1% of Corangamite CMA region**
- **2.8% public land**

Land use

- Conservation
- Forestry
- Cropping
- Horticulture
- Grazing
- Dairy
- Animal production
- Mining
- Peri-urban
- Urban
- Infrastructure
- Water



Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	3	53.7	0.1
Conservation	14	1717.5	2.5
Cropping	118	16968.2	24.8
Grazing	139	48110.4	70.4
Infrastructure	14	81.7	0.1
Peri-urban	8	114.5	0.2
Urban	5	5.8	0.0
Water	3	71.0	0.1
Total	**304**	**67122.8**	**98.3**

Figure C25: Land use in the Murdeduke Landscape Zone in 2000-2002

Assets

- 460 km of waterways, including Warrambine Creek and Mia Mia Creek.
- 65 wetlands (4.1% of area), including Ramsar and significant wetlands (Lake Murdeduke).
- Native vegetation conservation significance potential: 9.1% of total landscape zone is very high, 6.9% of total landscape zone is high.
- 236 km of roads, rail line and minor rural infrastructure.
- Cultural and heritage assets including Aboriginal archaeological sites.

Threats

To public assets

- *Secondary salinity.* Secondary salinity intersects with over 375 ha of native vegetation with very high and high conservation significance potential, and 235 ha of wetlands. These intersects occur along Mia Mia Creek, along Warrambine Creek north of Wingeel Swamp, and in groups of small wetlands east of Eurack near Hesse Road and north-east of Lake Murdeduke near McIntyre Road and Flemings Road. There are 32 intersections (~300 ha) within 50 m of a waterway and nine sites mapped within 50 m of a road (8 ha).

- *Potential acid sulphate soils.* Seventy potential acid sulphate soils are mapped within a 50 m buffer of a waterway (77.5 ha), and 11 within a 50 m buffer of roads (8 km). Around 85 ha of high value native vegetation and 9 ha of public land are also intersected. The sites are scattered, with a widespread distribution along low-lying poorly-drained areas.
- *Soil erosion due to water.* Small incidences (17 in number) of sheet/rill erosion amounting to approximately 16 ha total (0.02% of total area) includes 12 intersections with waterways (4.5 ha), three intersections with roads (0.3 ha) and eight intersections with high-value native vegetation (7 ha).

To private assets

- *Susceptibility to soil structure decline.* Around 7% (1,127 ha) of cropping land and 6% (2,734 ha) of grazing land is highly susceptible to soil structure decline, especially east of Eurack, south of Inverleigh and south-east of Wingeel.
- *Susceptibility to soil waterlogging.* Similarly, 7% (1,127 ha) of cropping land and 5% (2,618 ha) of grazing land is very highly susceptible to waterlogging, mostly east of Eurack, south of Inverleigh and south-east of Wingeel. About 17% (2,885 ha) of cropping land and 6% (2,695 ha) of grazing land is highly susceptible to waterlogging, all in one soil-landform unit north of Warrambine Creek, from Inverleigh to Wingeel.
- *Susceptibility to soil erosion by wind.* Over 2250 ha of grazing land and nearly 950 ha of cropping land is highly susceptible to wind erosion. These are mostly scattered alluvial soils associated with low-lying poorly-drained areas which are subject to wind erosion when dried.
- *Susceptibility to soil nutrient decline.* Very little area (~560 ha or <1% of the total area) is highly susceptible to soil nutrient decline.
- *Susceptibility to soil acidification.* Similarly to nutrient decline, less than <1% of the total area is highly susceptible to soil acidification.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C26):*

- secondary salinity poses the greatest risk to assets in the Murdeduke Landscape Zone, which was ranked the 12th-highest relative risk amongst all soil-related threatening process across the Corangamite region
- waterlogging and soil structure decline pose a relatively moderate risk to assets in the Murdeduke Landscape Zone
- wind erosion, acid sulphate soils, sheet/rill erosion, soil nutrient decline and soil acidification pose a relatively low risk to assets in the Murdeduke Landscape Zone
- landslides and gully/tunnel erosion were found to have no risk in the Murdeduke Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Secondary Salinity	12	1090
2. Waterlogging	58	218
3. Soil Structure Decline	=62	196
4. Wind Erosion	=104	93
5. Acid Sulphate Soils	=104	93
6. Sheet/rill erosion	127	35
7. Soil Nutrient Decline	=135	19
8. Soil Acidification	=135	19
9. Landslides	=143	0
10. Gully/tunnel erosion	=143	0

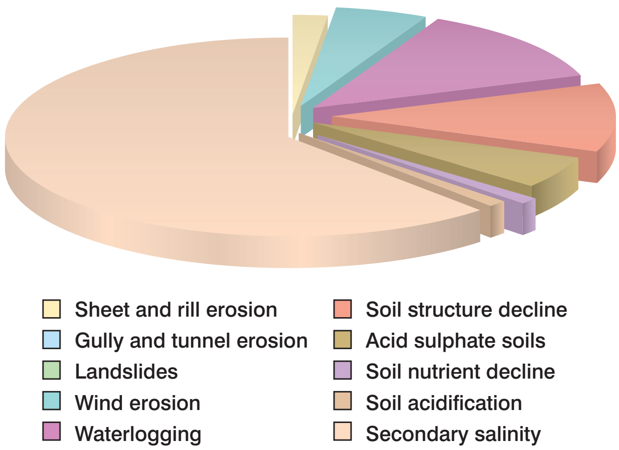


Figure C26: The rank and Relative Risk Values for soil-threatening processes in the Murdeduke Landscape Zone

C.14 Middle Barwon

- **70,618 hectares or 5.3% of the Corangamite CMA region**
- **2.4% public land**

Land use

Conservation	Animal production
Forestry	Mining
Cropping	Peri-urban
Horticulture	Urban
Grazing	Infrastructure
Dairy	Water

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Animal production	7	167.2	0.2
Conservation	87	1483.4	2.1
Cropping	144	13979.8	19.8
Forestry	3	93.5	0.1
Grazing	238	49431.6	70.0
Horticulture	3	168.4	0.2
Infrastructure	57	1203.2	1.7
Mining	3	170.9	0.2
Peri-urban	28	444.0	0.6
Urban	189	1692.1	2.4
Total	**759**	**68834.1**	**97.5**

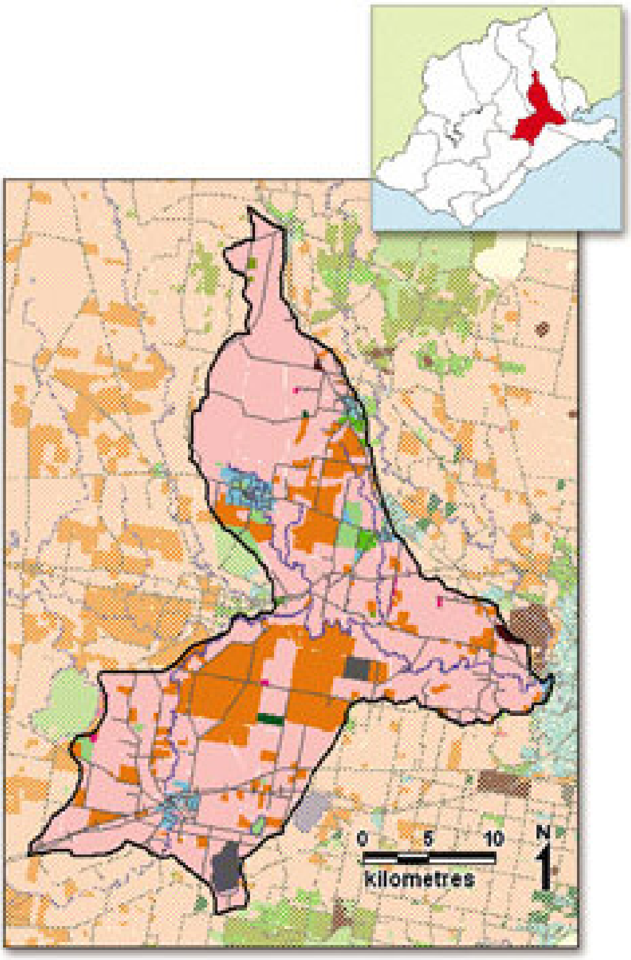


Figure C27: Land use in the Middle Barwon Landscape Zone in 2000-2002

Assets

- 703 km of waterways including the Barwon River.
- 104 wetlands (1.8% of area), mostly very small (Wurdee Boluc Reservoir and Lake Gherang are exceptions).
- Native vegetation conservation significance potential: 14.8% of total landscape zone is very high, 9.2% of total landscape zone is high.
- Infrastructure assets including 458 km roads, along with main railway and power lines. Parts of the City of Greater Geelong and peri-urban fringe.

Threats

To public assets

- *Soil erosion by water.* Waterways intersect with 14 mapped gully sites (24 ha) and 52 mapped sheet/rill sites (61 ha). There are 23 intersections of mapped erosion with native vegetation of very high and high conservation significance potential, the vast majority being small patches of sheet/rill erosion along drainage lines. Roads intersect with two gully erosion sites and four sheet/rill erosion sites.
- *Landslides.* There were 13 landslides mapped within 50 m of a waterway, almost all along the Barwon River east of Inverleigh. They are mapped on public land and eight intersect with native vegetation with very high or high conservation significance potential.

- *Secondary salinity.* Nearly 122 ha of secondary salinity sites are mapped within 50 m of a waterway, and 11.5 ha within 50 m of a road. Most occur on the volcanic landscapes north and west of Winchelsea, with some in the valleys of the Barrabool Hills. Secondary salinity intersects with 35 ha of native vegetation with very high conservation significance potential and 57 ha of high conservation significance potential.
- *Potential acid sulphate soils.* Approximately 11 km of waterways and 74 ha of high-value native vegetation intersect with potential inland acid sulphate soils, in scattered locations on the volcanic plains east of Lake Murdeduke and north of Winchelsea.

To private assets

- *Susceptibility to soil waterlogging.* Around 4% (561 ha) of cropping land and 6% (3,133 ha) of grazing land is very highly susceptible to waterlogging, mostly along the floodplain of the Barwon River. About 61% (8,453 ha) of cropping land and 64% (31,524 ha) of grazing land is highly susceptible to waterlogging in widespread locations. Cropping land is most threatened in the Winchelsea – Inverleigh district, and grazing land north of Teesdale to Meredith.
- *Susceptibility to soil structure decline.* Nearly 18,500 ha of grazing land and 5,250 ha of cropping land are highly susceptible to soil structure decline.
- *Susceptibility to soil nutrient decline.* The sandy soils just south of Wurdee Boluc Reservoir include 550 ha of soils used for grazing and 18 ha of soils used for cropping which are very highly susceptible to nutrient decline. Approximately 7,200 ha of grazing land and 2,900 ha of cropping land are highly susceptible to soil nutrient decline. These include the sandy soils south of Winchelsea, west and north of Lake Modewarre and a large area south of Lethbridge to Murgheboluc.
- *Susceptibility to soil acidification.* In general, the same soils that are susceptible to soil nutrient decline are also susceptible to soil acidification. These are described above.
- *Susceptibility to soil erosion by wind.* The soils of 3,100 ha of grazing land and 2,000 ha of cropping land are susceptible to wind erosion. These include the sandy and alluvial soils of the area west and north of Lake Modewarre, and the Sandy Creek catchment east of Teesdale.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C28):*

- secondary salinity, sheet/rill erosion, soil structure decline and waterlogging all pose a relatively moderate risk to assets in the Middle Barwon Landscape Zone
- landslides, acid sulphate soils, wind erosion, soil nutrient decline, soil acidification and gully/tunnel erosion pose a relatively low risk to assets in the Middle Barwon Landscape Zone.

Soil threatening process	Rank across entire region	Relative risk values
1. Secondary salinity	35	296
2. Sheet/rill erosion	36	294
3. Soil structure decline	=40	268
4. Waterlogging	42	257
5. Landslides	97	107
6. Acid sulphate soils	103	95
7. Wind erosion	=104	93
8. Soil nutrient decline	110	80
9. Soil acidification	=113	72
10. Gully/tunnel erosion	116	66

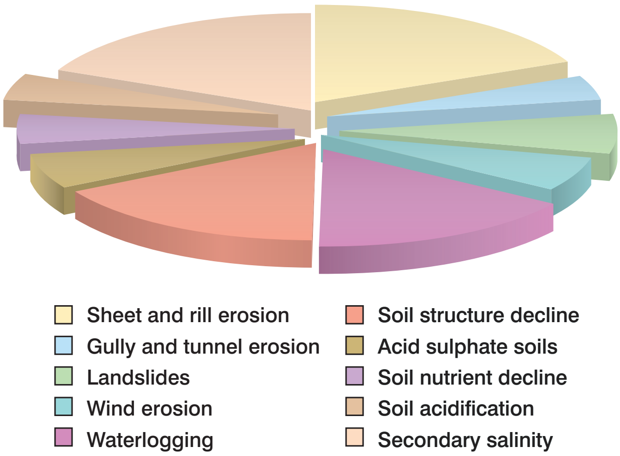


Figure C28: The rank and Relative Risk Values for soil-threatening processes in the Middle Barwon Landscape Zone

C.15 Aire

- **35,319 hectares or 2.6% of Corangamite CMA region**
- **60% public land**

Land use

Conservation	Animal production
Forestry	Mining
Cropping	Peri-urban
Horticulture	Urban
Grazing	Infrastructure
Dairy	Water

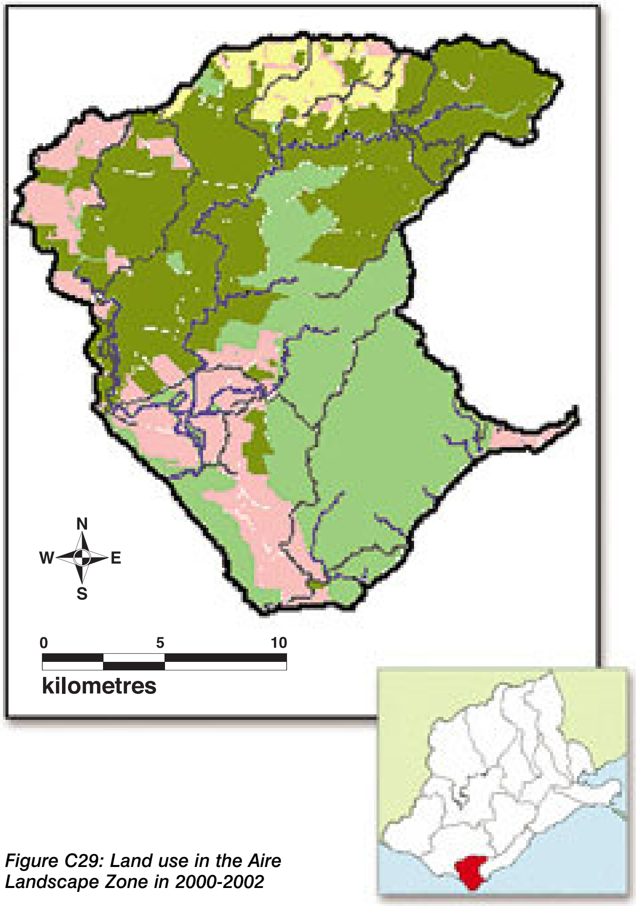


Figure C29: Land use in the Aire Landscape Zone in 2000-2002

Land use	Number of polygons mapped	Total area hectares	Total area percentage
Conservation	138	13017.9	36.9
Forestry	92	14005.0	39.7
Dairy	37	1773.5	5.0
Grazing	151	5780.0	16.4
Peri-Urban	2	1.1	0.0
Urban	6	11.5	0.0
Total	**426**	**34589.0**	**97.9**

Assets

- Many of the 989 km of waterways are high-value assets because of their pristine condition. In particular, the Aire River estuary is a high-value environmental asset.
- 4 wetlands (0.2% of area).
- Native vegetation conservation significance potential: 17.8% of total landscape zone is rated as very high, 5.4% of total landscape zone is rated as high.
- 152 km of roads.
- Great Otway National Park.
- Cape Otway coastline and associated marine parks.

Threats

To public assets

- *Landslides.* Eighty-three landslides occur within 50 m of a waterway in the upper Aire River valley, the west branch of the Ford River, and the Lower Aire River in the Hordern Vale district.
- *Soil erosion by water.* Five sheet/rill erosion sites are mapped within 50 m of a waterway, and one intersection with native vegetation of high conservation significance potential. The risk of sediment input through erosion of the upper Aire River is considered high. The high turbidity following rainfall events may contribute nutrients and degrade water quality.
- *Potential acid sulphate soils.* Approximately 465 ha of native vegetation with very high conservation significance value intersects with potential acid sulphate soils in the coastal region, as do five wetlands (60 ha). Potential acid sulphate soils have been mapped within a 50 metre buffer of nearly 300 km of waterways and 7 km of roads.

To private assets

- *Susceptibility to soil structure decline.* There are 98 ha of dairy land highly susceptible to soil structure decline in the Little Aire Creek valley, and 3,016 ha of grazing land highly susceptible to structural decline in the Hordern Vale, Glen Aire and Johanna Heights area.
- *Susceptibility to soil waterlogging.* About 1187 ha of grazing land is highly susceptible to soil waterlogging in the Cape Otway, Hordern Vale, and Glen Aire areas.
- *Landslides.* There are 17 landslides mapped in dairy land mostly in the Weeaproinah – Wyelangta area, and 43 landslides are mapped on grazing land mostly in the Hordern Vale – Glen Aire district and the Johanna Heights – Lavers Hill district.
- *Soil erosion by water.* The occurrences are relatively minor when compared to other landscape zones. Six sheet/rill erosion sites are mapped on dairy land and 14 sheet/rill erosion sites are mapped on grazing land.

Relative Risk to Assets

According to the relative risk to assets analysis, results indicate *(Fig. C30):*

- landslides pose the greatest risk in the Aire Landscape Zone, ranked 20th-highest relative risk of all soil-related threatening processes across the Corangamite region
- acid sulphate soils also pose a relatively high risk to assets in the Aire Landscape Zone
- soil nutrient decline and soil structure decline pose a relatively moderate risk to assets in the Aire Landscape Zone
- wind erosion, waterlogging, soil acidification and sheet/rill erosion pose a relatively low risk to assets in the Aire Landscape Zone
- no known gully/tunnel erosion or secondary salinity is found in the Aire Landscape Zone, and therefore pose no risk to assets.

Soil threatening process	Rank across entire region	Relative risk values
1. Landslides	20	548
2. Acid Sulphate Soils	30	402
3. Soil Nutrient Decline	=66	184
4. Soil Structure Decline	=78	145
5. Wind Erosion	93	118
6. Waterlogging	118	58
7. Soil Acidification	126	38
8. Sheet/rill erosion	131	26
9. Gully/tunnel erosion	=143	0
10. Secondary Salinity	=143	0

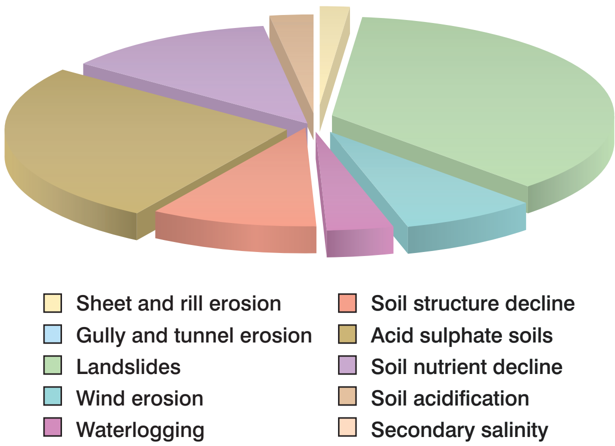


Figure C30: The rank and Relative Risk Values for soil-threatening processes in the Aire Landscape Zone

Appendix D: Processes and results for validating investment priorities

D.1 Validation of risks

Secondary salinity

The Salinity Action Plan (SAP) Background Report No 2 '*Process for the initial selection and validation of target areas for salinity management'* outlines the method used to define priority areas and the assessment process used to validate the risk from secondary salinity (Dahlhaus 2003). The results from this report in addition to the other SAP background reports have been used to verify the high risk to assets from secondary salinity in those landscape zones identified as a priority in the Corangamite SHS. Since both the SAP and SHS have adopted an assets-based approach to targeting investment, the high risk to assets caused by secondary salinity in the Lismore, Stony Rises, Woady Yaloak and Murdeduke landscape zones is ratified by the degree of overlap between the SAP target areas and the landscape zones where secondary salinity is a priority issue in this strategy *(Fig. D1)*.

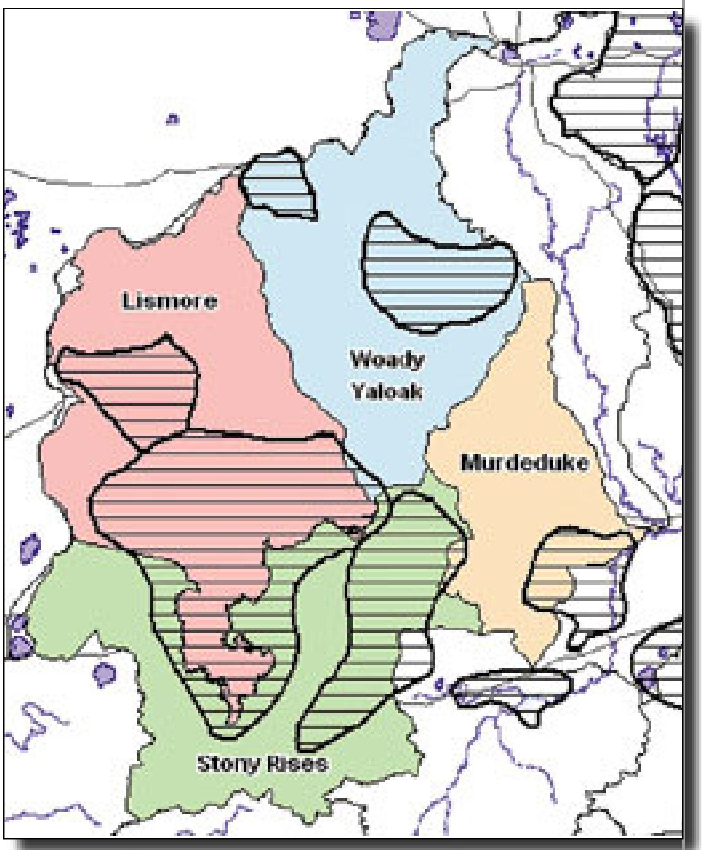


Figure D1: The overlap between the Corangamite Salinity Action Plan target areas (hatched) and the four landscape zones where secondary salinity is a priority in the Corangamite Soil Health Strategy

Lismore Landscape Zone

The Lismore Landscape Zone overlaps with the Lismore-Derrinallum and Lake Corangamite salinity management target areas of the SAP. The asset-threat investigations in the SAP confirmed that secondary salinity posed a possible risk to roads, rail, waterways, telecommunication cables, agricultural land, reservoirs, VROTS and Lake Corangamite in the Lismore Landscape Zone (Dahlhaus 2003).

Stony Rises Landscape Zone

The Colac-Eurack and Lake Corangamite SAP target areas overlap with the Stony Rises Landscape Zone where it has been recognised that secondary salinity threatens the integrity of roads, rail, electricity cables, waterways, telecommunication cables, agricultural production, VROTS, Ramsar wetlands and the urban development in the City of Colac (Dahlhaus 2003).

Illabarook Landscape Zone

The Pittong and Illabarook SAP target areas in the Woady Yaloak Landscape Zone were selected on the basis of the increasing salinity in the Woady Yaloak River and Lake Corangamite. It is also recognised that the area of agricultural land affected by salinity is increasing by 8% per annum in the Pittong area, where roads are also affected (Nicholson *et al.* 2006).

Murdeduke Landscape Zone

Approximately half of the Murdeduke SAP target area overlaps with the Murdeduke Landscape Zone, along with a small portion of the Colac-Eurack SAP target area. The SAP recognises that secondary salinity in these regions threatens the integrity of roads, electricity cables, telecommunication cables, agricultural production, VROTS and wetlands (Nicholson *et al.* 2006).

Landslides

The methodology for verification of risk associated with landslides throughout the Corangamite region focused on the confirmation of landslides at mapped locations, an assessment of the likelihood of further movement and the potential for impact on various assets classes including infrastructure, water quality, biodiversity (environment) and land use. A series of target areas based on a GIS analysis were proposed for each priority landscape zone and field inspections and risk assessments were undertaken in the Gellibrand, Curdies, Otway Coast, Upper Barwon and Aire landscape zones.

Gellibrand Landscape Zone

The highest-ranking landscape zone was the Gellibrand, which was found to contain a diverse range of landslides *(Table D1)*. Significant impacts were noted on major tourist roads at various locations on the Great Ocean Road, including a recent failure at Princetown requiring engineering works and major stabilisation. In excess of $700,000 for remediation works were required on Turtons Track due to landslide damage after a severe rainfall event in February 2004 and ongoing occurrences of landslides below these remedial works were noted during the recent inspection *(Fig. D2)*.

Other roads such as Kawarren Road and Colac – Lavers Hill Road have also been damaged or impacted through the occurrence of landslides. Ongoing landslide movement on the Princetown-Simpson Road on the western boundary of this zone has caused extensive road damage as well as the destruction of a number of sheds and the severe damage and ultimate demolition of a dwelling. The potential for damage to dwellings was also noted at Johanna, where a number of cabins are located on a large, active landslide.

Significant risk to water supply infrastructure and water quality was also confirmed at West Gellibrand Reservoir where an old landslide has reactivated in recent times on one of the flanks of the water supply reservoir. In addition, a landslide adjacent to Arkins Creek is known to have impacted on water quality whilst also threatening the main water supply to Camperdown. Other minor risks to water quality were also identified in the Johanna area and along the Gellibrand River, although impact was restricted due to limited travel distance or run-out.

Although inspection of forestry and logging operations was restricted by road access, such activity has been assessed as having potential to impact on water quality through initiation of landslides and erosion if good forestry practice is not adhered to. A major slide on the Aire River and subsequent plantation establishment resulted in some sections of this operation now being unusable due to the potential for further movements and impact on the river.

Finally, risks to agricultural land were identified in the Johanna area, the area east of Simpson at Tomahawk Creek and at Kennedy's Creek where shallow translational slides in the Gellibrand Marls have caused minor disruption to pastures and grazing lands.

Otway Coast Landscape Zone

The main impacts from landslides in the Otway Coast Landscape Zone were confirmed as damage to infrastructure and disruption to road infrastructure affecting tourism *(Table D1)*.

Significant numbers of dwellings have been located within or adjacent to two large coastal landslides at Fairhaven. Whilst impact to date has been minimal, potential risks exist if larger movements associated with reactivation under adverse conditions occur. Other locations within this zone have also been assessed as having moderate to high risks of property damage associated with the occurrence of landslides and include some isolated parts of Lorne, Wye River, the northern areas of Skenes Creek, Wongarra, some outer areas of Apollo Bay and rural developments in the adjacent valleys of Barham River and Wild Dog Creek.

A significant and ongoing impact from landslides has occurred on the Great Ocean Road and recent closures of this major tourist road have occurred at Big Hill outside Lorne and at Cumberland River. A large-scale failure occurred on the Great Ocean Road in the late 1970s at Windy Point to the west of Lorne. This slide closed the Great Ocean Road for six months and required significant engineering stabilisation works using numerous rock bolts. Such installations have a limited design life and further works can be expected in the future; newly installed monitoring instrumentation at the site by VicRoads confirms the ongoing risks associated at this site. Numerous slides also occur regularly along stretches of the Great Ocean Road near Jamieson River and Kennett River. Inspections of these sites indicate ongoing potential for minor failures requiring maintenance and clean-ups.

Curdies Landscape Zone

The main impacts within the Curdies Landscape Zone occur on major road infrastructure, sites of natural beauty and agricultural lands *(Table D1)*.

Significant and ongoing damage has been experienced along the Port Campbell – Cobden Road, which is a major tourist route to the Twelve Apostles and other sites of natural importance. Remedial works have failed to fully alleviate damage associated with shallow translational slides (so typical of the region) which transect the road in a number of locations. Damage to a series of timber retaining walls along minor roads (such as Williams Road), and the Timboon – Colac Road has also been identified as being caused by relatively shallow but long translational landslides. Significant damage has continued to occur on the Princetown – Simpson Road, which is located on the boundary with the Gellibrand Landscape Zone.

Significant disruption to agricultural land has occurred throughout the region due to numerous and widespread shallow translational landslides. Whilst the impact has been minor in many cases, some areas have been completely removed from usage and have been fenced off and, in some cases, actively remediated.

Ongoing landslides and instability along the coast have also recently impacted on the natural environment and include the collapse of one of the Twelve Apostles and London Bridge. Impact on waterways and wetlands is considered to be relatively minor, although many small failures are noted directly adjacent to creeks and streams with some potential for sediment loading.

Upper Barwon Landscape Zone

The Upper Barwon Landscape Zone is characterised by potential impacts to water quality, including Proclaimed Water Supply Areas, with some risks to agricultural lands *(Table D1).*

Minor slides on the Barwon River on the Lorne-Winchelsea Road were noted as having a minor risk to water quality, with a similar assessment of risks along some of the smaller creeks such as Scrubby Creek. More significant risks have been assessed for some sections of the water supply infrastructure in the region, with landslides known to have impacted on the main supply channel and associated syphons taking water from the West Barwon Dam to the Wurdee Boluc Reservoir. Other isolated slides are also known to have occurred adjacent to the channel near Wurdale Road. Any long-term disruption to this channel represents a significant risk to Geelong's water supply network.

The potential impact of rarer, large-scale landslides in this area was graphically illustrated in 1952 when the Lake Elizabeth landslide failed and blocked the east branch of the Barwon River. The slide was in the order of 60 hectares and significantly disrupted flows in the river until the landslide dam was breached in the following year, sending a 7 m wall of mud and water down the river.

Disruption and loss of agricultural lands was also noted along a long section of the Barwon River at Birregurra. Assessment of the Phillips Landslide indicated approximately four hectares had been lost as viable grazing land; there was also the potential that further reactivation may have an impact on the Barwon River *(Fig. D4).*

Aire Landscape Zone

The Aire is the smallest of the landscape zones within the Corangamite region and contains limited infrastructure but includes areas of significant environmental importance such as the Great Otway National Park *(Table D1).* As such, the risks are mainly associated with water quality and the environment.

Some minor infrastructure risks are present along the Great Ocean Road. A number of landslides directly adjacent to the road were noted during the recent inspection and will require remedial engineering works. Other recent engineering repair works due to landslides have also been undertaken by Colac Otway Shire on Wait–a-While Road. Landslides are also known to have caused some damage on the Hordern Vale Road.

Risks to water quality and the environment were recently emphasised by the closure of the Ford River due to a landslide, which occurred after forestry activities. Other areas of logging and forestry were also noted at the northern end of Bins Road and in the Beech Forest area and whilst access to such areas was restricted, risk to water quality and the environment are considered possible if good forestry practice is not employed *(Fig. D3).*

Water erosion

The verification of risk associated with water erosion used the same method as for landslides. A series of target areas based on a GIS analysis were proposed for each priority landscape zone; field inspections and risk assessments were undertaken in the Woady Yaloak, Moorabool, Thompsons, Upper Barwon and Leigh landscape zones.

Field verification showed that sheet/rill erosion and gully/tunnel erosion were found together and there were no clear spatial boundaries that could distinguish where gully/tunnel and sheet/rill started and finished. Therefore, it was decided that sheet/rill erosion and gully/tunnel erosion should be assessed together and they would be ranked together for each priority landscape zone.

Woady Yaloak Landscape Zone

Along with the Moorabool, erosion by water in the Woady Yaloak Landscape Zone was verified to have the highest risk of all landscape zones *(Table D2)*. The most severe erosion in the Woady Yaloak, and perhaps the Corangamite region, was on the hills surrounding the Misery and Moonlight creeks *(Fig. D5)*. This area had extensive sheet, rill and gully erosion. Significant sedimentation to the Misery and Moonlight creeks from the erosion is highly likely. Much of this sediment will flow into the Woady Yaloak River, which will eventually flow into Lake Corangamite.

Priority Landscape Zones	Land use	Water Quality	Bio-diversity	Infrastructure	Verification of risk score	Revised rank according to verification
Gellibrand	3.0	4.0	1	4.5	**12.5**	**1**
Curdies	3.5	2.0	1	4.0	**10.5**	**3**
Otway Coast	2.0	2.0	3	5.0	**12.0**	**2**
Upper Barwon	2.0	4.5	1	1.0	**8.5**	**4**
Aire	1.0	3.0	2	2.0	**8.0**	**5**

Table D1: Field verification scores for landslide risk in priority areas.
Risk to assets is indicated as very high-5, high-4, medium-3, low/medium-2, low-1

Figure D2: New failure below recent remedial works on Turtons Track (Gellibrand Landscape Zone) Photograph: A. Miner 2006

Figure D3: Forestry and logging with minor landslides and erosion on waterway just off the Great Ocean Road (Aire Landscape Zone)
Photograph: A. Miner 2006

Figure D4: Landslides adjacent to Scrubby Creek (Upper Barwon Landscape Zone) Photograph: A. Miner 2006

The erosion has significantly impacted on agricultural production in the Misery and Moonlight area. Many of the hills have no livestock as there is no ground cover available for feed. Some farmers have spent thousands of dollars over the years to address the erosion and to bring back the productive value of their land. Amelioration of erosion in the area has had varying success.

There are also a number of erosion sites along the Rokewood-Ballarat Road, Paddy Gully Road and the area just north of Rokewood township. Some of these erosion sites are large, but relatively stable. Other sites are active and appear to be impacting on the water quality of nearby creeks that eventually flow into the Woady Yaloak River. Agricultural production is also degraded as a result of the erosion in these areas. A few gravel roads are possibly under threat from erosion.

Some remnant vegetation along the gullies may be at risk from the erosion. Erosion may occur around trees and shrubs, causing them to fall. The impact of erosion on native grasslands is relatively unknown.

Moorabool Landscape Zone

According to the field verification, the Moorabool Landscape Zone is equally at the highest risk from water erosion *(Table D2)*. The severity of erosion in the Moorabool Landscape Zone is not quite as significant as the Woady Yaloak, but the consequences in the Moorabool are much higher, mostly because it is within a Proclaimed Water Supply Area.

Field verification found a number of active erosion sites along most of Eclipse Creek, which is a tributary of the Moorabool River north-east of Meredith *(Fig. D6).* This area has numerous sheet, rill and gully erosion sites, most of which were active.

Sedimentation from Eclipse Creek is likely to contribute sediment loads into the Moorabool River and eventually into water supply reservoirs and into the Barwon River, which flows into Lake Connewarre. Investigations have linked sediments found at Lake Connewarre to sediments derived from the Moorabool River. Central Highlands Water and Barwon Water have expended large resources in the past for water quality treatment and dredging sediments from their water supply reservoirs.

The Eclipse Creek area is used mostly for grazing purposes. Erosion in this area adversely impacts on pasture production used for agriculture.

The upper west branch of the Moorabool River also has significant and active erosion that causes sedimentation of the Moorabool River and adversely impacts on agricultural production. Erosion is obvious in farming areas bordering the Brisbane Ranges National Park. Some erosion is found within the actual national park, which potentially threatens remnant vegetation. Some smaller gravel roads also appeared to be under threat from erosion, particularly around the Brisbane Ranges.

Leigh Landscape Zone

The Leigh Landscape Zone was verified to be the third-highest area at risk from water erosion, after the Moorabool and Woady Yaloak Landscape Zones *(Table D2)*. Severe erosion sites are located along Sand Road between Grenville and Garibaldi. Some of these sites are gullies up to eight metres deep, with tunnel erosion also occurring nearby *(Fig. D7)*. High sediment loads are likely from these erosion sites into tributaries of the Leigh River. The Leigh River also enters the Barwon River, which flows into Lake Connewarre. It is likely that a significant volume of sediment at Lake Connewarre has come from the Leigh River.

Agricultural production is adversely impacted along Sand Road. However, there are a number of properties in this area that do not use the land for agriculture.

Gully erosion is found along the Bamganie Road, east of Mount Mercer. Some of these sites are active, while others have grassed over and are now stable. Sedimentation of waterways from the active sites is likely to impact Cargerie and Woodbourne creeks, which flow into the Leigh River.

Gully and tunnel erosion sites are found on Moss Avenue and Magpie Road, just north of Buninyong. Erosion has impacted the road along Moss Avenue, which has been ameliorated by the City of Ballarat. Deep tunnel erosion is occurring in a native forested area along Magpie Road. This site is up to five metres deep and is likely to be contributing significant sediment loads to the Leigh River. Remnant vegetation is also under threat, with much of the erosion area being taken over by gorse, a noxious woody weed that is widespread in this locality.

Upper Barwon Landscape Zone

The Upper Barwon was ranked fourth-highest landscape zone for erosion by water after verification *(Table D2)*. The likelihood of erosion causing risk to water quality was relatively low, but the consequence of sedimentation is high as the area sits within a Proclaimed Water Supply Area.

Verification found that many of the erosion sites mapped along the Warncoort-Birregurra Road are streambank sites that have recently been fenced off and revegetated. As a result of these works, the erosion appears to be relatively stable.

Stream-bank erosion sites around Coal Mine Road have also recently been fenced off and revegetated. It appears these sites were once very active, but works appear to have stabilised much of the erosion.

A few smaller active erosion sites were found along the Barwon River and may contribute some sediment into the waterway.

Tunnel and gully erosion was verified to be impacting on Wormbete Station Road and the Deans Marsh Road, at Deans Marsh. These sites were 2-3 metres deep and were undercutting the road. VicRoads has stabilised the sites using stabilisation sand. These roads may still be under threat from tunnel erosion, with the risk from tunnelling more difficult to assess.

Small areas of agricultural production were threatened by erosion throughout sections of the Upper Barwon Landscape Zone, mostly on grazing land. Some riparian remnant vegetation may be at risk from streambank erosion.

Thompsons Landscape Zone

Field verification ranked the Thompsons Landscape Zone the lowest risk out of all erosion priority areas, as there was little evidence of erosion causing risk to high-value public assets *(Table D2)*. Many of the sites assessed had stabilised and were showing little signs of impact.

According to the desktop analysis, 20 ha of high conservation area overlapped with a sheet/rill erosion site. Verification found that there was very little impact from the erosion on this conservation area.

Priority Landscape Zones	Land use	Water Quality	Bio-diversity	Infrastructure	Verification of risk score	Revised rank according to verification
Woady Yaloak	4	4	3	2	**13**	**=1**
Moorabool	3	5	3	2	**13**	**=1**
Thompsons	1	2	2	1	**6**	**5**
Upper Barwon	2	3	2	1	**8**	**4**
Leigh	2	3	3	2	**10**	**3**

Table D2: Field verification scores for water erosion risk in priority areas.
Risk to assets is indicated as very high-5, high-4, medium-3, low/medium-2, low-1

Figure D5: The pale areas indicate areas of sheet, rill and gully erosion in the Moonlight Creek area (Woady Yaloak Landscape Zone)

Figure D6: A gully erosion site along Eclipse Creek (Moorabool Landscape Zone)

Figure D7: A gully erosion site connecting with a tributary close to the entry of the Leigh River (Leigh Landscape Zone)

Acid sulphate soils

Bellarine Landscape Zone

Acid sulphate soils in the Bellarine Landscape Zone ranked highly according to the initial relative risk to assets analysis.

An investigation was carried out by CSIRO in 2005 that assessed the potential risk of acid sulphate soils in the City of Greater Geelong, which includes the Bellarine Landscape Zone. Results from the CSIRO study indicated that despite 11,745 ha of potential acid sulphate soils found in the Bellarine region, most were located in areas that are unlikely to be disturbed and therefore pose no threat.

The conclusion from the CSIRO investigation was although potential acid sulphate soils are found throughout the City of Greater Geelong, they are mostly confined to public conservation and resource areas. An exception to this in the Bellarine Landscape Zone was the tidal flat adjacent to the smelting plant at Point Henry. The site at Point Henry was the only one tested which had any acid sulphate soil potential and this was considered marginal at most (CSIRO 2005).

As a result of the CSIRO study, it could not be verified that there is a high-potential risk from acid sulphate soils in the Bellarine Landscape Zone. Because of this, the initial high rank for acid sulphate soils in the Bellarine Landscape Zone could not stand and, accordingly, was re-ranked as a lower priority.

The overstating of the Relative Risk Value for acid sulphate soils in the Bellarine Landscape Zone was created by the large area of potential acid sulphate soils that overlap with wetlands. Potential acid sulphate soils are normally found in wetland environments, but when left undisturbed and saturated they pose no risk. Wetlands found in the Bellarine Landscape Zone normally lie in protected reserves that are unlikely to be disturbed and therefore the risk from acid sulphate soils in these areas is low.

Thompsons Landscape Zone

There was no information available to verify the potential risk of acid sulphate soils in the Thompsons Landscape Zone. From the CSIRO study carried out for the Bellarine area, it can be assumed that most of the potential acid sulphate soils in the Thompsons area are also located where disturbance is unlikely and risk is low. Because of this, acid sulphate soils in the Thompsons Landscape Zone remained as a low-ranked priority.

D.2 Impact on high value public assets

The true benefit of soil health management actions depends on the effectiveness of the action in reducing the risk of a threat to a specific asset. For example, on-ground works to reduce or stop active gully erosion in a Proclaimed Water Supply Area will have a greater benefit than on-ground works to reclaim an inactive gully outside of the water supply catchment. Similarly, in the relative risk assessment, the Relative Asset Value does not discriminate between the relative values of the same asset class. In other words, the Relative Asset Value for a wetland is 10, regardless of the fact some wetlands have international status, (those listed under the Ramsar Convention, or under migratory bird treaties) and others have only local status.

Appendix E: Community Engagement Processes and Results

E.1 Community engagement logic and methodology

Location: The initial questions asked of each asset manager were to establish whether they knew the location of threats posing risk to assets. These questions helped establish actions based on whether:

- research was needed to understand the location of risks to assets
- the location of risk to assets was already known, and the asset managers needed to be informed and given access to this information.

Results from the interviews found that most asset managers were quite capable of recognising where landslides, gully and tunnel erosion and secondary salinity were a risk in the landscape. However, many struggled to locate sheet and rill erosion and potential acid sulphate soil sites.

Asset managers did not commonly hold maps or other documentation locating threats to assets, despite many of these threats having been recently mapped. Asset managers do not appear to be aware of the availability or how to access these maps.

Technology: Questions were asked of asset managers on the broad topics of the technology used or known to address each soil threatening processes. These questions helped establish actions based on whether:

- research or trials were needed for new technologies to address the threats to assets
- asset managers needed to be informed and educated about known technologies that would effectively reduce the risk to assets.

Results show that local government and infrastructure asset managers predominantly used engineering-based treatment options to ameliorate landslides, erosion and salinity risks. Municipalities and other asset managers often followed mandatory practises during urban and infrastructure development activities to reduce the risk of certain soil-related threatening processes, particularly sheet/rill erosion. Some municipalities are developing, or are planning to develop, tools and policies to reduce the risks of landslides and erosion through their local planning scheme.

Landholders across all landscape zones used revegetation treatment options to ameliorate landslides, sheet/rill erosion, gully/tunnel erosion and secondary salinity. However, a secondary treatment was also used, which might include engineering, earthworks or drainage treatments. Acid sulphate soils were not treated. If recognised in the landscape, they are generally left undisturbed. The conclusion was that more cost-effective treatment options are needed to address the risks associated with landslides, erosion and potential acid sulphate soils.

Attitudes: The questioning surrounding attitudes helped establish the asset managers' views of the soil threats which they identified as high risk in their area and their perceptions on how effective and appropriate the treatments used in the past were. These questions helped develop actions based on:

- educating asset managers about the processes, condition, potential impacts and treatments and risks to assets caused by various threats identified in their areas
- developing new cost-effective technologies that will significantly reduce the risks and be accepted by relevant asset managers
- informing asset managers of known cost-effective technologies for addressing risks.

Most asset managers were aware of the risk to assets, and understood the importance and consequences of the recognised threats. However, many were not aware of the consequences of acid sulphate soils and farmers were not too familiar with addressing sheet and rill erosion. Their attitude to addressing the threatening processes was generally positive. Activity is being constrained by their capacity.

Asset managers were generally satisfied with the effectiveness of technologies used to address landslides, erosion and salinity problems. Most asset managers were not aware of the technologies for acid sulphate soils. The main concern amongst asset managers was the high cost of technologies, particularly engineering and earthwork technologies for treating landslides and gully/tunnel erosion.

Managers of Proclaimed Water Supply Areas and Parks Victoria managers all acknowledged the need to address soil-related threatening processes. They are positive about providing finances to fund the implementation of technologies, but rely on others to coordinate and carry out the implementation of on-ground works.

Capacity: Questions were asked around 'capacity' to determine asset managers' ability to adopt technologies for treating risks to assets. These questions identified the barriers that may inhibit technology adoption. Questions were based on:

- what forms of assistance asset managers felt were needed to help develop skills required to implement technologies for treating threats
- informing asset managers on where to access experts, who have the skills to effectively implement technologies to address the threat to assets
- seeking and coordinating incentive funds to help asset managers pay for technologies that will reduce the risk to assets.

Results show that the asset managers' capacity to treat the threats to assets is highly variable. Municipalities and infrastructure managers generally have in-house technical expertise, but often need technical assistance for more complicated matters. Most landholders feel the need for technical advice for technologies other than simple re-vegetation and fencing options. However, some individual landholders have excellent skills in ameliorating erosion. Asset managers generally do not have the capacity to manage acid sulphate soils, simply through ignorance of their location.

Most asset managers feel that they lack the financial understanding to decide about investment in treatment technologies, particularly engineering. Many believe that the cost of implementing treatments is more than the benefit of reducing the risk. In general, asset managers indicated that financial incentives would help them adopt treatments.

Results from the semi-structured interviews, and perceptions developed from interviews with asset managers from past workshops, forums and other dealings have all helped develop the results in *Table E1*. This table summarises asset managers' ability to:

- identify the location of risk to their assets
- recognise the technologies available to effectively treat threats
- understand the importance of threats to assets and judge the effectiveness of poor treatment technologies
- adopt technologies to treat risks.

Categories used for each asset manager in each priority area included 'Low', 'Moderate' or 'High'. Brief comments were also made under each category for each of the asset managers.

E.2 Community engagement results in priority areas

Asset Managers	Priority Areas	Locate Risk *(Ability to locate where the risk may occur and treatment is required in the landscape)*
1. Landslides		
LANDHOLDERS	Gellibrand	**Moderate** (new landholders do not understand risk)
	Curdies	**High** (recognise where risk lies)
	Otway Coast	**Moderate** (new landholders do not understand risk)
	Upper Barwon	**High** (identify highly susceptible areas)
	Aire	**Moderate** (some do not understand where to locate risk)
COLAC OTWAY SHIRE	Gellibrand, Aire, Otway Coast and Upper Barwon	**High** (1:25,000 scaled susceptibility maps will be used post 2006)
CORANGAMITE SHIRE	Curdies and Gellibrand	**Moderate** (staff know where high susceptibility areas are located)
SURF COAST SHIRE	Upper Barwon	**Low** (staff have limited idea where risk may occur)
VICROADS	Gellibrand, Aire, Otway Coast, Curdies and Upper Barwon	**Moderate** (inventory of landslides impacting VicRoads roads)
PARKS VICTORIA	Gellibrand, Aire, Otway Coast and Upper Barwon	**Moderate** (staff have good understanding where risks are located)
BARWON WATER	Upper Barwon & Gellibrand	**Low** (other agencies identify threats to their assets for them)

Table E1: Ability of asset managers in the Corangamite region to identify and address priorities in the Soil Health Strategy (continued next page)

	Technology *(Evidence of technology used to treat the risk to asset)*	Attitude *(Asset managers' attitude to treatment options used and available to them)*	Capacity *(Existing capacity of the asset managers to adopt appropriate treatment options)*
	Low (revegetation treatment options only used)	**Low** (not willing to give up pasture land for treatment options)	**Low** (technical advice and co-investment)
	Moderate (revegetation, drainage and earthwork treatments used)	**Moderate** (effective treatments used, but too expensive)	**Low** (technical advice and incentive grants needed)
	Low (revegetation treatment options only used)	**Low** (not willing to give up pasture land for treatment options)	**Low** (technical advice and co-investment)
	Moderate (no earthworks or engineering used)	**Moderate** (revegetation has shown to be effective)	**Low** (need technical advice)
	Low (limited revegetation treatment used)	**Low** (unconvinced of the return of investment)	**Low** (technical advice and incentives needed)
	High (tools developed to reduce risk through planning scheme)	**Moderate** (treatment options effective, but new options need investigating)	**Moderate** (greater funds needed for treatments, some technical advice required)
	Moderate (engineering treatment options used)	**Low** (need more long-term and cost-effective treatment options)	**Moderate** (some in-house technical people, but more technical support and funding needed)
	Moderate (engineering treatments options used)	**Low** (treatments are expensive and not all landslides are treatable)	**Low** (little expertise in-house, funding needed)
	High (range of engineering options used)	**High** (high-risk areas are treated immediately)	**High** (technical expertise available, funding is always found for treatment of high-risk areas)
	Low (fence off tourists from high-risk areas)	**High** (priority to protect tourists from landslides)	**Low** (technical expertise and funding needed)
	Low (other agencies develop and implement treatment)	**High** (co-invest with CCMA to reduce threat of risk to their assets)	**Moderate** (funding is available to support treatment, no technical advice available)

Asset Managers	Priority Areas	Locate Risk
2. Sheet and Rill Erosion		
LANDHOLDERS	Woady Yaloak	**Low** (unable to recognise risk)
	Thompsons	**Low** (risk needs to be mapped)
	Moorabool	**Low** (not always recognised as a risk)
	Upper Barwon	**Low** (bare soil identified as production loss, not erosion)
	Leigh	**Low** (not familiar with the nature of the risk)
GOLDEN PLAINS SHIRE	Woady Yaloak, Moorabool and Leigh	**Low** (risk not mapped)
MOORABOOL SHIRE	Moorabool and Leigh	**Low** (limited understanding on the location of risks)
BALLARAT CITY	Leigh	**Moderate** (locate general areas of high susceptibility)
SURF COAST SHIRE	Thompsons, Upper Barwon	**Low** (no maps available)
COLAC OTWAY SHIRE	Upper Barwon	**High** (1:25 000 susceptibility maps used post 2006)
VICROADS	Woady Yaloak, Moorabool, Thompsons, Leigh	**Moderate** (unsealed roads in Otways are at high risk)
PARKS VICTORIA	Woady Yaloak, Moorabool, Thompsons, Leigh	**Moderate** (unsealed roads highly susceptible)
DSE CROWN LAND	Woady Yaloak, Moorabool, Thompsons, Leigh	**Low** (limited understanding of where the threat is a risk)
BARWON WATER	Moorabool, Upper Barwon	**Low** (no idea where the risk is located)
CENTRAL HIGHLANDS WATER	Moorabool	**Low** (little understanding of where risk is located)

Table E1: (Cont.)

Technology	Attitude	Capacity
Moderate (re-sowing pastures and crops on bare soil)	**Moderate** (needs to impact productivity)	**Moderate** (incentives are available to help manage threat)
Moderate (fenced off and replanted with trees and pastures)	**Low** (other treatments need exploring)	**Low** (technical advice and extension needed)
Moderate (prevention is best, do not sow crops on steep slopes)	**Moderate** (other treatment options needed)	**Low** (technical advice and extension needed)
Moderate (re-sow bare soils into pasture)	**Moderate** (return bare soil back into productive pastures)	**Moderate** (knowledge to establish suitable pastures)
Low (limited treatment implemented)	**Moderate** (perennial pastures and deep ripping often works)	**Low** (new cost-effective treatments needed)
Moderate (mandatory practices to reduce threat used)	**Moderate** (practices used seem to be effective)	**Moderate** (technical skills available, but funding is limited)
Moderate (mandatory practices to reduce threat used)	**Moderate** (reduce the risk of the threat is in their policy)	**Moderate** (technical skills available, but funding is limited)
Moderate (tools to address the threat are in the planning scheme, but it needs reviewing)	**Moderate** (host soil erosion training days to investigate treatment options)	**Moderate** (coordinated approach is needed to address the threat properly)
Moderate (mandatory practices used during road works)	**Moderate** (practices used seem to be effective)	**Moderate** (engineers can implement treatments)
High (tools to be used to reduce development in high-risk areas)	**High** (costs to treat the threat is built into all road construction costs)	**Moderate** (new treatment options need exploring)
Moderate (often no room for silt traps)	**High** (treatments used seem to be effective)	**High** (technical expertise available)
Moderate (silt traps and correct road design used)	**Moderate** (mandatory treatments used)	**Moderate** (requires technical expertise)
Moderate (revegetation is used to stabilise soils)	**Moderate** (seen as a priority if there is a high risk to assets)	**Moderate** (investment to fix the risk is provided if seen as a priority)
Low (relies on CMA and others for technical skills)	**High** (invest in ameliorating risk to their assets)	**Low** (relies on others for technical skills)
Moderate (support winter cropping in potato areas to reduce threat)	**Moderate** (provides $10,000 to CCMA to manage erosion risk)	**Low** (relies on others to identify and treat sites)

Asset Managers	Priority Areas	Locate Risk
3. Gully and Tunnel Erosion		
LANDHOLDERS	Woady Yaloak	**High** (aware of threat locations on their properties)
	Leigh	**High** (aware of threats on their property)
	Moorabool	**High** (know where the risk is on the property)
	Upper Barwon	**High** (aware of threat locations)
GOLDEN PLAINS SHIRE	Woady Yaloak, Moorabool, Leigh	**Moderate** (a general idea, but nothing mapped)
MOORABOOL SHIRE	Moorabool, Leigh	**Moderate** (staff know where risk is generally located)
BALLARAT CITY	Leigh	**Moderate** (no recent mapping conducted)
SURF COAST SHIRE	Upper Barwon	**Low** (little understanding and no mapping conducted)
COLAC OTWAY SHIRE	Upper Barwon	**High** (1:25 000 susceptibility maps available)
VICROADS	Woady Yaloak, Moorabool, Leigh	**Moderate** (general understanding of where it occurs)
PARKS VICTORIA	Woady Yaloak, Moorabool, Leigh	**Moderate** (general understanding where threats are located)
DSE CROWN LAND	Woady Yaloak, Moorabool, Leigh	**Low** (limited understanding of where the threat is a risk)
BARWON WATER	Moorabool, Upper Barwon	**Low** (relies on others to locate risks)
CENTRAL HIGHLANDS WATER	Moorabool	**Low** (assumed it's mostly in the Ordovician Sedimentary soil)

Table E1: (Cont.)

Technology	Attitude	Capacity
Moderate (a range of treatment types used)	**Low** (treatment is too expensive)	**Low** (technical advice and incentives are needed)
Moderate (engineering, earthworks and revegetation treatment used)	**Low** (treatments are not cost effective)	**Low** (technical support needed)
Moderate (soil is sown down to pastures or fenced off for tree)	**Low** (earthworks and rock chutes are too expensive)	**Low** (incentives are needed to increase treatment adoptions)
Moderate (revegetation options used, CCMA uses rock chutes)	**Moderate** (treatments have worked, but are not cost-effective)	**Moderate** (CCMA pays for total costs of treatment for priority sites)
Moderate (some engineering treatments used)	**Low** (more cost effective treatments needed)	**Low** (greater funds needed)
Low (revegetation used only, through Grow west program)	**Low** (revegetation is effective and cheap)	**Low** (technical expertise available, but resourcing needed)
Moderate (battering, revegetation and engineering treatments used)	**Low** (follow-up maintenance of treatments required)	**Low** (resources needed to employ contractors)
Moderate (rock lining, revegetation and some drainage)	**Low** (cheaper treatment options are needed)	**Low** (funding is needed for treatments)
Moderate (engineering, earthworks and revegetation used)	**Moderate** (revegetation is cheap, but engineering is expensive)	**Moderate** (technical expertise needed)
Moderate (battering, new drains and beaching options used)	**Moderate** (treatments used have been effective, but are open to new treatment options)	**High** (resources made available for all high-risk areas)
Low (relies on outside resources for technical advice)	**High** (must treat the threat when impacting priority assets)	**Low** (limited funding and technical expertise available)
Low (little or no treatment used)	**Moderate** (seen as a priority if there is a high risk to asset)	**Moderate** (requires technical advice from outside)
Low (relies on others for treatment options)	**High** (co-invest with others to reduce risk to their assets)	**Moderate** (provides incentives, but requires technical skills)
Moderate (promotes treatment options such as buffer strips)	**High** (prevent sedimentation of reservoirs is more important)	**Moderate** (incentives used to treat risk to their assets)

Asset Managers	Priority Areas	Locate Risk
4. Acid Sulphate Soils		
LANDHOLDERS	Bellarine	**Low** (no idea of where it is located)
	Thompsons	**Low** (want it mapped)
CITY OF GREATER GEELONG	Bellarine	**Moderate** (mapped by CSIRO '04, but sites have been missed)
SURF COAST SHIRE	Thompsons	**Low** (threat identified in Anglesea, but not mapped anywhere)
VICROADS	Bellarine, Thompsons	**Low** (do not know where it is located)
PARKS VICTORIA	Bellarine, Thompsons	**Low** (do not know where the risk is located)
DSE CROWN LAND	Bellarine, Thompsons	**Low** (no regional knowledge of where the threat impacts on Crown Land)

Table E1: (Cont.)

Technology	Attitude	Capacity
Low (do not recognise the threat)	**Low** (not that interested in understanding risk)	**Low** (threat needs locating so they can treat it appropriately)
Low (not aware of the threat or treatment options)	**Moderate** (huge gap in knowledge that urgently needs filling)	**Low** (technical experts required for treatment)
Moderate (know not to disturb the potential threat)	**Moderate** (planners do not use the map to reduce risk)	**Moderate** (recent maps of the threat are available to identify risk)
Low (no treatments explored)	**Low** (limited concern of the threat in the organisation)	**Low** (minimal understanding of the risk or treatment)
Low (need to be informed of treatment options)	**Moderate** (resources will be made available for high risk areas)	**Low** (no knowledge of location of threat or treatment)
Low (unaware of treatment options)	**Moderate** (protection of priority assets from the threat is vital)	**Low** (no technical skills or resources available)
Low (treatment and knowledge of the threat by staff is limited)	**Moderate** (if proven to be impacting on their assets, the threat is seen as a priority)	**Moderate** (finances may be found if the threat is seen to be a high priority)

Asset Managers	Priority Areas	Locate Risk
5. Secondary Salinity		
LANDHOLDERS	Lismore	**High** (threat noticeable in the landscape)
	Woady Yaloak	**High** (threat is obvious in the landscape)
	Stony Rises	**High** (threat easily recognisable)
	Murdeduke	**High** (threat obvious in the landscape)
GOLDEN PLAINS SHIRE	Woady Yaloak, Murdeduke	**High** (threat has been recently mapped)
CORANGAMITE SHIRE	Lismore, Stony Rises	**High** (threat has been recently mapped)
COLAC OTWAY SHIRE	Stony Rises, Murdeduke	**High** (threat has been recently mapped)
VICROADS	Woady Yaloak, Murdeduke, Lismore, Stony Rises	**Moderate** (threat has recently been mapped)
PARKS VICTORIA	Woady Yaloak, Murdeduke, Lismore, Stony Rises	**Low** (additional mapping required)
DSE CROWN LAND	Woady Yaloak, Murdeduke, Lismore, Stony Rises	**Moderate** (update of public/Crown Land mapping required)
INFRASTRUCTURE MANAGERS (e.g. TELSTRA)	Woady Yaloak, Murdeduke, Lismore, Stony Rises	**Moderate** (latest maps on salinity discharge required)

Table E1: (Cont.)

Technology	Attitude	Capacity
Moderate (current treatments only marginally better than the status quo)	**Moderate** (unconvinced of the return for the investment)	**Moderate** (need technical advice and incentives)
Moderate (examples available on revegetation of discharge sites)	**Moderate** (keen to address the threat)	**Low** (technical advice and incentives needed)
Moderate (current treatments only marginally better than the status quo)	**Moderate** (unconvinced of the return of investment)	**Moderate** (need technical advice and incentives)
Moderate (wider range of treatments sought)	**Moderate** (some landholders are keen, others require encouraging)	**Moderate** (technical assistance and incentives required)
Low (risk to assets is not treated)	**Moderate** (treatment should be effective)	**Moderate** (greater resources are needed)
Low (risk to assets is currently not treated)	**Moderate** (Salinity Management Overlay will reduce the risk to future developments)	**Moderate** (additional resources are needed to implement SMO)
Moderate (theoretically possible to use engineering options)	**Low** (potentially too high costs)	**Low** (needs skills and financial support)
High	**High**	**High**
Low (additional research required on treatment options)	**High** (keen group with a management plan)	**Moderate** (limited resources to implement management plan)
Moderate (target treatment for reserve land only)	**High** (understand the importance of these reserves)	**Low** (under-resourced to effectively manage all areas)
High	**High**	**High**

Appendix F: Common management actions used to address soil-based threats

Soil-threatening processes	Risk to Assets	Management Practice Options
Waterlogging	Waterlogging reduces production for dairy, cropping, broadacre grazing, horticulture and forestry-based industries.	• raised bed cropping • surface and sub-surface drainage
Soil Structure Decline	Soil structure decline reduces production for dairy, cropping, broadacre grazing, horticulture and forestry-based industries. Soil structure decline increases the likelihood of erosion. Erosion may impact on water quality, infrastructure and biodiversity.	• conduct regular soil tests • land class fencing, including alleyways • stock and machinery traffic control • add gypsum to dispersive clays • restrict machinery and stock on wet soils • minimal/non-tillage • maintain and incorporate stubble
Soil Nutrient Decline	Nutrient decline reduces production for dairy, cropping, broadacre grazing and horticulture-based industries.	• conduct regular soil tests • carry out nutrient budgets • apply fertilisers according to the needs of the pastures/crops
Soil Acidification	Acidification reduces production for dairy, cropping, broadacre grazing and horticulture-based industries.	• conduct regular soil tests • apply lime where appropriate • grow perennial species with clover pastures
Soil Contaminants	Contaminants impact on agricultural production, land value, waterways, wetlands and biodiversity.	• monitor high-risk contaminated areas • clearly identify contaminated sites • conduct management practices according to the nature of contamination • store and maintain chemicals properly • follow OH & S recommended practices to reduce the risk to human health
Wind Erosion	Wind erosion impacts on agricultural production, air pollution, cultural heritage sites and water quality.	• maintain ground cover (perennial pastures) • retain or incorporate stubble • establish tree belts for windbreaks

Table F1: Risks to assets caused by threats, and management practices implemented to address these threats

Land Practice	Current adoption of best management practice by land manager	Risk to assets being addressed by the best management practice
Broadacre Grazing	Approx. 30% of broadacre grazing land grazed and spelled based on plant and soil needs.	Maintain agricultural production by reducing soil structure, nutrient and organic carbon decline.
	Approx. 10% of broadacre grazing soils appropriately limed and fertilised.	Maintain agricultural production by addressing soil acidification and nutrient decline. Also maintain water quality by reducing the likelihood of excess nutrients from fertilisers entering waterways.
	<5% of broadacre grazing land is currently fenced out according to land classes.	Maintain agricultural production, reduce sediments/nutrients entering waterways, protect biodiversity areas by reducing the likelihood of all soil-related threatening processes causing risk.
	Approx. 0.5% of broadacre grazing land has trees planted as windbreaks.	Maintain water and air quality, and agricultural production by addressing wind erosion.
Cropping	Approx. 10% of crop area in beds.	Maintain agricultural production by reducing soil structure decline and the risk from waterlogging.
	Approx. 20% of crop land appropriately limed and fertilised.	Maintain agricultural production by addressing soil acidification and nutrient decline. Also maintain water quality by reducing the likelihood of excess nutrients from fertilisers entering waterways.
	Approx. 5% of crop area under stubble retention.	Maintain agricultural production and water/air quality by addressing soil organic carbon and biota decline and erosion processes.
	Approx. 60% of cropping land being direct drilled or minimal tillage.	Maintain agricultural production by addressing soil structure decline.
Dairy	Approx. 45% of dairy soil appropriately limed and fertilised.	Maintain agricultural production by addressing soil acidification and nutrient decline. Also maintain water quality by reducing the likelihood of excess nutrients from fertilisers entering waterways.
	<5% of dairy land is managed to reduce sediment loss.	Maintain water quality, by reducing practices that encourage erosion.
	<5% of dairy land has machinery traffic control.	Maintain agricultural production, by addressing soil structure decline caused by compaction.
	Approx. 30% of dairy land is managed for waterlogged conditions.	Maintain agricultural production, by addressing waterlogging.
	Approx. 15% of dairy land is managed to reduce nutrient run-off.	Maintain water quality, by reducing the nutrient run-off.
Forestry	Approx. 15% of farm forestry land is managed to improve soil and catchment health.	Maintain agricultural production, water quality, infrastructure and other assets by reducing the likelihood of threats such as secondary salinity, erosion and landslides.
	Approx. 50% of private forest managers adopt ‘Code of Practices’ regularly. Approx. 90% of native public forests adopt ‘Code of Practices’.	Maintain forest production, water quality and infrastructure by reducing the risk of erosion, soil structure decline and landslides.
	Approx. 65% of roads on private plantations and on farms designed, developed and maintained to reduce erosion and sediments entering waterways. Approx. 80% of roads in native public forests designed, developed and maintained to reduce erosion and sediments entering waterways.	Maintain water quality by addressing sediment loss (erosion process) from roads.

Table F2: Current adoption of soil health-based best management practices from asset managers in the Corangamite region

Appendix G: An example data sheet for monitoring the progress of targets

Monitoring is needed to measure the effectiveness actions have on meeting management action targets (MATs) and resource condition targets (RCTs). These monitoring results will help provide confidence to investors that their funds have been spent wisely and are producing effective outcomes. As a result continued support from investors is likely.

Table G1 outlines a few examples of possible targets and methods used to monitor them. A similar spreadsheet will be developed for the implementation of the SHS to help monitor and record the progress of meeting targets.

Management action targets	Method for assessing progress towards target	Resource condition targets	Method for assessing progress towards target
e.g. Shires to adopt tools and policies to reduce the risk of landslides on new built developments through planning schemes.	By liaising with shires, monitor the number of active and effective tools and policies used to reduce landslide risk through planning processes.	No newly developed built infrastructure to be impacted by landslides.	By using field assessment techniques and liaising with shires, monitor the impact of landslides caused to any new built developments since the implementation of the relevant tools and policies.
e.g. No potential acid sulphate soils will be disturbed.	Liaise with infrastructure and water stakeholders and monitor their ability to identify and not disturb potential acid sulphate soil sites.	No potential acid sulphate soils will become acid sulphate soils.	Liaise with stakeholders and monitor any disturbed acid sulphate soil sites. Use appropriate field techniques to assess impacts.
e.g. Stabilise seven active gully erosion sites per year in the Woady Yaloak Landscape Zone.	Liaise with relevant stakeholders and use available databases to count the number of gully erosion sites stabilised per year in the Woady Yaloak Landscape Zone.	No net gain in active gully erosion sites in the Woady Yaloak Landscape Zone from 2007 to 2012.	Monitor the effectiveness of on-ground works to stabilise erosion, by measuring sediment lost from sites and entering waterways.
e.g. Increase the establishment of perennial grasses in areas subjected to sheet and rill erosion in the Moorabool Landscape Zone.	Monitor the number of people attending training events on managing erosion, and visit them after these events to assess whether they have adopted appropriate best management practices.	No net gain in sheet and rill erosion in the Moorabool Landscape Zone.	Monitor the area affected by sheet and rill erosion through aerial photo interpretation and other techniques to assess whether the problem is improving or not in the Moorabool Landscape Zone.

Table G1: Risks to assets caused by threats, and management practices implemented to address these threats

Appendix H: Assumptions used for the Soil Health Strategy

Risk to assets

The risk to assets analysis was the most appropriate and accurate process to develop priority areas with the data available.

Impact to on-farm assets

Where high susceptibility or incidence of threats occur at the same location as assets, there is an impact.

Impact to off-farm assets

Where a high susceptibility or incidence of threats causing offsite impacts, it is likely that there will be impacts on assets downstream.

Susceptibility maps

Indicates where potential incidents or risks will occur.

Resilience of assets

All assets had equal resilience against the impact caused by different soil-related threatening processes.

Information

Further regional studies will be conducted through the implementation of the strategy and elsewhere, which will improve information available to help reprioritise threatening processes and redefine target areas.

Developing actions

All actions needed to address soil health issues were captured by this study.

Priority actions

Priority actions are predominantly based on protecting public assets.

Integrating strategies

Other regional strategies will later influence the priority of actions and target areas in the SHS, just as the SHS will influence the priority of actions and target areas of other regional strategies.

Forming partnerships

All potential stakeholders identified as potential partners in implementing the strategy will be keen to participate.

Appendix I: Background reports for the Soil Health Strategy

1. Risk to Assets Analysis for Soil-Related Threatening Processes in the Corangamite Region (Dahlhaus & Clarkson 2006)

This study forms the basis for the risk to assets analysis in the Corangamite SHS. It outlines the methodology used and all results developed from the investigation.

2. Verification of Priority Areas for the Corangamite Soil Health Strategy (Clarkson & Miner 2006)

This study verifies the risk to assets caused by erosion, landslides, acid sulphate soils and secondary salinity. Landscape zones were assessed where threatening processes have been identified as priority areas according to the Corangamite Soil Health Strategy. It uses field assessments for erosion and landslides, and assesses previous investigations carried out on secondary salinity and acid sulphate soils to justify their impact to assets. The aim of the study was to justify the priority areas identified by the Corangamite Soil Health Strategy and to use the results from the verification process to re-rank the priority areas according to proven risk to assets.

3. The Mapping of Potential Acid Sulfate Soils in the City of Greater Geelong (CSIRO 2005 – Cox)

This study mapped all potential acid sulphate soils in the City of Greater Geelong. It also examined the growth areas for development and carried out an overall risk assessment. The report covers the processes and management of acid sulphate soils. This study was used to verify the real risk of potential acid sulphate soils in the Bellarine Landscape Zone.

4. Salinity Action Plan (Nicholson *et al.* 2006)

The Corangamite SHS will work closely with the SAP to address secondary salinity in the Corangamite region. The implementation principles for the SAP and SHS are similar as they both will be the responsibility of the Soil and Salinity Operational Portfolio Group. The SHS also links closely with other sub-strategies under the Regional Catchment Strategy as outlined in Chapter 1.

5. Corangamite CMA Landslide and Erosion Database (Feltham 2005)

This report identifies the location of sheet/rill erosion, gully/tunnel erosion and landslides in the Corangamite region. The study has used ortho-photograph interpretation to identify the location of landslide and erosion sites throughout the region. Feltham (2005) has conducted ground 'truthing' and has worked with DPI to engage with the community on its knowledge of where erosion and landslides are found. The information from this study was used in the Corangamite SHS as part of the risk to assets analysis for sheet/rill erosion, gully/tunnel erosion and landslides.

6. Economic Analysis of the Corangamite Soil Health Strategy (URS 2005 – Hamilton and Branson)

The economic analysis was conducted for the Corangamite SHS to help prioritise soil-threatening processes for investment. The study developed the benefit-cost analysis for soil health actions for private and public-based threatening processes. The study was conducted with the best information provided at the time, but did not consider environmental and social factors in its analysis.

7. Landslides and Erosion: Background information for the development of the Corangamite Soil Health Strategy (Dahlhaus 2003)

This report was written by Dahlhaus in 2003 and outlines the condition and processes for landslides and erosion in the Corangamite region. It investigates management options for landslides and assesses the potential impact if no amelioration was carried out.

8. Land Resource Assessment (Robinson *et al.* 2003)

The Land Resource Assessment (LRA) for the Corangamite region report undertook a soils and landforms inventory to develop a spatial dataset for the region. It also provided hazard susceptibility for soil-related threatening processes at a 1:100 000 scale. The report provides information on a land capability assessment for the catchment, which aims to increase the efficiency and effectiveness of natural resource utilisation in the region.

9. Soil Health Strategy for the Corangamite Region (MacEwan 2003)

This report aimed to justify the need for a Soil Health Strategy for the Corangamite region. It discusses the soil-related threatening processes and explains how they are a risk to regional assets. It also discusses the complications associated with setting targets for soil health. Essentially, this document formed the foundation of the Corangamite Soil Health Strategy.

Appendix J: Stakeholders involved with the development of the Soil Health Strategy

Soil Health Steering Committee for Draft 1 Corangamite SHS (2003)		Soil Health Steering Committee for Final Corangamite SHS (2006)	
Name	**Organisation**	**Name**	**Organisation**
Mike Boyd *(Chair)*	DPI CAS	Peter Hirth *(Chair)*	Farmer
Troy Clarkson *(Project Manager)*	DPI CAS	Troy Clarkson *(Project Manager)*	DPI CAS
Peter Hirth	Farmer	Peter Dahlhaus	University of Ballarat
Peter Dahlhaus	University of Ballarat	John Turner	CCMA
John Turner	CCMA	Richard MacEwan / David Rees	DPI PIRVic
Richard MacEwan	DPI PIRVic	Ron Page	WestVic Dairy
Ron Page	WestVic Dairy	Leigh Dennis	CCMA
Col Hacking	Southern Farming Systems	Cam Nicholson	Nicon
Mark Imhof	DPI PIRVic	Ian Crook	Crossfield
Sally-Anne Mason	CCMA	Nick McCristal	CCMA

Table J1: Steering Committee for development of Draft 1 and Final Corangamite Soil Health Strategy

Name	Organisation	Contribution
Warren Felman / Peter Dahlhaus	University of Ballarat	Incident maps for landslides, sheet/rill erosion and gully/tunnel erosion.
Tony Miner / Warren Felman	University of Ballarat	1:25 000 susceptibility maps for landslides, sheet/rill erosion and gully/tunnel erosion.
Jim Cox	CSIRO	Acid sulphate soil desktop study.
Richard MacEwan	PIRVic	1:100 000 susceptibility maps for soil-related threatening processes in the Corangamite region.
Peter Dahlhaus	University of Ballarat	Identifying processes threatening assets and setting priorities.
Joanne McNeil / Richard MacEwan	PIRVic	Using the Land Use Impact Model.
John Keany	Kean Plan	Schedules for the Erosion Management Overlays.
Tony Miner	ASM Geo	Supporting documents for the Erosion Management Overlay.

Table J2: Technical organisations contributing to the development of the Corangamite Soil Health Strategy

Other technical contributors			
Richard MacEwan (DPI)	Chris Bluett (DPI)	Austin Brown (DPI)	Troy Clarkson (DPI)
Nerissa Court (DPI)	Doug Crawford (DPI)	Peter Dahlhaus (University of Ballarat)	Mark Imhof (DPI)
Cam Nicholson (Nicon)	John Turner (CCMA)	Graeme Ward (DPI)	Ian Crook (Crossfield)
Nick McCristal (CCMA)	Greg Edwards (CCMA)	Angela Vary (CCMA)	Chris Pitfield (CCMA)
Helen Anderson (DPI)	Graeme Anderson (DSE)	Paul Carroll (DPI)	Peter Dixon (DPI)
Liz Hamilton (DPI)	Sue Harris (DPI)	David Hopkins (Consultant)	Richard Gloyne (Draintech)
Joanne McNeil (DPI)	David Rees (DPI)	Peter O'Loughlin (Consultant)	Nathan Robinson (DPI)
Gary Sheridan (DSE)	Paul Whinney (DPI)	Bruce Wightman (DPI)	

Table J3: Other technical contributors to the development of the Corangamite Soil Health Strategy

Corangamite Catchment Management Authority
64 Dennis Street, Colac. 3250 **T:** 03 5232 9100 **E:** info@ccma.vic.gov.au
W: www.ccma.vic.gov.au

For further information on Soil Health in the Corangamite region: **www.ccma.vic.gov.au/soilhealth**