West Gippsland Catchment Management Authority

Soil Erosion Management Plan

2008

West Gippsland
Catchment Management Authority

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It should be noted that specific reference to funding levels in this plan are for indicative purposes only. The level of government investment in this strategy will depend upon budgets and Government priorities.

Accessibility

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Abbreviations and Definitions

Abbreviation	Definition
BRS	Bureau of Rural Sciences
CMA	Catchment Management Authority
DEM	Digital Elevation Model
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
DWSC	Declared Water Supply Catchment
EBMP	Environmental Best Management Practice
EMS	Environmental Management Systems
EVCs	Ecological Vegetation Classes
FSV	Farm Services Victoria
FFSR	Future Farming Systems Research
ISC	Index of Stream Condition
LGA	Local Government Authorities
LUIM	Land Use Impact Model
MATs	Management Action Targets
MBIs	Market-based Instruments
PIRVic	Primary Industries Victoria (now FFSR)
PMAs	Priority Management Areas
RCTs	Resource Condition Targets
RCS	Regional Catchment Strategy
RHS	River Health Strategy
SAPs	Special Area Plans
SEDNET	A catchment hydrology model used to assess sediment loads
SEMP	Soil Erosion Management Plan
WGCMA	West Gippsland Catchment Management Authority
WGNPV	West Gippsland Native Vegetation Plan
WGSMP	West Gippsland Salinity Management Plan
WQAP	Water Quality Action Plan
WG	West Gippsland

Glossary

Acidic - Soils with a pH less than 7.0 in water. While some plants thrive in acid soils, others don't and require lime to make the soil more alkaline. This term is also used as a Subgroup distinction for a number of Soil Orders in the Australian Soil Classification (Isbell, 1996). It refers to soils with a B2 horizon that on the whole is strongly acid.

A horizon - The surface mineral horizons where some have organic matter accumulation. They are usually darker in colour than the lower horizons. If they are lighter in colour, then the horizons have lower silicate clay and/or sesquioxide content (McDonald *et al*., 1990).
The A Horizons can be broken down into three distinct layers:

- A1 Horizon - Soil surface (if no O Horizon present) with some organic matter content. Usually darker in colour than horizons below with biological activity. Can be subdivided into A11, A12, A13, etc. sub-horizons.
- A2 Horizon - It is usually paler in colour from the A1 horizon. It can have less organic matter, sesquioxides, silicate clay.
- A3 Horizon - Transitional horizon between the A and B horizons but has predominantly A Horizon properties.

Aeolian - Soil transported and deposited by wind. This term describes a soil not a "soil-forming process".

Aerenic - Soils in which at least the upper 0.5 m of the profile is non-gravelly and of sandy texture throughout. It is also loosely or weakly coherent (see consistence) and may have aeolian (wind-blown) cross-bedding. This term is used in the Australian Soil Classification (Isbell, 1996) to describe Rudosols and Tenosols.

Alluival - Soil particles and sediments deposited by water.

Aquic - These soils have stagnant water on the soil surface and/or can be saturated in some part of the upper 0.5 m of the profile, more or less continuously for 2 to 3 months. In this condition, the soil is free of dissolved oxygen. Gley (bluey-grey) colours are often an indication of prolonged saturation. The definition is used as a Suborder distinction for Podosols and Vertosols in the Australian Soil Classification (Isbell, 1996).

B horizons - Subsoil horizons consisting of one or more mineral layers differing to the A Horizon by:

- clay, iron, aluminium or organic matter concentrations;
- structure and/or consistence;
- colour.

The B Horizons can have one or more of the following layers:

- B1 Horizon - Transitional layer between the A and B horizons but dominated by B Horizon properties.
- B2 Horizon - Has the dominant feature of greater clay, iron, aluminium, humus and/or maximum development of pedagogical organisation. May be divided into subhorizons B21, B22, B23, etc.
- B3 Horizon - Transitional layer between the B and C horizons, dominated by B Horizon properties but integrating into the C material below (McDonald et al., 1990).

Calcarosol - A Soil Order of the Australian Soil Classification (Isbell 1996). These soils are either calcareous throughout the solum (or at least directly below the A1 horizon or at a depth of 0.2 m, which ever is shallower) and do not have clear or abrupt textural B horizons. The carbonate must have resulted from soil forming processes.

Chromosol - Soil Order of the Australian Soil Classification (Isbell, 1996). Soils with a clear or abrupt textural change at the B2 horizon where the pH is 5.5 (water) or greater in the upper B2 horizon. The B2 horizon is often brightly coloured.

Colluvial - Soil sediments deposited by gravity.

Consistence - Consistence indicates a soils resistance to deformation and is a measure of the degree of cohesion of soil peds.

Dermosol - Soil Order of the Australian Soil Classification (Isbell, 1996). Soils that have structured B2 Horizons more developed than weak throughout the major part of the horizon. They also lack strong texture contrast between the A and B horizons.

Dispersible soils - Soils that are structurally unstable and disperse in water into basic particles i.e. sand, silt and clay. Dispersible soils tend to be highly erodible and present problems for successfully managing earth works

Erosion - Erosion is the carrying away or displacement of solids (sediment, soil, rock and other particles) usually by the agents of currents such as, wind, water or ice by downward or down-slope movement in response to gravity or by living organisms (in the case of bioerosion).
Erosion is distinguished from weathering, which is the process of chemical or physical breakdown of the minerals in the rocks, although the two processes may be concurrent. Further information on erosion processes is provided in Appendix 1.

Ferrosol - Soil Order of the Australian Soil Classification (Isbell, 1996). These soils lack strong texture contrast between the A and B horizons. The B2 horizon has structure more developed than weak and a fine earth fraction which has a free iron oxide content greater than 5% (as opposed to a Dermosol).

Horizon - Soil layers within the profile which are reasonably homogeneous in terms of morphological characteristics and properties (e.g. colour, texture, and structure) to the layers above and below.
A soil profile usually has these basic layers:

- A1 surface
- A2 subsurface
- B subsoil
- C substrate

Kandosol - A Soil Order of the Australian Soil Classification (Isbell, 1996). These soils lack strong texture contrast and have massive or only weakly structured B horizons. The B2 horizon is well developed and has a maximum clay content in some part of the B2 Horizon which exceeds 15%. They are also not calcareous throughout.

Kurosol - A Soil Order of the Australian Soil Classification (Isbell, 1996). These soils have a clear or abrupt textural change at the A/B boundary. The upper B2 horizon is strongly acidic, i.e. less than 5.5 in water.

Pedological - relating to soils, their characteristics and origins.

Ped - The natural unit of soil structure formed by the soil's tendency to fracture along planes of weakness.

Podosols - A Soil Order of the Australian Soil Classification (Isbell, 1996).These soils have a B Horizon dominated by the accumulation of compounds of organic matter, aluminium and/or iron. These horizons may occur individually or in combination within a profile.

Profile - The vertical section of the soil from the soil surface down through the horizons including the parent material. If formed from the underlying earth and rock it consists of two parts: the solum and the parent material.

Raster data - Raster data is a spatial digital data in which each pixel, the smallest unit of information in the grid, displays a unique attribute. An example of raster data is a scanned image or photograph (i.e. *.jpg file).

Regolith - All of the weathered earth material and weathered rock between the surface of the land and the underlying unweathered rock or unweathered earth material. Regolith includes soil. Regolith does not include sediments (weathered or unweathered) which have not been weathered *in situ*.

Rudosol - A Soil Order of the Australian Soil Classification (Isbell, 1996). These soils have limited pedagogical organisation as well as minimal development of the A1 horizon.

Slaking - The break down of soil aggregates when immersed in water into smaller sized micro-aggregates. These aggregates may subsequently disperse.

Sodosol - A Soil Order of the Australian Soil Classification (Isbell, 1996). These soils have a clear or abrupt textural change between the A Horizons and B Horizons. The top 20 cm of the B2 horizon is sodic and is not strongly acid. Soils with a subplastic B2 horizon are excluded.

Sodic - A sodic soil contains sufficient exchangeable sodium to interfere with the growth of plants.

Solum - A and B horizons that have developed from the parent material by the processes of soil formation.

Sub-plastic - These soils have a consistence or textural property (after kneading for 1-2 minutes) that suggests less clay-sized particles than the soil actually contains. A subplastic soil increases in field texture after 10 minutes of kneading i.e. the soil texture becomes more clayey and harder to work. It is a feature of relatively deep subsoils and much energy is required to break down the soil aggregates. Also, these soils do not shrink/swell greatly when wet (McDonald *et al*., 1990).

Structure - Describes the way the soil particles are arranged to form soil peds. Structure is defined by three characteristics:

- GRADE measures the degree of development and the distinctiveness of the peds. It varies depending on the soil-water status and can be divided into five groups:

single grain, loose and incoherent mass of individual particles;

massive, when displaced the soil separates into fragments which may be crushed into ultimate particles;

weak, peds indistinct;

moderate, peds are well formed and visible but not distinct in undisplaced soil. Adhesion between peds is usually firm and when displaced between one third and two thirds of the soil material consists of peds, and;

strong, peds distinct in undisplaced soil, adhesion between peds is firm, and when displaced, two-thirds or more of the soil material consists of peds.

- SIZE is measured and described based on the average least dimension of the peds.
- TYPE of structure refers to the shape of peds. For example, platy, prismatic, columnar, angular blocky, subangular blocky, polyhedral and lenticular.

A number of different grades and sizes of peds may occur within a horizon. This is referred to as **compound pedality**. An example of this is when prismatic structure breaks down into smaller blocky peds.

Tenosol - Soil Order of the Australian Soil Classification (Isbell, 1996). These soils generally have weak pedological organisation throughout the profile apart from the A Horizon. Tenosols display more profile development than Rudosols and may include a weakly developed B Horizon with 15% clay or less.

Texture - Refers to the relative amounts of coarse sand, fine sand, silt and clay size particles in a particular soil. Soil texture influences many soil physical properties such as water-holding capacity and hydraulic conductivity. Numerous soil properties affect the determination of texture such as type of clay minerals, organic matter, carbonates, etc. Texture is determined in the field by measuring the behaviour of a small handful of soil when moistened and kneaded until it does not stick to the hand as described by (McDonald *et al*., 1990).

Executive Summary

The aim of the Soil Erosion Management Plan (SEMP) is to provide a guide for future investment to mitigate, prevent and remediate soil erosion in the West Gippsland Management Catchment Authority (WGCMA) region.

This is a Plan to address erosion in the West Gippsland region over the next five years. The Plan uses an assets-based approach to prioritise management actions and target areas for their activities that can be undertaken to reduce, prevent and remediate the effects of erosion on land within the West Gippsland region.

The SEMP is an initiative of the WGCMA as part of its Land Program. It was developed by the Department of Primary Industries on behalf of the WGCMA.

The SEMP augments the West Gippsland Regional Catchment Strategy (RCS) (West Gippsland Catchment Management Authority, 2004) and The River Health Strategy (RHS) (West Gippsland Catchment Management Authority, 2005a) developed by the WGCMA in 2005. The SEMP details strategic interventions which compliment those listed in the RCS and the RHS.

The plan aims to provide a guide to future actions in the region to mitigate the effects of erosion and further prevent the occurrence of soil erosion.

Soil erosion in West Gippsland

The SEMP reviews previous studies of soil erosion in West Gippsland and describes the diversity of erosion problems encountered across the region. Tunnel and gully erosion are perceived to be the greatest risk across the region. Sheet and rill erosion are also seen as being major erosion issues in some cropping areas and in steeper parts of the region. Wind erosion is described as being limited to coastal dune fields.

Asset-based approach - the effect of erosion on the region’s assets

The SEMP provides a summary of the primary assets of the region; water, land, people and communities, biodiversity and infrastructure; categorised in the West Gippsland Regional Catchment Strategy (2004) and details the potential impact of erosion on the services provided by these assets. Impacts identified include: high turbidity and sediment loads in rivers and streams; siltation of dams; poor water quality; increased costs of water treatment; reduced long-term sustainability; reduced productive capacity of land; loss of income and other impacts.

The Land Use Impact Model

The SEMP was developed using the Land Use Impact Model (LUIM). LUIM is a risk-assessment tool used to assess the impacts of land use and land management practices on natural and built assets.

The LUIM is applied within a risk framework to produce maps that identify land, water, biodiversity or built assets in the landscape at risk of degradation. The LUIM can be used at a farm, regional, state-wide or national scale. The LUIM allows for review and revision of priority setting for natural resources, reporting on catchment condition, monitoring change in condition over time, and strategic planning for sustainable development.

The LUIM uses a range of data to identify and value the assets that need to be protected, to describe the landscape, to identify how the landscape operates, and to estimate how well the landscape may be working. Data includes mapped landscape information, expert knowledge, and information derived from process models or empirical research. The LUIM has an aspatial component that incorporates knowledge of relationships between landscape characteristics and management practices, and a spatial component that uses a Geographical Information System to map where these relationships are known to exist, or, are likely to exist. A network function embedded in the LUIM is used to combine the biophysical landscape data, expert knowledge and scientific information to produce outputs with associated probability distributions.

Priority sub catchments for future on ground works were identified using the LUIM risk results in combination with the WGCMA River Health Strategy outcomes, which identify priority reaches for protection and remediation works. Six soil erosion processes were assessed; sheet, rill, gully, tunnel, landslides, and wind erosion. The principal spatial data required for the risk analysis were soil and landform and land use information. Susceptibility maps were developed using rule tables modified from Elliott and Leys (1991), van Gool and Moore (1998), and Baxter *et al*. (1998). Sensitivity was assessed using rules derived from a workshop of soil specialists. Asset value was derived using a method adapted from Heislers and Clifton (2004). Each land use category mapped for the region was assessed based on a set of economic, environmental and social criteria. Regional stakeholders then assigned scores to each criterion. The land use categories of the region were used in this project as the assets at risk of erosion. The results from the on-site erosion risk assessment were also linked to off-site impacts on key water assets such as rivers, streams, wetlands and reservoirs identified in the RHS..

Priority setting

The LUIM assessed the risk to land from erosion across the West Gippsland Catchment. The priorities for action were targeted at land classified as having high to very high risk. These areas were then prioritised according to the extent high to very-high risk in aggregated sub-catchments termed Priority Management Areas (PMA) in order to focus work in these areas.

The PMAs when mapped almost mirror the Catchment Ecosystems recently identified by the WGCMA as key sub-catchments and land management units within their region.

Resource Condition Targets

A number of Resource Condition Targets (RCTs) were set using LUIM model data which are considered to be achievable provided appropriate funding is forthcoming. The key resource condition targets relate to:

1. Changing land management in high and very high erosion risk areas to reduce risk and prevent potential soil erosion. It is estimated that approximately 30% of high to very high risk areas can be so managed over 20 years. This equates to approximately 40,500 ha of land, by 2027.

2. Rehabilitating existing eroded areas, estimated at 5% of land in high to very high erosion risk. This equates to some 6,750 ha, by 2027.

Other targets include:

- a reduction in the risk of landslips after high rainfall intensity events,
- a reduction in areas of active landslips,
- a reduction in risk in tunnel and gully erosion, in high to very high risk areas with associated improvements in water quality, stream condition and biodiversity.

Management options

The SEMP details the main management options available to manage soil erosion including a range of on-ground works, planning options, resource assessment, capacity building, regulation and market-based instruments. A number of suggestions are made as to activities which can be undertaken to "roll-out the SEMP" and potential management actions are listed for each management option. For instance for the on-ground management option, actions to be taken could include: revegetation, protection of remnants, stock-exclusion fencing, earthworks and structures, and land-class fencing.

Management Action Targets

A number of management-action targets (MATs), designed to improve resource condition have been set in the SEMP. Three soil-management areas containing the greatest areas of high to very high erosion risk were identified for prevention and treatment over 20 years, as follows:

Table 1: Management Action Targets proposed in the Soil Erosion Management Plan

	Targets for Prevention and Treatment over 20 years							
SEMP Priority Management Area	High-Very High Risk Gully-Tunnel		High-Very High Risk Sheet-Rill		High-Very High Risk Landslip		Estimated Total Area for MATs Calculations: Gully-Tunnel+50% (Sheet-Rill+ Landslip)	
	Prevent	Treat	Prevent	Treat	Prevent	Treat	Prevention	Treatment
	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha
West Strzelecki	18,000	2,700	600	80	410	50	18,500	2,765
North Strzelecki	7,500	1,200	1,800	240	10	1	8,400	1,320
Corner Inlet	8,500	1,300	600	80	480	59	9,040	1,370
Contingency /Other	6,000	1,500	1,200	300	300	80	6,750	1,690

Current knowledge gaps

The SEMP identifies knowledge gaps and the need for more high-quality technical information. The LUIM model is a useful risk management tool; however it does not provide information on existing soil erosion sites. The need for a regional survey especially in high and very high risk areas for gully, tunnel and landslip erosion to enable the current extent of these erosion types to be established, is identified in this Plan. Such a survey would also allow for on-ground truthing of areas predicted to be of high risk using the LUIM model.

The application of the LUIM model was limited to private land due to the lack of soil mapping data available for public land in West Gippsland. If and when this information becomes available, it may be possible to reapply the LUIM to investigate soil erosion threats on public land not currently addressed in this Plan.

Limitations of the Land Use Impact Model

A number of limitations using the LUIM model were identified. The model relies on the use of subjective, relative ratings in a number of cases rather than measured, numeric data. 1:100,000 scale maps were used and this may lead to accuracy issues on-ground. Basing the model on current land use is problematic as it does not account for the potential of land to be farmed differently in the future. The unavailability of data for public land means that the LUIM could not provide risk assessments on land known to be highly affected by erosion.

The LUIM model output provides focus for agency staff and land holders for actions to minimise soil erosion and reduce risks of degradation to on-site and off-site assets. However if change is to occur in land management, effective engagement of land managers is of paramount importance. LUIM is an effective tool for identifying areas at risk and for setting management action targets but effective on-ground works, as outlined in this Plan, need to be undertaken if erosion in West Gippsland is going to be arrested and the soil, Gippsland's precious physical asset, is going to be protected into the future.

1 Introduction

The Regional Catchment Strategy (RCS) for the West Gippsland Catchment Management Authority (WGCMA) region, recognises a range of threats to soil and land. These include:

various forms of soil erosion exacerbated by such things as land clearing, cultivation, over-grazing in dry conditions, forestry operations, fire, pest animals such as rabbits and native animals such as wombats,

- soil-structure decline exacerbated by over stocking, poor drainage and water logging, cultivation, compaction, salinity and sodicity,
- disturbance and exposure of acid sulfate soils,
- deteriorating soil health through inappropriate fertilizer use, cultivation techniques, and contamination,
- productive use precluded by non-productive development (for example, urbanisation of potato soils), and
- land salinity caused by elevated water tables from increased recharge due to vegetation change and irrigation.

This Soil Erosion Management Plan (SEMP) addresses the first point, that is, the various forms of soil erosion that occur in West Gippsland. The SEMP identifies the threats to on-site and off-site assets caused by soil erosion, and suggest appropriate management actions to prevent or reduce the impact of soil erosion.

The types of soil erosion assessed were sheet and rill erosion, tunnel and gully erosion, landslips and wind erosion. The SEMP has identified high-risk areas for priority attention. The management actions suggested in this plan should be considered as being provisional; a first attempt to set meaningful actions to address soil erosion in West Gippsland. They are set for five years, and will be modified during the delivery of programs, as techniques are refined and better information becomes available.

The SEMP provides the first step towards the development of a Soil Health Strategy, which would address the full range of soil health issues listed above.

1.1 Scope

The scope of the SEMP was to include all land in the WGCMA region. In developing the SEMP, it became evident that the soil dataset for the region did not include soil data for any Crown land areas. Hence, any Crown land areas have been eliminated from the analysis and are outside the scope of the project. This includes all State Forest and National Park areas. Some interpretation of ‘Parks areas’ was carried out by local park rangers to determine areas of wind erosion risk along the coast.

Soil erosion is one of the key threats to the West Gippsland region’s assets. Arguably it is the soil health issue that currently has the greatest impact on the WGCMA region. The scope of this plan is to tackle the main soil erosion processes active in West Gippsland and will include sheet and rill erosion, gully erosion, tunnel erosion, wind erosion and mass movement (resulting in the appearance of landslips).

The SEMP does not address issues related to stream bed and bank erosion as these are addressed in the West Gippsland Regional River Health Strategy (RHS) (West Gippsland Catchment Management Authority, 2005a) and the Water Quality Action Plan (WQAP) which covers both East and West Gippsland Catchment Management Authority regions (East and West Gippsland Catchment Management Authorities, 2005).

The SEMP has been developed with consideration of other threats listed in the introduction since they are related. However, comprehensively addressing all of the threats to soil and other related assets is beyond the resources available for developing the SEMP, and would be more properly considered in the development of a Regional Land or Soil Health Strategy. Consequently, the range of issues used to prioritise management actions and target areas mainly focuses on soil assets, water assets and the services they provide.

Significant wildfire events have serious consequences to soil loss and water quality downstream of the “burnt catchment” areas. Consequently fire management needs to be considered when investigating soil health issues in any future planning scenarios. The SEMP will not address wildfire as a threat process for soil erosion.

The scope of this plan is not to develop a full-scale strategy for management of soil erosion. As such it does not include a cost-benefit analysis of the threat of soil erosion or the management actions required. The SEMP does consider the direct economic impact of soil erosion in the consideration of ‘asset value’ during the modelling process.

1.2 Plan development

Currently there is no state-wide framework for the development of strategies and plans such as soil erosion management plans. Therefore, plan development utilised the experiences and information from previous plans and strategies, and worked within the limitations of knowledge and data on natural resources in the WGCMA region.

A number of studies are currently being implemented to guide the development of soil health strategies by other Victorian Catchment Management Authorities and the Department of Sustainability and Environment.

Because of the paucity of data on the severity and extent of soil erosion in the WGCMA region, development of the SEMP was based on the application of the Land Use Impact Model (LUIM). Application of the LUIM was limited to private land, due to the lack of soil mapping in public land at an appropriate scale. LUIM utilised data on assets (including soil, land and other assets), land-use, climate, expert soil and land management knowledge, and community consultation. Prioritization of areas for management actions was based on the risk posed by soil erosion as well as on the priorities established in the RHS and WQAP. Management actions were selected from field-proven options and were applied to the appropriate combinations of soil erosion process and priority area.

1.3 Plan aim

The SEMP aims to:

- Identify the risk from soil erosion across the region and in relation to the region's land and water assets.
- Identify and set prescriptive management actions to protect key assets in identified high risk areas.
- Identify gaps in knowledge, skills and capacity in relation to soil erosion in West Gippsland.
- Provide a sound basis for investment by a range of funding bodies focusing on West Gippsland.

The SEMP will result in the implementation of targeted works that will mitigate, prevent and remediate soil erosion in the WGCMA region.

2 The West Gippsland Region

The WGCMA region covers an area of 1,768,500 hectares of which 58 % (981,100 hectares) is freehold and 42 % is public land (703,300 hectares). Of the freehold land 86% has been cleared for agriculture. Agriculture is dominated by grazing industries based on permanent perennial pastures grown under high rainfall in the west of the region, with rainfall reducing towards the east. Here some irrigation is carried out in the Macallister Irrigation District, which supports a valuable dairy industry.

A total of 828,246 ha of remnant native vegetation remains in West Gippsland. The majority of remnant native vegetation is on public land in the northern part of the region. Significant areas of public and private land are used for forestry including land that was once cleared for agriculture.

The region can be divided into several physiographic areas each with a unique combination of soil, climate, topography and geology:

- The Strzelecki Ranges and Wilson's Promontory (both are part of the Southern Victorian Uplands),
- Southern slopes of the Great Dividing Range including the Victorian Alps (Eastern Victorian Uplands),
- Riverine plains of the waterways that make up the South Gippsland basin, and the La Trobe and Thomson River basins (Southern Victorian Riverine Plains), and
- Coastal plains from San Remo to Lakes Entrance (Southern Victorian Coastal Plains).

2.1 West Gippsland geology and soils

In the south the region is divided by the Strzelecki Ranges, a deeply dissected range with steep cretaceous sandstone hills and tertiary basalts, rising to a height of around 500 metres. This forms a southern extension of the Great Dividing Range with Wilson's Promontory at its southern-most point. Both Wilson's Promontory and the southern slopes of the Strzelecki Ranges have relatively short waterways that drain directly into Bass Strait. The northern slopes of the Strzelecki Ranges drain into the La Trobe River. Brown Dermosols dominate the Strzelecki Ranges although Red Ferrosols, a minor soil type, are economically important. Aerenic Podosols and Shallow sandy Rudosols dominate Wilson's Promontory.

The northern part of the region includes the Victorian Alps (Eastern Victorian Uplands). Most of this area is covered by native vegetation and is public land. Hills and mountains of Devonian granites and Paleozoic sedimentary rock dominate this area. Many of the soils in this area are coarse and medium textured Rudosols and Tenosols.

The riverine plains (Southern Victorian Riverine Plains) include three major catchment basins: the South Gippsland basin, the Thomson River basin and the La Trobe River basin. The South Gippsland basin consists of a series of relatively short river catchments that drain the southern slopes of the Strzelecki Ranges into Bass Strait, between San Remo and Lochsport. The La Trobe and Thomson Basins rise on the southern slopes of the Great Dividing Range and the northern slopes of the Strzelecki Ranges. These basins drain into Lake Wellington, the most western of the interconnecting Gippsland Lakes.

The riverine plains are composed of Tertiary and Quaternary sediments eroded from the surrounding ranges. There are a wide range of soils including large areas of poorly developed soils such as Rudosols, Tenosols and Podosols. There are large areas with well developed soils where there is either a gradual increase in clay content with depth in the profile (Dermosols), or a strong contrast in texture between the sandy to clay loamy surface soils and the clay subsoil (Sodosols, Chromosols and Kurosols).

The soils in the western part of the riverine plains experience a higher rainfall and tend to be more acidic. Soils in the eastern part of the riverine plains tend to be more sodic than soils in the west of this area and contain aeolian deposits, reflecting a geological history of stranded beach ridges and successive episodes of deposition of wind-eroded material from the receding marine shore-line. Consequently, surface soils are often sandier in the east than in the west, where there are generally finer-textured surface-soils developed exclusively from alluvial deposits.

The coastal plains (Southern Victorian Coastal Plains) are characterised by dunefield landscapes on the current shore of Bass Strait. The dunefields consist of dunes, swales and swamps all dominated by wind-blown sands. The dunes and swamps represent opposite extremes in drainage. These areas are dominated by sandy Aerenic Rudosols and sandy Podosols. Further description of soils in West Gipplsand are included in Appendix 9.

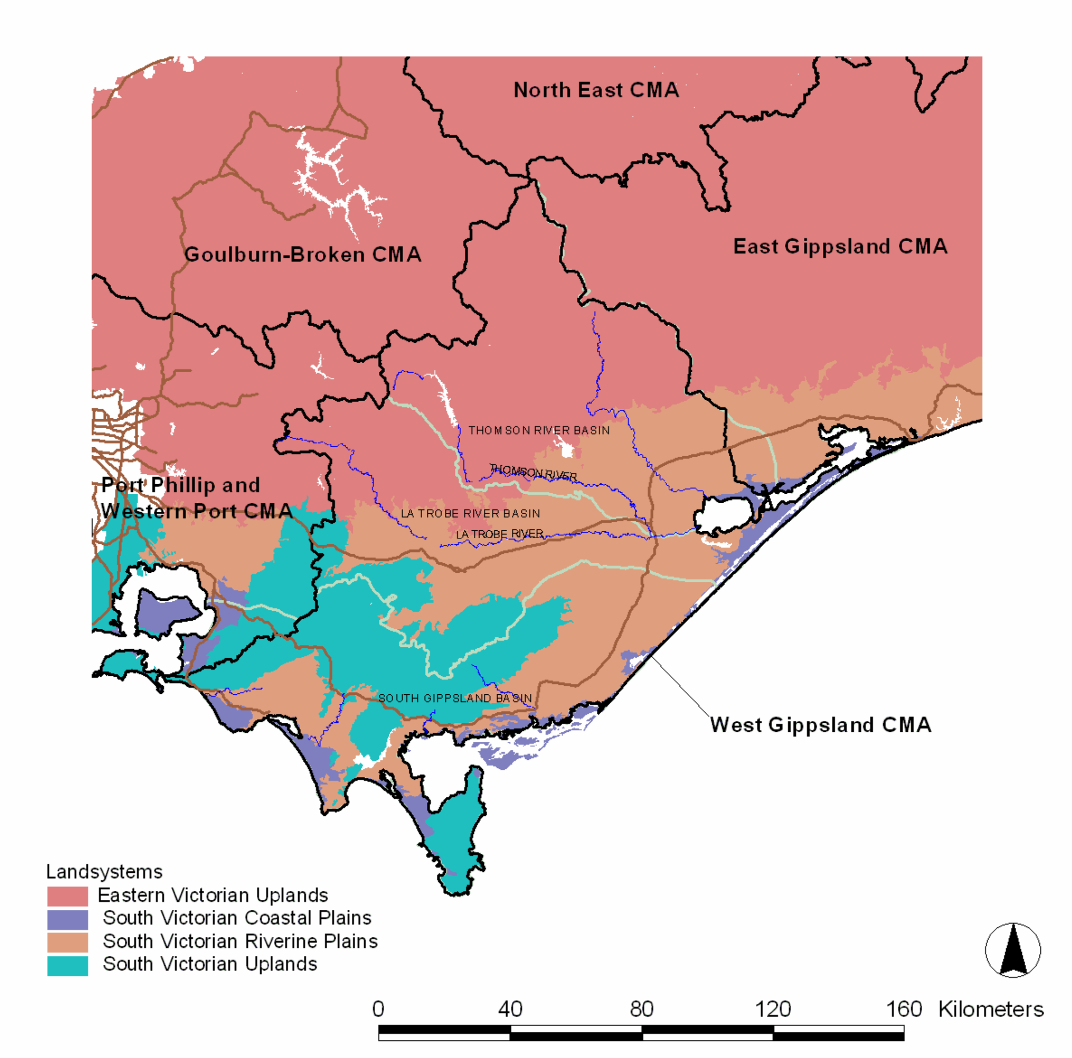

Figure 1: Geomorphology of the West Gippsland Catchment Management Authority region as described by land systems (Rowan, 1990)

3 Related Strategies, Plans and Schemes

The SEMP is designed to integrate with other strategies and plans developed for and by the WGCMA, planning schemes of local government within the WGCMA region, and Matters for Target. It will also inform the current and future Regional Catchment Strategy.

3.1 West Gippsland Catchment Management Authority strategies and plans

3.1.1 Regional Catchment Strategy

The Regional Catchment Strategy (RCS) provides the over-arching framework for natural resource management for the West Gippsland region. The RCS lists the following strategic interventions for protecting land:

- PM1 Develop local and regional future land use plans.
- PM2 Review and improve planning regulations regarding sustainable practices on the local level.
- PM3 Develop a suite of incentives for the protection of threatened land uses.
- PM4 Integrate land management and land use.
- MEB1 Develop a systematic approach to the responsible management of the impact of production activities on the environment.
- MEB3 Ensure the sustainability of production and harvest while securing the protection of assets and minimizing risk.
- MEB6 Protect and improve coverage of native vegetation.
- MEB8 Control and limit the spread of agricultural and environmental pest plants and animals.
- MEB9 Protect and enhance the coastal assets of the West Gippsland Region.
- CBCS1 Support and build on existing community capacity to achieve natural resource management outcomes.
- IC4 Provide support for coordination and partnership development.
- MR2 Monitor, evaluate and report on resource condition and management action targets implemented from the RCS.

In the development of management actions for plans and strategies developed for the West Gippsland region, it is important to integrate the SEMP with other plans and strategies to realise any potential synergies and multiple outcomes that can be achieved. It is also important to avoid duplication or conflicts, which can waste limited resources and produce undesirable outcomes.

Strategies and plans for the region that have a significant influence on the incidence and remediation of soil erosion are briefly discussed below.

3.1.2 River Health Strategy

The River Health Strategy (RHS) (West Gippsland Management Authority, 2005a) envisages

- protecting high value rivers,
- maintaining the condition of ecologically healthy and representative rivers,
- achieving an improvement in the environmental condition of rivers in general,
- maintaining the social and economic river asset values across the WGCMA region, and
- enhancing community capacity and involvement in river health programs and decision-making.

The management actions of the RHS are focused on the waterways including rivers, streams and natural waterways. The waterways comprise the channel, the riparian zone, floodplains, floodplain wetlands and the estuary or the terminal lake. Waterways are prioritised using reaches defined by Index of Stream Condition (ISC) within each sub-catchment.

The RHS complements and informs the development of the SEMP because soil erosion has off-site impacts on the region's water assets.

3.1.3 Water Quality Action Plan

The Water Quality Action Plan (WQAP) for the WGCMA region (East and West Gippsland Catchment Management Authorities, 2005) is subordinate to the RHS. It is similarly important to the SEMP. The aims of this plan that are directly important to the SEMP are:

- identify surface water quality issues,
- link identified water quality issues with other land, water or vegetation management issues, and
- develop management actions that address the causes of poor water quality.

Many management actions in the WQAP, directly impact on the SEMP. For example, development of whole farm plans, farm forestry and audits of road crossings of streams.

3.1.4 Native Vegetation Plan

The West Gippsland Native Vegetation Plan (WGNVP) (West Gippsland Management Authority, 2006) has strong links to soil erosion. Clearing of native vegetation during European settlement has resulted in large scale soil erosion. Revegetation with native vegetation and protection of remnant vegetation are key remedial and preventative actions available to combat soil erosion.

3.1.5 Salinity Management Plan

The West Gippsland Salinity Management Plan (WGSMP) (West Gippsland Management Authority, 2005b) outlines many management actions to combat salinity and many of these can also be linked to soil erosion, for example, whole farm planning and revegetation. The loss of soil from recharge areas can be detrimental to efforts to re-establish native vegetation in these areas. The breakdown of soil structure due to salinity or compaction will also exacerbate the incidence of soil erosion in areas affected by salinity.

3.2 Code of Practice for Timber Production

The forestry industry uses the 'Code of Practice for Timber Production' (Department of Sustainability and Environment, 2007), for all forestry-related activities. It has a strong focus on minimisation of soil erosion.

3.3 Declared Water Supply Catchments

The *Catchment and Land Protection Act 1994* has proclaimed 20 catchments within West Gippsland as 'Special Areas' under the Act (see Figure 2). All of these are water supply catchment areas to supply potable water for town supplies. Some of these areas have 'Special Area Plans', which set land use conditions and guidelines for various land uses within each area (Table 2).

Declaration imposes responsibilities on public bodies to the planning of land use within a declared area. Six of the Declared Catchments have Special Area Plans (SAPs) that place conditions on land use within the catchment area. Most of these plans were developed many years ago with the management actions largely being superseded by new plans and policies.

The conditions set in the SAPs assist planners and those managing land development activities to determine the suitability of proposed activities within these catchment areas. They also enable specific conditions to be placed on proposed developments to minimise the impact of developments on water quality.

Where a Declared Water Supply Catchment is identified in a high erosion risk area, these areas will have a higher priority for action than other land areas within the same risk category.

Figure 2: Declared Water Supply Catchments in West Gippsland (key to numbers in Table 2)

Table 2: Declared Water Supply Catchments in West Gippsland declared under the *Catchment and Land Protection Act 1994*

River Basin	Catchment number in Figure 2	Catchment Name	Area (ha)	Special Area Plan
La Trobe	19	Tyers River	31,969	Yes
	26	Mirboo North	895	Yes
	30	Billy's Creek	2,344	Yes
	62	Tanjil River	50,687	Yes
	66	Narracan Creek	8,347	No
	68	Sunny Creek	388	No
	71	Rollo Creek	447	No
	75	Walkley Creek	767	No

River Basin	Catchment number in Figure 2	Catchment Name	Area (ha)	Special Area Plan
	120	Deep Creek & Loch River, Noojee	12,304	No
Thomson	5	Glenmaggie	190,277	No
	43 & 76	Thomson River	14,674	No
South Gippsland	38	Tarra River	2,830	Yes
	53	Lance Creek	1,862	No
	54	Tennant Creek (Candowie Reservoir)	1,793	No
	96	Deep Creek (Foster)	1,915	No
	97	Agnes River	6,700	No
	118	Tarwin River	107,700	No
	119	Merrimans Creek	54,400	No
	94	Ruby Creek (Leongatha)	900	No
	95	Battery Creek (Fish Creek)	200	No

3.4 Local government planning schemes

The WGCMA region includes parts or all of five local government areas: Bass Coast, South Gippsland, La Trobe, Baw Baw and Wellington Shires. Local government planning schemes address the issue of soil erosion by the inclusion of environmental significance overlays (ESO) for areas which are either susceptible to erosion, dominated by high quality agricultural land, are water catchment areas, or are coastal land. The planning schemes also set guidelines and conditions under which specific developments can be undertaken, that is they have an impact when land use changes.

4 Management Areas

Development of the Soil Erosion Management Plan (SEMP) is facilitated by separating the West Gippsland Catchment Management Authority (WGCMA) region into areas within which the characteristics that affect soil erosion processes are relatively uniform: soils and their management, geomorphology, climate, and geology. That is, by land assets into management areas. However, while management areas must account for these characteristics, it is helpful to utilise previous divisions of the region, such as the resource management areas used during the development of previous strategies and plans for water assets.

The WGCMA River Health Strategy (RHS) and Water Quality Action Plan (WQAP) divides the region into three basins: Thompson River Basin, La Trobe River Basin and South Gippsland Basin. These in turn are divided into 35 sub-catchments (Figure 3), each of which contain up to 11 reaches defined by the Index of Stream Condition (ISC) assessment. While appropriate for the RHS and its subordinate strategies and plans, this division of the region does not facilitate prioritisation of management actions onto different parts of the landscape, i.e. the sub-catchments do not differentiate between land assets such as defined by soils, land uses, their different kinds of management, landscapes, etc.

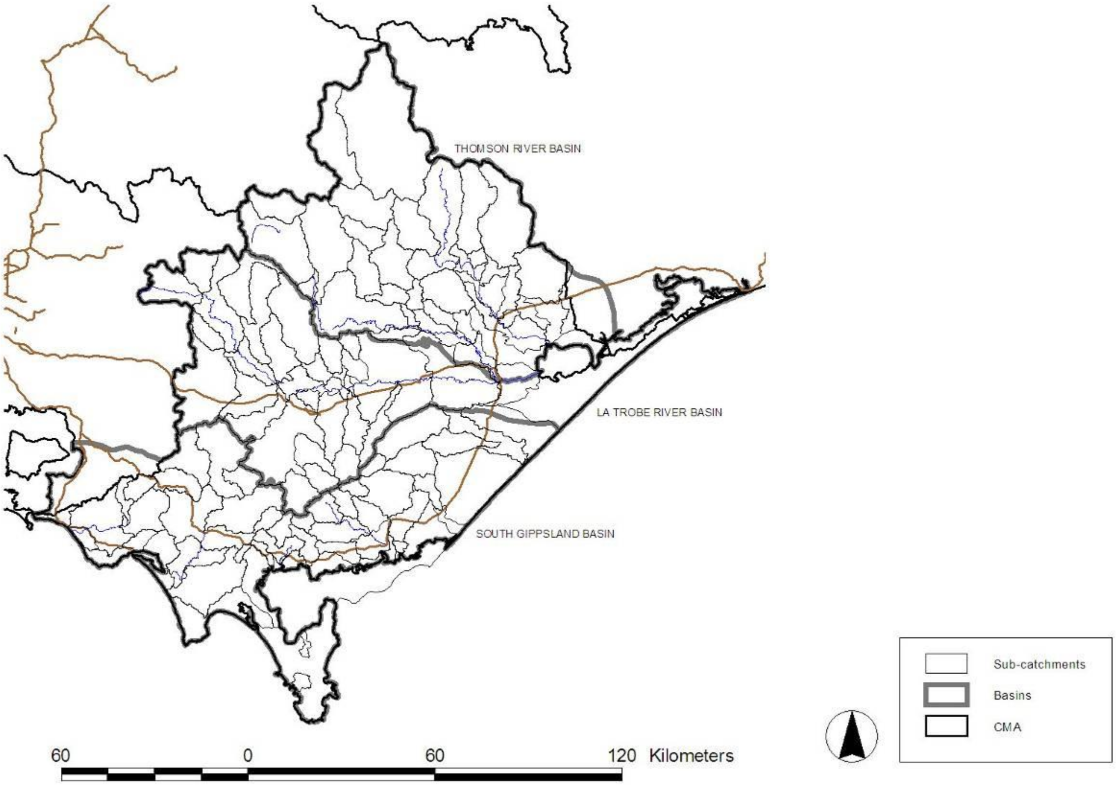

Figure 3: Sub-catchments used in the West Gippsland Catchment Management Authorities River Health Strategy and subordinate strategies and plans

When developing management units, it is important to use spatial datasets that are consistent with the objectives of the SEMP, the data upon which it is based, and, in particular, the scale of the plan. For example, the Interim Biogeographic Regionalisation for Australia (IBRA), Version 5.1- Sub-regions (Department of the Environment and Heritage, 2000), is accurate to at least a scale of 1:250,000, whereas Sargeant and Imhof's soil/land survey (Sargeant and Imhof, 2006) used in developing the SEMP is accurate to a scale of 1:100,000.

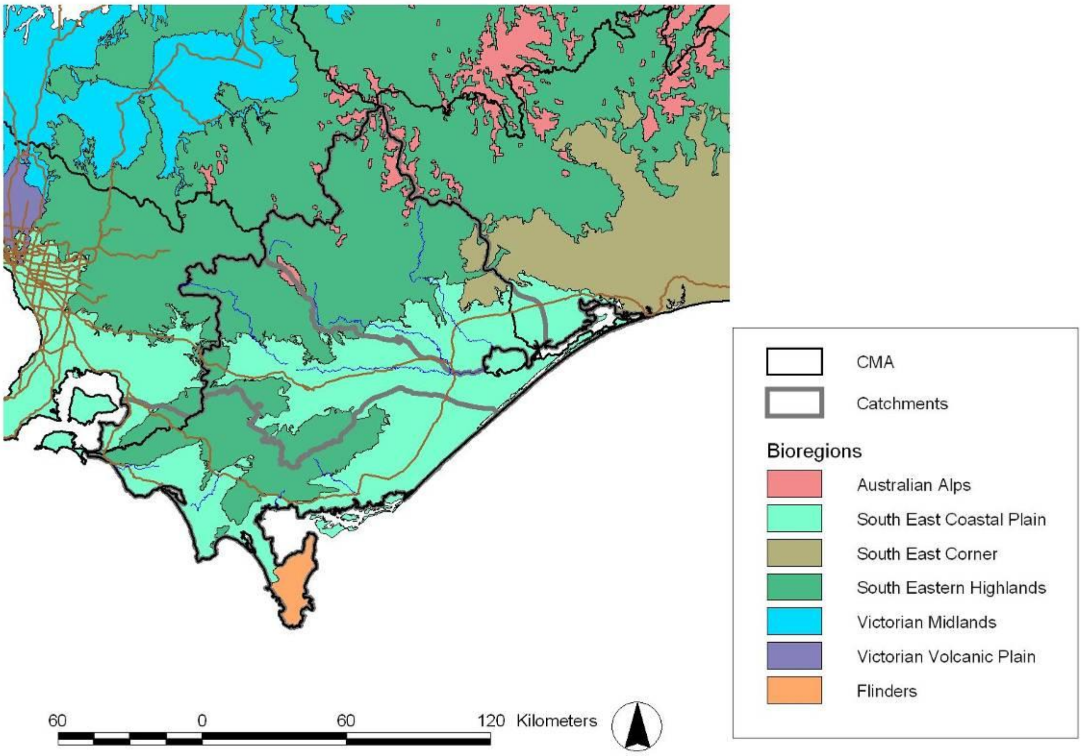

Figure 4: Bioregions (Department of Heritage and Environment, 2000) in the West Gippsland CMA region

Also, IBRA (Figure 4) does not separate the land systems of Southern Victorian Riverine Plains from Southern Victorian Coastal Plains whereas the land systems developed by Rowan (1990) (Figure 1) which overlie the soil mapping, does.

Therefore, for the purposes of the SEMP, spatial data defining the basins and sub-catchments from the RHS and the WQAP, and land assets (e.g. land systems), soils, are utilised to guide selection of priority areas for the application of management actions, after definition using land asset boundaries.

5 Previous Erosion Studies

The extent and severity of soil erosion is not well understood in the West Gippsland Catchment Management Authority (WGCMA) region due to the limited kinds and amount of information available for this region. Appendix 2 includes a comprehensive review of studies and surveys that have been carried out to assess soil erosion in West Gippsland. The following section provides a brief summation of the work undertaken.

The limited number of studies and surveys that have been carried out give an incomplete view of the current extent and severity of soil erosion in West Gippsland. Moreover, these are "after the fact" and do not necessarily allow extrapolation into the future. They must be interpreted within the conditions in which soil erosion occurred. These conditions may not be the same in the future. Furthermore, extrapolating these studies and surveys to dissimilar environments especially where there are important differences in soils, climate, management, etc., is not valid. Consequently, development of the SEMP depended on data from previous research as well as alternative kinds of information.

However, it is necessary to understand the limited information that is available, to verify the outputs of the development of the SEMP. There are few studies that quantify and characterise soil losses, the impacts from the different types of soil erosion considered in SEMP, and the sediment that is deposited onto land surfaces, into waterways and into water bodies that receive eroded soil.

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Figure 5: Tunnel erosion near Foster

The lack of quantitative information on soil erosion causes, extent and trends represents a substantial knowledge gap. This gap means that during the development of land and water management plans and strategies, management actions are selected without a factual basis and the management action targets that are set are at risk of not being met. Furthermore, it means that the selection of target areas is not optimised; an important weakness where funds are limited.

Lorimer *et al*., (1996) measured soil movement at 23 sites across Victoria. While only two sites were in the WGCMA region, many of the 21 sites not in the WGCMA region serve as analogues for landscapes and land management within the WGCMA region. They reported that there was relatively low soil erosion by wind or water where cultivation did not occur, that is, where soil was protected by a permanent cover of pasture. At sites where soil was exposed by cultivation, however, the most serious losses of soil were observed.

Several research reports have focussed on nutrient run-off from grazed pastures in small catchments of less than 3.6 ha, in West Gippsland (Greenhill, *et al*., 1983ab; Nash and Murdoch, 1997; Nash *et al*., 2005). These reports indicate that most of the Phosphorus (P) in run-off from well-managed, permanent perennial pastures is likely to be in the form of reactive P rather than as P carried by sediment. In fact, sediment yield from such pastures is minimal (D Nash, pers. comm.).

Prosser et al. (2001) reviewed Australian research on erosion and sediment transport in the rivers of Australia. They concluded that the main source of sediment found in the waterways of most catchments, is from stream-bank erosion. Much of the sediment from the erosion of hill-slopes, gullies and channel banks, is stored in stream beds. A draft report by Wilkinson *et al*. (2005) on sources of sediments in the Gippsland Lakes, supports this statement. They have made a preliminary conclusion that over 80% of suspended sediment entering these waters, is from stream bank erosion. They also concluded that a significant proportion of the suspended sediment supplied to the La Trobe and Thomson Rivers is deposited within the catchment on floodplains and in reservoirs. Their draft report states that very little soil eroded from hill-slopes is delivered to the streams.

However, it is likely that catchment-scale studies for the South Gippsland basin would find contrasting results to those for the La Trobe River and Thomson River basins. The latter have long low-gradient stream channels surrounded by extensive alluvial plains, emptying into Lake Wellington whereas the rivers and streams of the South Gippsland basin have only short reaches with narrow alluvial plains, emptying into Bass Strait, Andersons Inlet, Shallow Inlet and Corner Inlet. Hill-slope erosion is likely to constitute a greater proportion of the sediment delivered to rivers in these catchments.

Landslips have not been assessed across the WGCMA region. The only assessment, (Brumley 1979) reported on landslips in the southern part of the former Shire of Narracan. It highlights the impact of landslips on infrastructure, especially roads. It is uncertain if other areas of the WGCMA region are similarly affected.

Several surveys of farmers (Fuller 1995) and natural resource managers (Department of Natural Resources and Environment 1997) provide qualitative information on soil erosion. These provide a better geographic coverage than the quantitative studies discussed above.

A survey (Fuller 1995) of full-time farmers of South and West Gippsland by Fuller found that they perceived tunnel erosion (Figure 5) and the resulting gully erosion to be the most important “land degradation problem” and it posed the greatest risk. Landslips and streambank erosion were the other two main land degradation problems. Landslips, declining soil structure, stream-bank erosion and soil acidification were ranked as lesser risks, in that order.

This is in accord with the Department of Conservation and Natural Resources staff perception of gully and tunnel erosion (Department of Natural Resources and Environment, 1997), and is consistent with the results of the modelling for erosion risk detailed later in this plan.

Sheet and rill erosion was rated as severe in the hills of the Strzelecki ranges, the Moondarra Plateau and along the Avon, Thomson and Macalister Rivers (Figure 6). The Thorpdale potato production areas are included in the severe rating, which would not be the case if these robust soils were not cultivated.

Figure 6: Sediment covering the road surface is an example of an off-site impact of soil erosion

6 Asset-based Approach

Assets are elements of our region that are valued by people for a variety of reasons. The reasons can be for their economic, environmental or social values or some combination of these. Assets can also be valued for the services they provide.

West Gippsland is rich in environmental, social and economic assets supporting a prosperous agricultural sector dominated by the dairy and grazing industries, an industrial sector dominated by the coal and electricity industry and a strong tourism sector based around the Gippsland Lakes, National Parks, wetlands, coastal areas and beaches.

Significant environmental assets include the Gippsland Lakes and associated wetlands, the forested areas of the Great Dividing Range, Wilson’s Promontory National Park, Tarra Bulga National Park, a spectacular coastline, many other parks and reserves, and the forests of the Strzelecki Ranges.

The West Gippsland Regional Catchment Strategy (2004) categorises the region's assets into the following asset classes:

- Water (surface water and groundwater; inland and coastal; permanent and temporary)
- Land (soil, geology, landform, minerals, coal, gas and petroleum)
- Biodiversity (terrestrial and aquatic, species and ecosystems)
- Atmosphere and Climate
- People and Communities (individual, community and institutional capacity)
- Infrastructure (transport networks; energy generation and distribution; water supply and drainage; flood mitigation; waste treatment; industrial, commercial, domestic and civic premises)
- Production (timber and agricultural production systems including timber, fisheries)

The asset classes can be further described in secondary classes and the services that these assets provide to the environment and the community as shown in Table 3.

The key direct impacts of soil erosion are on Water, Land and Productivity assets. Soil erosion will impact each asset in a different way. Some of these impacts are minor while other assets will be affected in a major way. Identifying and quantifying the sources of impacts, (e.g. the soil or soils in one or more parts of a catchment that are yielding the sediment that increases water turbidity in different reaches of the waterway), is yet to be done for each soil erosion process across all of the sub-catchments of the WGCMA region. This represents a significant knowledge gap.

Table 3: Assets most vulnerable to soil erosion

Primary assets	Secondary assets	Asset services	Erosion impact on the asset or service
Water	• Waterways, Rivers and streams	• Potable water • Stock and Domestic water • Irrigation water • Aquatic habitat • Recreation • Clean water • Sediment transport	• High turbidity and sediment loads, reduced water quality • Reduction of aquatic habitat quality • Increased algae and weed growth • Increased wear on pumps & pipes • Impact on stock health due to poor water quality
	• Reservoirs / Dams	• Potable water • Stock and Domestic water • Irrigation water • Aquatic habitat • Recreation • Water storage • Sediment capture • Industrial water	• Reduction of water quality • Siltation of dams, drains • Poor water quality impacts on stock health • Increased cost of water treatment • Increased algae and weed growth • Reduced amenity, tourism visitation
	• Estuaries	• Aquatic habitat • Recreation • Biodiversity • Fish nurseries • Sediment capture	• Loss of aquatic habitat • Reduction of fish stocks • Siltation of estuaries • Increase in algae and weed growth • Reduced amenity, tourism visitation

Primary assets	Secondary assets	Asset services	Erosion impact on the asset or service
Land	• Dairy • Grazing • Horticulture • Forestry • Other • Mining areas • Coastal land	• Local employment • Food and fibre production • Economic activity • Clean water • Recreation • Biodiversity • Soil stability • Water harvesting • Carbon sequestration • Water storage buffer • Healthy waterways • Landscape values • Timber production • Energy production	• Reduced productive capacity • Reduced area of production • Loss of income • Loss of topsoil • Reduced visual amenity • Increased difficulty of land management • Cost of replacing lost soil nutrients • Sedimentation of farm tracks, drains and other infrastructure • Reduced long term sustainability • Erosion of tracks and roads
Biodiversity	• State and National Parks and Reserves. • Private native vegetation • Coastal Reserves • Marine National Parks	• Biodiversity and habitat • Rare and threatened species • Recreation • Sediment capture • CO_2 sequestration • Nutrient cycling • Runoff attenuation	• Direct loss of vegetation • Sedimentation of vegetated areas • Smothering of aquatic habitat • Reduction in habitat quality due to soil nutrient loss
People and Community	• Rural communities • Urban communities	• Local Landcare groups and other Natural Resource Management groups • Farmer industry groups • Volunteer community services • Regional cohesion and sense of 'community' • Environmental management	• Increased demand for community intervention for degraded areas • Reduced local and off site amenity • Increased demand for government intervention and investment

Primary assets	Secondary assets	Asset services	Erosion impact on the asset or service
Infrastructure	• Urban Infrastructure	• Recreation • Housing • Roads • Drainage • Communications services	• Situation of land, drains, open space, roads • Erosion of roads and tracks • Exposure and damage to underground services • Undermining of foundations to housing, roads, bridges, etc. • Increased maintenance costs
	• Rural Infrastructure	• Roads – Access and communication • Bridges • Farm buildings • Dams • Communication services	• Situation of land, drains, open space, roads, dams • Erosion of roads and tracks • Exposure and damage to underground services • Undermining of foundations to housing, roads, bridges etc • Breaching of farm dams, flooding • Increased maintenance costs

7 Land Use Impact Model

As discussed, data available on the current extent and severity of soil erosion within the WGCMA region is incomplete. As a surrogate for the lack of data, an assessment was carried out using a range of landscape data and land-use information, expert knowledge, and the Land Use Impact Model (LUIM) to identify areas in the region at risk from six soil erosion processes: sheet, rill, gully, tunnel, slumping, and wind erosion under current land management regimes.

The LUIM operates within a risk-assessment framework to produce maps that rank the likelihood and level of risk associated with a particular threatening process. The ranking of likelihood and risk can then be used to guide investment to the areas of greatest risk. The LUIM has an aspatial component that incorporates knowledge of relationships between land qualities and activities on the land, and a spatial component that uses Geographic Information Systems (GIS) to map these relationships.

This section provides an overview of the approach used to model risk to assets from erosion for the WGCMA region using the LUIM and presents the results of that risk assessment. Further information on the LUIM and how it has been used in this application has been published in a journal paper titled 'Using GIS and a land use impact model to assess risk of soil erosion in West Gippsland' (McNeill *et al*. 2006). Further details on the LUIM tool, the risk framework, data requirements, development history, and how it has been used in other projects is documented in McNeill and MacEwan (2007).

7.1 The risk assessment framework

The risk framework (Figure 7) is based on the Australian Standard for risk management (Standards Australia and Standard New Zealand,1995) which defines risk as the chance of a specified event occurring (likelihood) and the magnitude of the likely consequences (consequence).

7.1.1 Definition of terms

In a landscape context, threats are generally broad-scale landscape processes rather than discrete catastrophic events. The risk is not so much whether or not a process will occur, but whether the process will be of a sufficient magnitude to cause concern. Thus the definitions of likelihood, consequence and risk have been modified from the Australian Standards for risk management (Standards Australia and Standards New Zealand, 1995) to suit the specific purpose of the LUIM.

Risk: The product of the likelihood that degradation will occur to an asset and the consequence suffered if it happens.

Likelihood: The likelihood that degradation will occur depends on the susceptibility of the asset and the role that land-use practice may play in causing, aggravating or moderating degradation (management). Hence likelihood is a product of the asset's inherent susceptibility to degradation and the imposed land use and associated practices.

Consequence: The consequence of degradation depends on how incapacitated or dysfunctional the asset becomes (sensitivity) and on the productive and ecological qualities of the asset (value). Consequences may also exist for offsite assets.

The additional terms used in the LUIM framework (Figure 7) are:

Susceptibility: the chance (percentage) of a threatening process reaching a threshold rate or magnitude at a given point in the landscape, based on fundamental landscape characteristics.

Management: management actions that influence the susceptibility of the landscape to specific threatening processes.

Sensitivity: the level of response of an environmental asset to a specific threatening process of a threshold rate or magnitude. Sensitivity could also be considered as the degree of resilience or ability to recover from disturbance as a result of a threatening process.

Value: the assumed worth of a biophysical or built asset based on environmental, social and economic services provided by that asset.

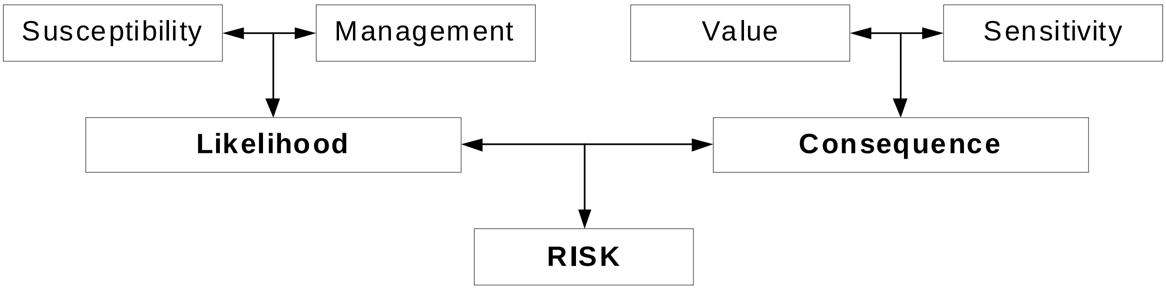

Figure 7: Schematic representation of components of risk posed by any hazard or threatening process

7.2 Likelihood, consequence and risk

Each component of the risk framework is mapped individually using a range of soil, landscape, rainfall, land use, and slope information which is combined into a single spatial layer using a GIS. The spatial data is used within the LUIM, in combination with expert knowledge of land management and landscape processes, to produce spatially explicit outputs rating the risk to land assets from various forms of degradation.

Expert knowledge is used to set the parameters or 'rules of assessment' within the LUIM framework. Likelihood of occurrence of degradation under specific land management regimes is rated using a matrix (Table 4) adapted from the Australian Standard for risk management (Standards Australia and Standard New Zealand,1995). This matrix combines the land management practice classifications with the susceptibility ratings.

Table 4: Likelihood matrix relating management practices and susceptibility (example)

Management practices	Susceptibility				
	Very low	Low	Moderate	High	Very high
Strongly negative	Very low	Moderate	High	Very high	Very high
Moderate negative	Very low	Low	Moderate	High	Very high
Weakly negative	Very low	Low	Low	Moderate	High
Neutral	Very low	Very low	Very low	Low	Low
Beneficial	Very low	Very low	Very low	Low	Low

Further information regarding how the likelihood matrices were developed and management practices were classed as: strongly negative, moderately negative, weakly negative, neutral or beneficial is included in Appendices 5, 6 and 7.

Similar matrices are used to combine sensitivity and asset value to provide a measure of consequence, and to combine likelihood and consequence to derive risk. The user has complete control over the ratings in the matrices.

7.3 Data requirements

Key data required for an application of the LUIM to assess land degradation issues at any scale, and what must be done to provide them, are:

- Threat identification. List the threatening processes to be assessed (water erosion, sedimentation, etc).
- Identification of assets. Identify and map the assets to be assessed for risk from threatening processes.
- Development of map units and attribute data. Create a spatial data layer containing all of the attributes required for the assessment.
- Asset susceptibility. Determine or rate the susceptibility of assets to each threatening process.
- Land use and land management practices. Compile the spatial data and expect knowledge on the land use management practices for the region. This requires an inventory of practices and their spatial distribution, and knowledge of their potential impact on each threatening process.
- Asset sensitivity. Identify the sensitivity of the assets to each threatening process.
- Asset value. Classify the assets for their economic, social and environmental value.

Specific data layers, and methods used to develop required data for this project are detailed below.

7.3.1 Threat identification

Six soil erosion processes were identified as key threats to be included in the risk assessment by the Steering Committee. These were: sheet erosion, rill erosion, gully erosion, tunnel erosion, slumping, and wind erosion.

Sheet and rill erosion were assessed together, as were gully and tunnel erosion. The factors influencing the occurrence of the combined erosive processes are similar enough to make this a sensible approach to take, and it has been adopted in the literature (van Gool and Moore, 1999; Elliott and Leys, 1991; Baxter *et al*., 1998).

7.3.2 Primary map units

The primary map units used in the risk analysis for the WGCMA were formed by intersecting three digital spatial data sets: soil and landform, digital elevation model (DEM), and land use. The combination of these data sets created a single polygonal layer in which each map unit (MU) had a set of associated attribute information on soil type, slope and current land use.

The soil information was sourced from a previously mapped 1:100 000 scale land resource assessment of the region (Sargeant and Imhof, 2006). This layer was not available for public land areas of the region and so the assessment was carried out for private (largely agricultural land) only. The DEM was sourced from a state-wide raster data set represented at 1:25 000 scale. A five-class slope polygonal layer was derived from the DEM for the region. Land use information was sourced from a previously mapped 1:100 000 scale land-use map (Sposito *et al*., 2000). All spatial data layers from the corporate data library of the State of Victoria that were used in the LUIM, or developed for this project to be used in the LUIM, are listed in Table 5 and Table 6, respectively.

Table 5: Primary data collated from the corporate data library of the State of Victoria

Data Set	Description	Scale		Comments / Limitations
soil_v23_amg_z55	Soil and landform mapping for West Gippsland	1:100,000	DPI	Incomplete coverage for the CMA region. Public land areas are not currently mapped. Several versions of this data layer are in the process of being incorporated into a single version by DPI.
DEM25	Digital elevation model	1:25,000	DPI	Clipped for the CMA region from a state wide DEM
LU100	Land-use map for south west Gippsland	1:100,000	DPI	Originally mapped in 2000 as part of the BRS land-use mapping program, it was reviewed and updated by local regional DPI extension officers as part of this project.
Isohyet500	Isohyet contour lines in 50mm intervals based on a surface of mean annual rainfall	1:250,000	DPI	
CMA100	Delineates the CMA regional boundaries for the state	1:100,000	DPI	

Table 6: Data layers created for this study

Data Set	Description	Scale		Comments / Limitations
Slope_soil_luse	Shapefile derived by combining the soil landform, DEM and land use layers	1:100,000	DPI	
WG11	Geodatabase, derived from Slope_soil_luse	1:100,000	DPI	This layer was developed by converting the slope_soil_luse layer into a geodatabase. The LUIM requires spatial data to be in a geodatabase format in order to run.
WG_LUIM_ Results	Shape file containing the LUIM results			Derived from WG11. This layer contains only the model results. All primary data has been removed.

7.3.3 Identification of assets

Land was the primary asset to be assessed for risk from soil erosion processes. Using expert knowledge for West Gippsland, the Bureau of Rural Sciences (Bureau of Rural Sciences 2002) land use categories (Sposito *et al.*, 2000) were modified by grouping together similar categories and splitting some broader categories to better reflect land use in West Gippsland. Through this process 20 relevant Land-use Categories were established for the LUIM (see Table 7). The related land-use map is shown in Figure 8.

Land uses excluded from the risk assessment were urban land, infrastructure, mining and quarries, services and other non-agricultural land uses. National parks, state forests and other parks and reservations, were excluded from the assessment due to the lack of soil information for public land.

Table 7: Land use categories used to define assets

LUIM Land use categories
Cropping
Dryland dairy
Grazing of native vegetation
Hardwood plantations
High-rainfall mixed dairy and beef
Horticulture
Irrigated crop-pasture rotations
Irrigated dairy
Irrigated horticulture
Irrigated permanent cropping
Low-rainfall mixed beef / sheep
Mining
Native vegetation
Permanent cropping
Production forests
Quarries
Softwood plantations
Water
Other
Unknown

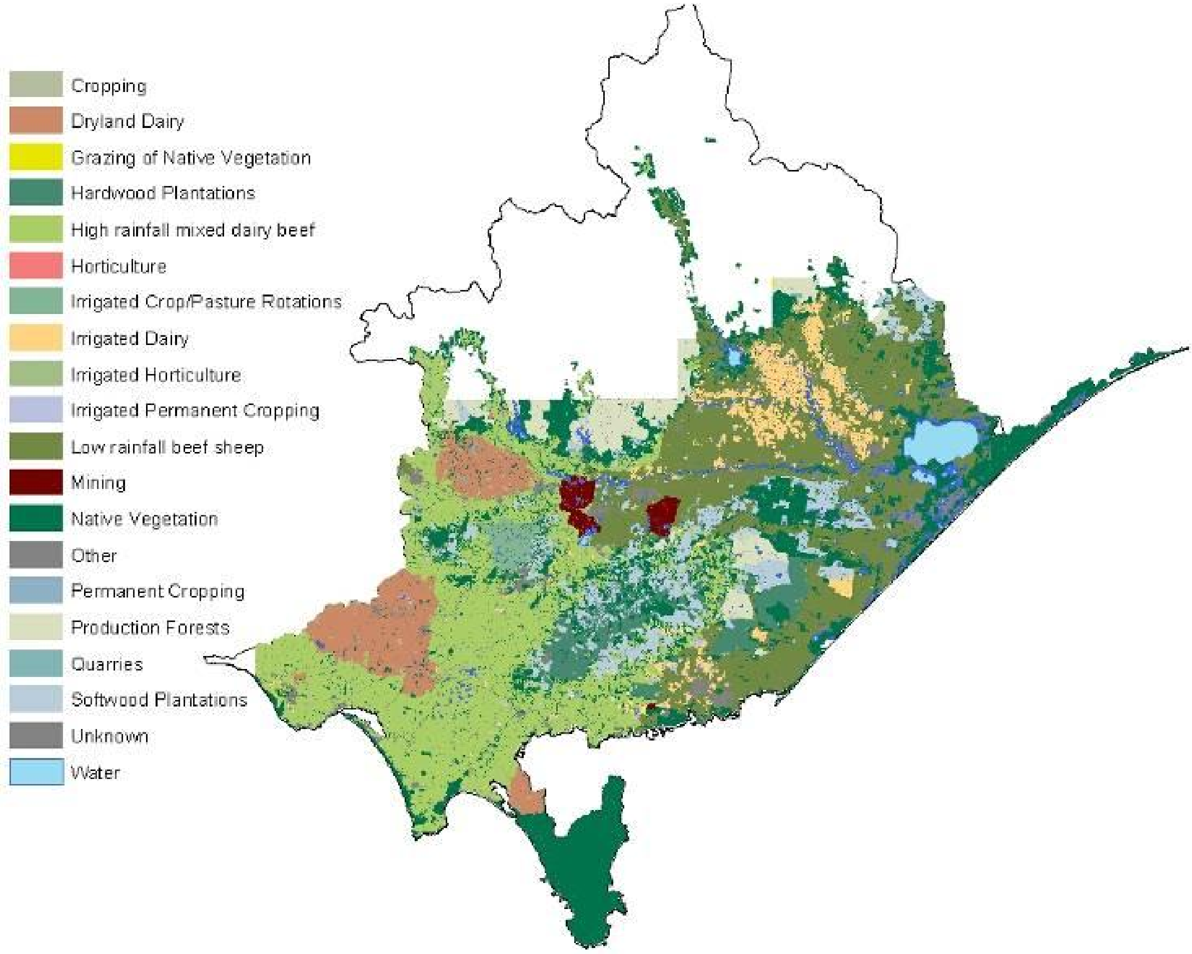

Figure 8: Revised Land use map for West Gippsland

7.3.4 Asset susceptibility

Map units were classified (very low, low, moderate, high, or very high) for their inherent susceptibility to each of the threatening processes (apart from wind erosion and slumping) using rule tables modified from Elliott and Leys (1991), van Gool and Moore (1999), and Baxter *et al.* (1998). Susceptibility to slumping and wind erosion was assessed using an expert classification by Ian Sargeant, the regional soils and landscapes expert. Figures 9 (a) and (b) show the susceptibility maps for sheet or rill erosion and gully or tunnel erosion. Figures 10 (a) and (b) show the susceptibility maps for wind erosion and slumping. The white areas on the maps represent areas in the region where primary soil data were not available and these were therefore excluded from the assessment.

(a) (b)

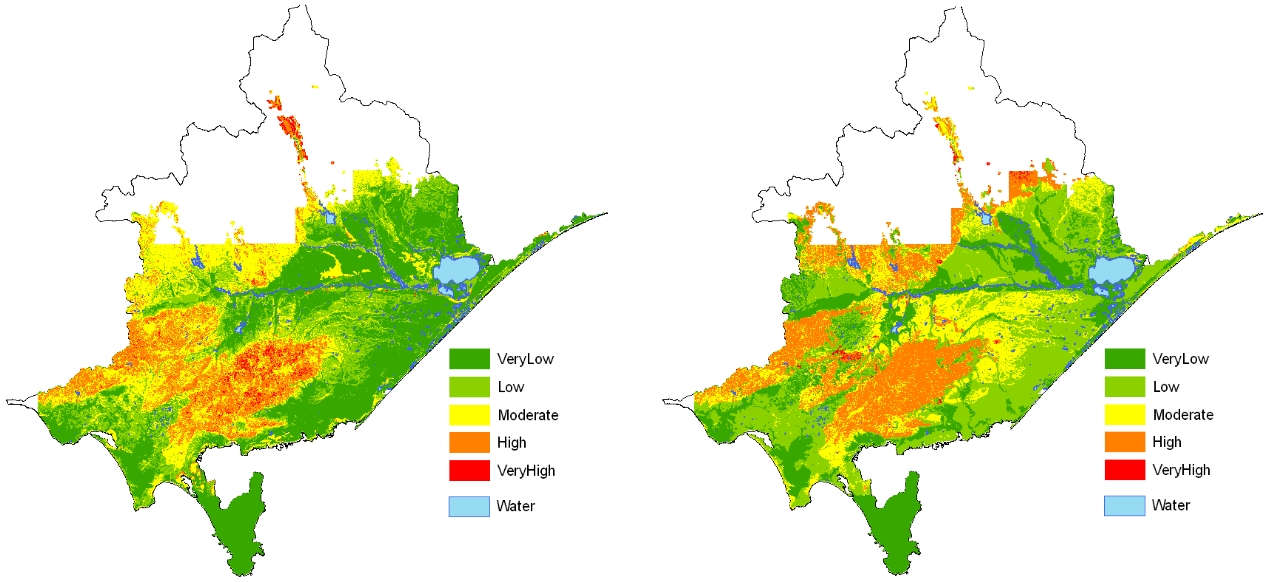

Figure 9: (a) Susceptibility of management to sheet or rill erosion, and (b) susceptibility to gully or tunnel erosion

(a) (b)

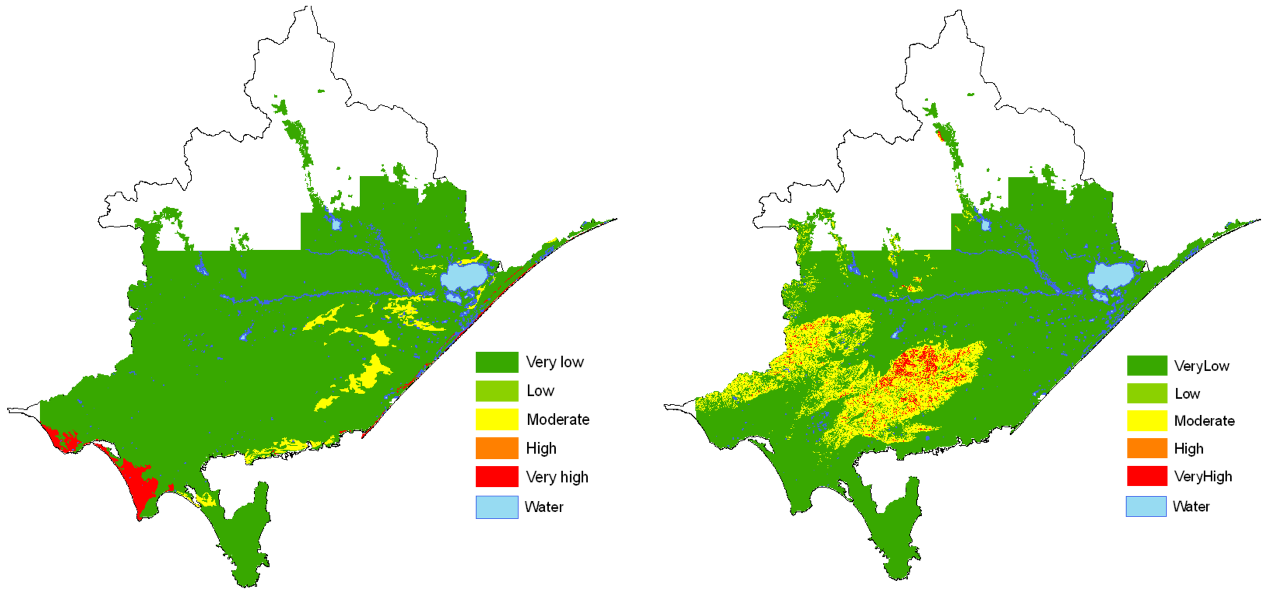

Figure 10: (a) Susceptibility of management units to wind erosion, and (b) susceptibility to slumping

7.3.5 Asset sensitivity

Inherent sensitivity was assessed using rules derived from a workshop of soil specialists who determined which soil attributes would influence sensitivity to erosion. Topsoil depth was chosen as the key attribute to be used, with the logic being that the less topsoil there is to lose to soil erosion, the more imperative it is to prevent loss. Linking this factor with a measure of asset value can help identify priority areas for protection from erosion. Topsoil depth was grouped into three classes and rated low, moderate or high for sensitivity (Table 8). It should be noted that the “depth of topsoil” map (Figure 11) only represents a generalised representation of soil depth across the region due to the scale of the soil mapping (1:100,000 scale). In reality, there will be a range of soil depths within any area in the region, but these cannot be accounted for at the scale in which the soil is currently mapped.

Table 8: Sensitivity rating criteria

Top soil depth (cm)	Sensitivity rating
>40	Low
20-40	Moderate
<20	High

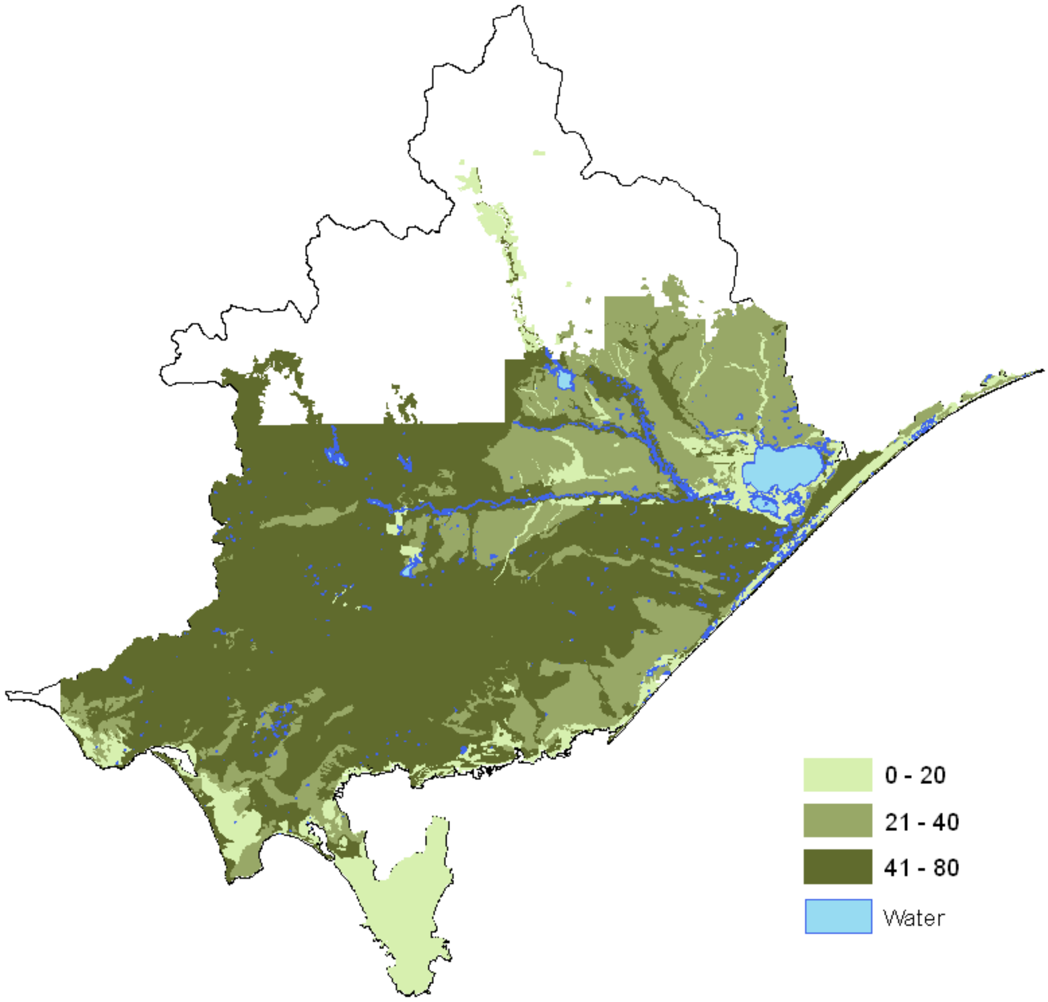

Figure 11: Depth (cm) of topsoil for West Gippsland

7.3.6 Land use and land management information

Spatially explicit knowledge about the type of land management being applied in the landscape is required for the risk assessment. However, information on the uptake and spatial distribution of current land management practices in West Gippsland is not available.

In lieu of actual data, regional experts, through a series of workshops, were asked to:

- identify management practices for each land use category that could influence the occurrence of erosion,
- identify the most common practices through to the least common, and
- estimate the distribution of each of these practices for the region,
- assign a rating for each combination for their influence, positive or negative, on the potential for erosion to occur.

The information collected through these workshops is documented in Appendices 5, 6 and 7. An example of a description of the type of information collected for each of these steps is given in Figure 12.

A management practice example for the land use Dryland dairy:

1. Regional experts identified practices for the land use category ‘Dryland dairy’ that have the potential to influence the occurrence of sheet and rill erosion.
2. The regional distribution of each of the identified practices was estimated using local knowledge, identifying the most common practices through to the least common. The practices and their estimated distributions are:

Practice category	Practices	Estimated distribution %
Grazing system:	graze and spell	70
	set stock	30
Pasture composition:	perennial	80
	sown annual	5
	annual	15
Renovation method	direct drill	35
	cultivation	65

3. The combinations of practices were ranked from best to worst and then given a rating (strongly negative, moderately negative, weakly negative, neutral, beneficial). An example of the best and worst dryland dairy practice combinations for soil erosion and their ratings are:

Best practice scenario:	Graze and spell system, perennial pasture composition, and direct drill pasture renovation method	Beneficial
Worst practice scenario:	Set stocking, annual pasture composition, and cultivation pasture renovation method	Moderately negative

Figure 12: An example of the type of management practice information collected in workshops with regional experts

This regional expert management practice information did not allow assumptions about what management was occurring in a particular paddock. However, when used in combination with the spatially explicit land use data, the estimated practice distributions were used to inform the probability of each practice occurring in a management unit. For example, for any management unit classified as dryland dairy, there was a 35% chance of the pasture renovation method being direct drill, and a 65% chance it would be cultivation.

Experts were asked to rate combinations of practices for their influence on the occurrence of erosion for each land use and erosion process. This process enabled the identification of the best and worst-case management-practice scenarios. However, whether or not erosion might occur under the different combinations of practices ultimately depends on the inherent potential of a site to erode. In the LUIM the susceptibility and management practice information is combined to derive a likelihood of occurrence of erosion under specific management regimes.

7.3.7 Asset value

Each land-use category mapped for the region was assigned an asset value rating by regional stakeholders. Each land use was given a score by the group based on a set of economic, environmental and social criteria (Table 9) adapted from Heislers and Clifton (2004). The results are presented in Table 10. During the course of assigning asset value, land use categories as defined by the BRS (Bureau of Rural Sciences, 2002) were further split to better differentiate assets (Table 10).

Using the land use map as a base, asset value is mapped for each of the three value classes (economic, environmental and social) using the sum of the ratings for each of the assessment criteria for each value class (Table 10). The total asset value is derived by adding up the scores for all criteria and classifying the results into three equal-interval classes. The results are presented in Figure 13 and Figure 14. The total asset value scores were used in the risk assessment. Off-site assets, such as rivers, streams and wetlands, were rated for value using scores from the RHS (West Gippsland Catchment Management Authority, 2005a).

Table 9: Assessment criteria for defining asset value

Value class	Assessment criterion
Economic	Asset/service element directly generates substantial economic activity
	Asset/service element has a high capital value (cost of purchase, construction or establishment)
	Asset/service element facilitates significant economic activity
Environmental	The asset/service is of international, national or regional significance
	The asset is in excellent (environmental) condition
	The asset is rare
Social	Heritage value (The asset has strong cultural significance)
	The asset or its use contributes to maintenance of community (provides significant direct or indirect employment)
	Visual amenity
	Social amenity (The asset/service provides substantial amenity to users (shelter, landscape value/personal wellbeing)

Table 10: Land uses and their assigned value as assets (according to economic, environmental and social criteria adapted from Heislers and Clifton 2004) for the WGCMA

Land Use Category	Economic	Environmental	Social	Total
Cropping	4	0	4	8
Dryland Dairy	9	2	7	18
Grazing of Native Vegetation	3	7	5	15
Hardwood Plantations	7	3	7	17
High Rainfall Mixed Dairy/Beef	6	2	7	15
Horticulture	8	0	5	13
Irrigated Crop/Pasture Rotations	7	0	6	13
Irrigated Dairy	9	1	5	15
Irrigated Horticulture	8	0	5	13
Irrigated Permanent Cropping	7	0	6	13
Low Rainfall Beef/Sheep	3	2	5	10
Mining	9	0	6	15
Native Vegetation	5	9	11	25
Other	9	3	9	21
Permanent Cropping	7	0	6	13
Production Forests	7	6	10	23
Quarries	5	0	3	8
Softwood Plantations	7	1	6	14
Unknown	0	0	0	0
Water	0	0	0	0

(a) (b)

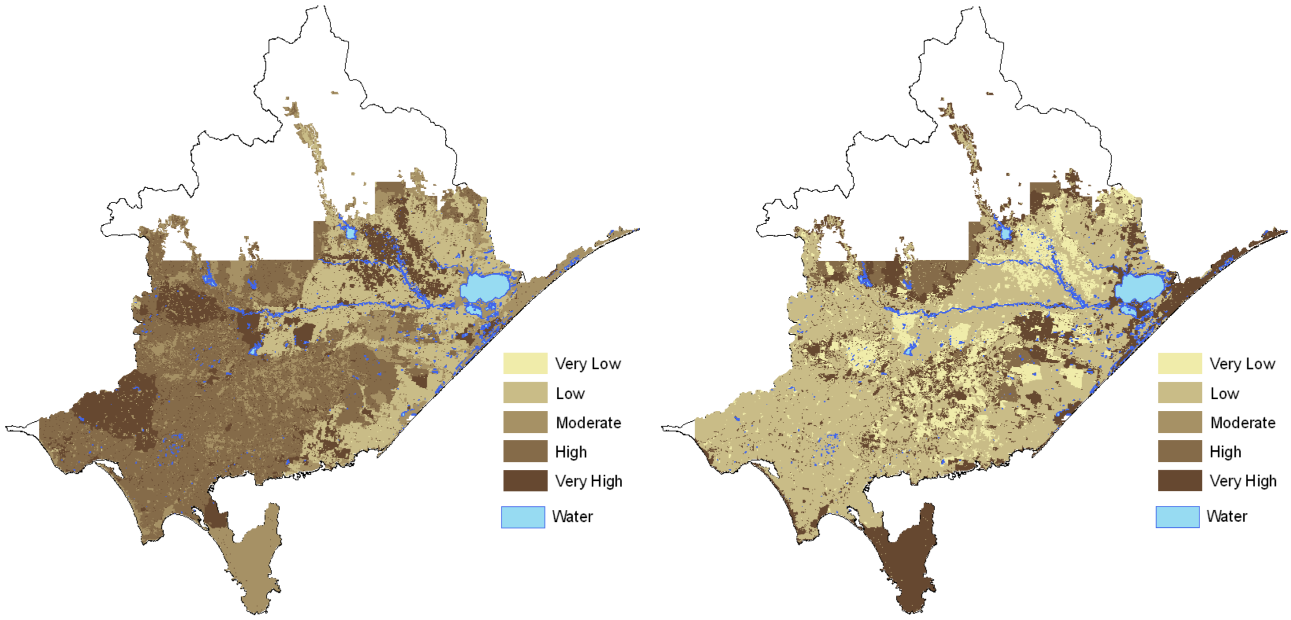

Figure 13: (a) Economic asset value and (b) Environmental asset value

(a) (b)

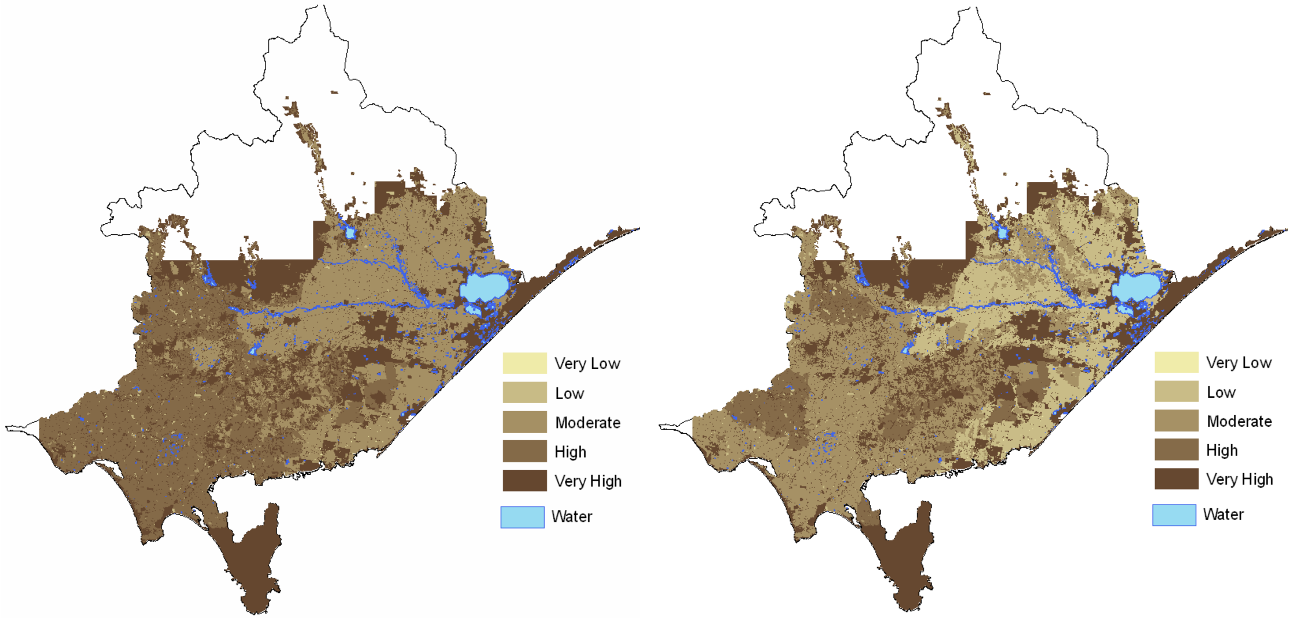

Figure 14: (a) Social asset value, and (b) Total asset value using the combined economic, environmental and social scores

7.3.8 Likelihood and risk maps

Two main outputs were generated from the risk assessment:

1. Maps showing the likelihood of land degradation occurring under current land management for the region. The likelihood results are useful for understanding the extent of the erosion problem in the region under current land management without any bias on the results based on the consequences of erosion on high-value assets.
2. Maps showing the risk of land degradation under current land management for each threatening process for the region. The risk maps do not represent the total area likely to experience erosion, but they highlight areas that are of high value where the consequences of erosion will be most significant. The risk maps, representing differences across the region, can be used to inform priority setting.

The maps of susceptibility to erosion identify areas within the WGCMA region with an inherent potential for erosion. However, in order to identify the extent of erosion in the region, land management information is required to supplement the susceptibility data. The likelihood maps are a result of the combination of the susceptibility assessments with land management information within the LUIM. The likelihood maps differentiate between areas susceptible to erosion that are being managed in ways that minimise erosion and susceptible areas that are being inappropriately managed.

The final output of the LUIM is a risk map for each erosion issue. The risk maps are the result of incorporating a measure of the consequence of erosion, with the likelihood outputs. The likelihood maps can be used to inform natural resource managers of the potential extent of erosion under current land management across a region and the risk map enables prioritisation of these areas based on their economic, environmental or community value.

Risk and likelihood maps were generated for each of the erosion processes (Figures 15 to 22). For comparison, maps of the likelihood are presented together with the results of the risk assessment mapping.

Review of the risk maps was undertaken by a panel of regional soil and industry experts. With some revisions, there was agreement that the likelihood maps correlated quite strongly with the panel's knowledge of areas that are actively eroding in the region. The risk maps were harder to review, being a more qualitative product. However, the panel accepted the risk results as useful for prioritising high value assets likely to experience soil erosion. A key focus for future work will be the on-site validation of the LUIM outputs.

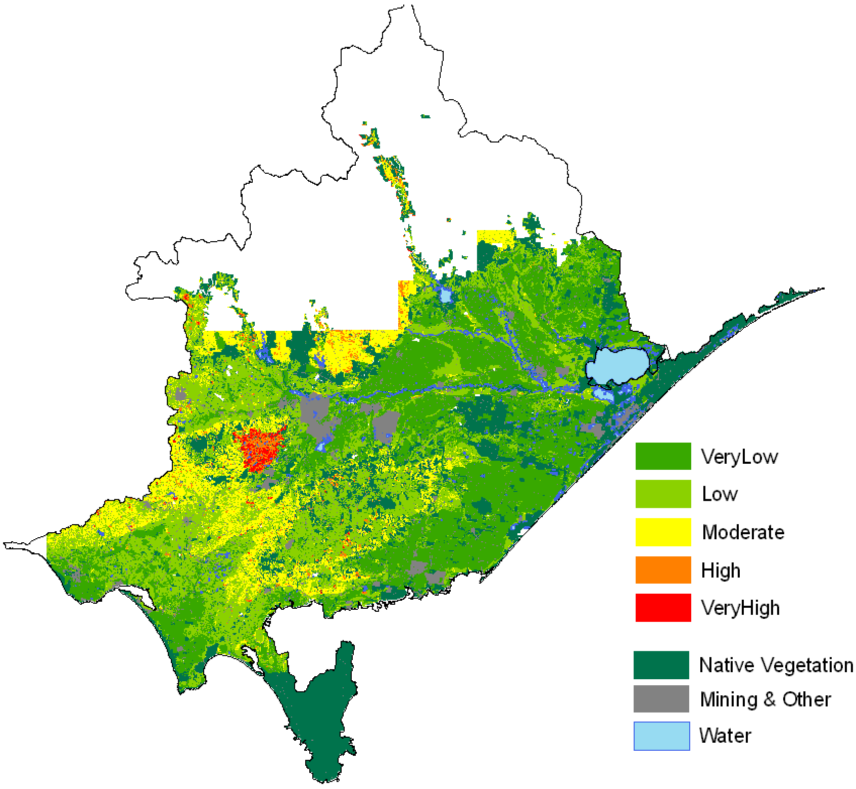

Figure 15: Likelihood of occurrence of sheet or rill erosion

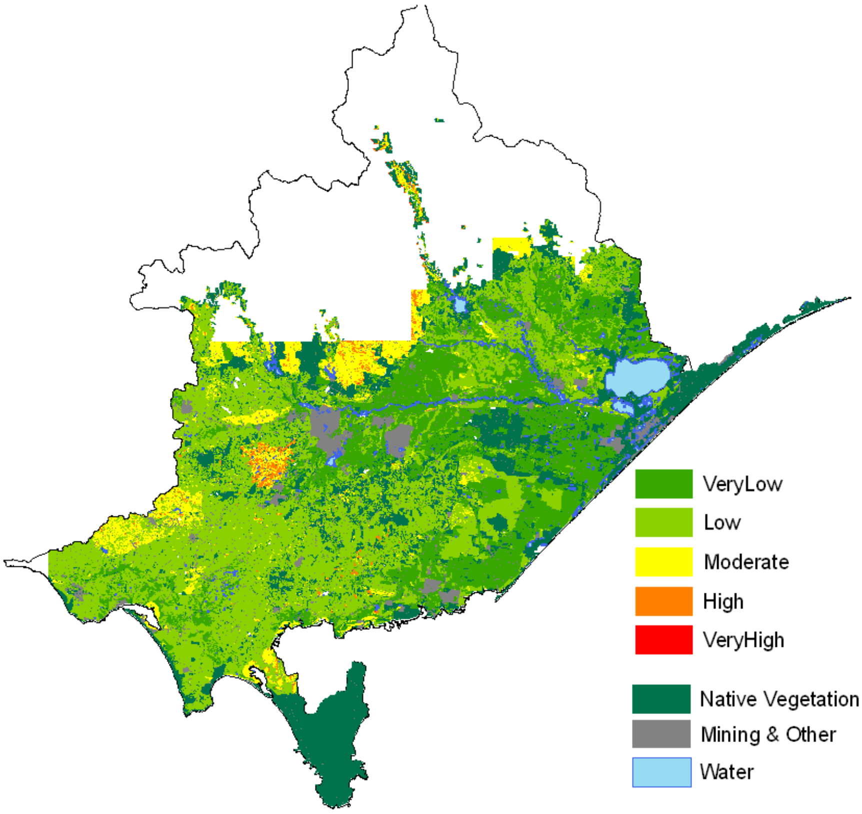

Figure 16: Risk of sheet or rill erosion

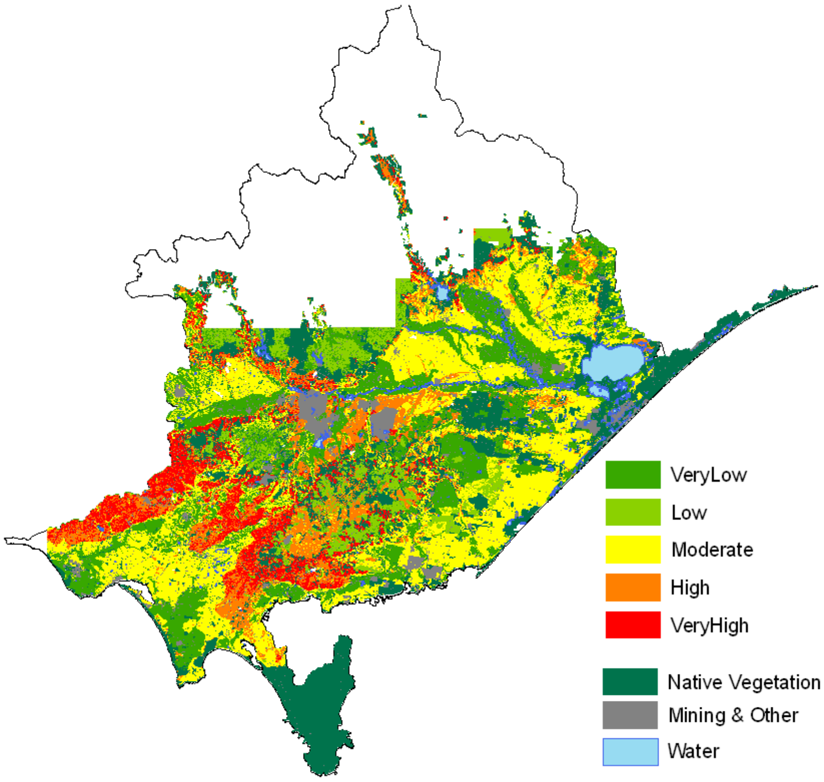

Figure 17: Likelihood of occurrence of gully or tunnel erosion

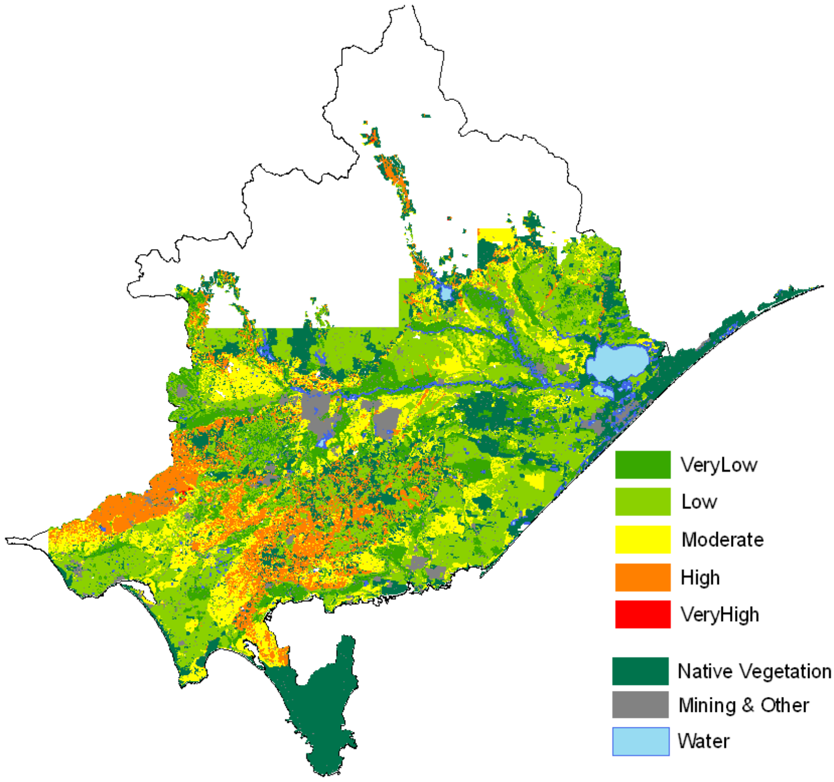

Figure 18: Risk of gully or tunnel erosion

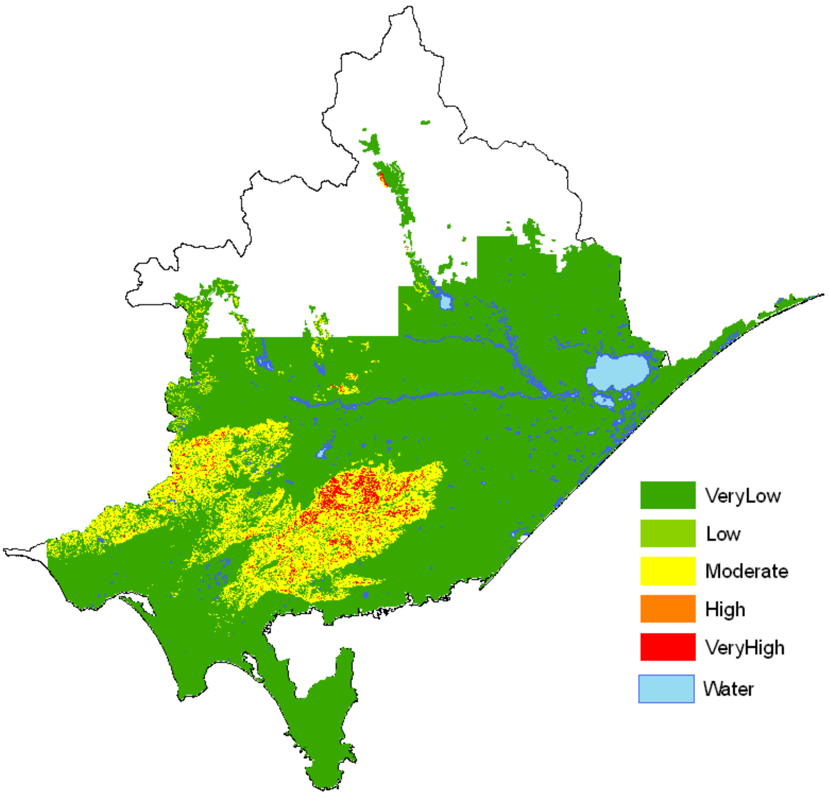

Figure 19: Likelihood of the occurrence of slumping

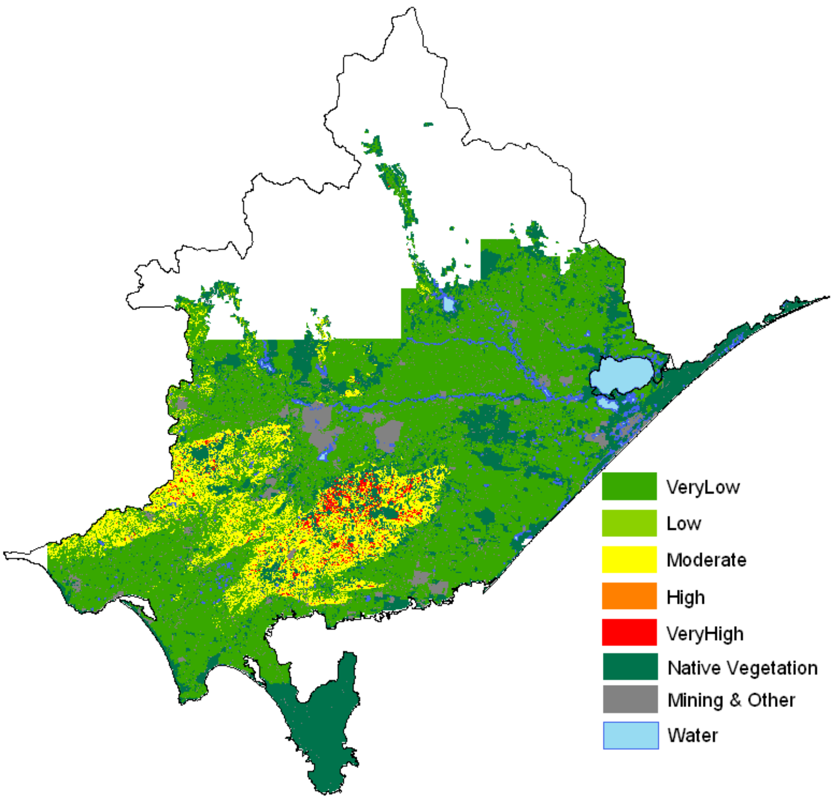

Figure 20: Risk of slumping

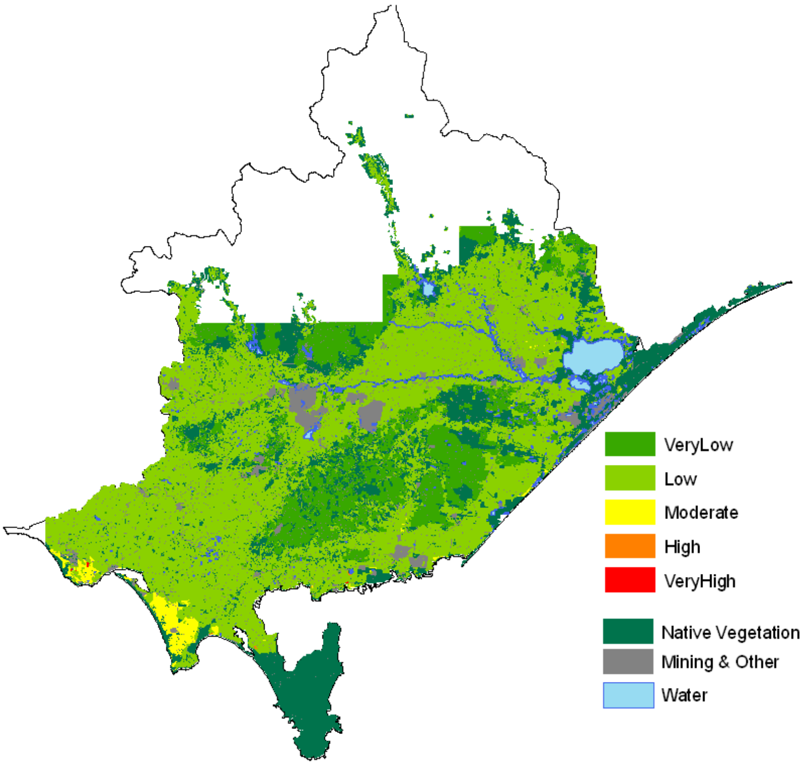

Figure 21: Likelihood of occurrence of wind erosion

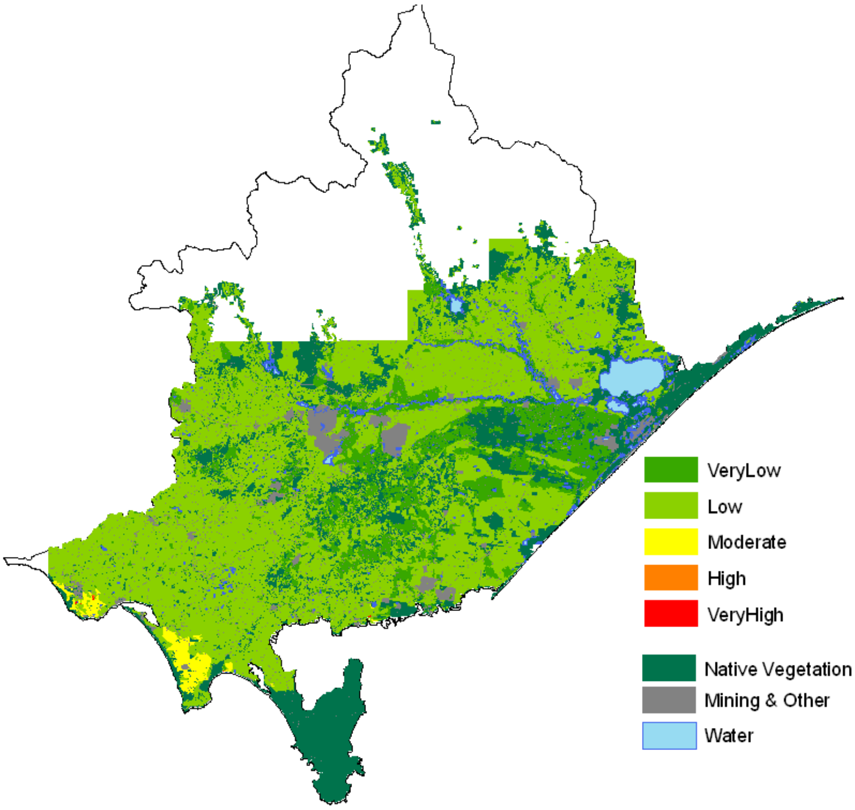

Figure 22: Risk of wind erosion

7.3.9 Area statements

The LUIM results can be used to identify where in the WGCMA region each erosion process is most likely to occur under current land use and land management and the risk to various assets. The results can also be used to identify the percentage of area within each likelihood category for each erosion process (Figure 23). This information is useful as an overview of the potential extent of the erosion issues in the region. Over time, the LUIM can be re-run to show the change in the area in each likelihood category. Such information could be used as an indicator of the success of the Soil Erosion Management Plan in initiating land management change and remediation works to reduce erosion.

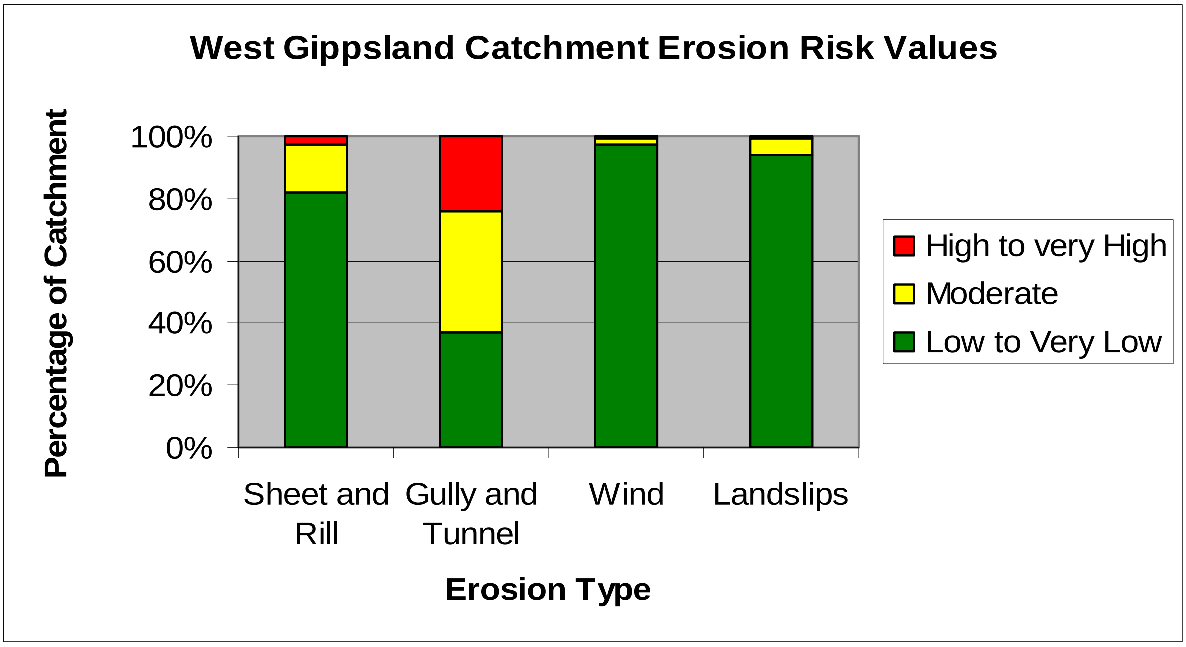

Figure 23: Percentage of Area within each risk category for each erosion types

7.3.10 Mapping uncertainty in the risk outputs

The risk results are mapped in categories from very low to very high within each class for each map unit but are derived from a probability distribution (McNeill and MacEwan 2007). The risk rating with the highest probability score is used as the measure of risk for each mapping unit and mapped. The combined probability scores of the other four risk classes can be mapped as a measure of confidence in the final risk output. Thus the final risk output is not simply ‘high’ or ‘low’, indicating relative risk of degradation across an area, but has an associated probability distribution that can be used to map the uncertainty in the risk results. This is useful for identifying areas classified as a particular category where there is high spatial variability within a management unit or uncertainty in the land management data. This information can be mapped to identify areas where additional probability distribution data are necessary to provide greater confidence to decision-makers.

7.4 Assumptions and limitations of the model

The LUIM, its associated data and rule sets including expert knowledge, offers a transparent and flexible approach that can be reviewed and revised in future planning, monitoring and priority setting. The challenge for the immediate future is in making the approach and its associated products accessible to the natural resource management decision-makers. Enhanced accessibility and continued relevance requires collaboration between the scientists who have developed the information and the purchasers, regional stakeholders and users of the products, involving the end users in the process from the beginning. Potential future uses of the LUIM, associated data and risk results in the region include predictive land use change impact analysis, and identification of industry-specific best-management practices for the region.

The LUIM exploits GIS as an integral tool for decision making for land management. The usefulness of the LUIM lays not so much in the power of GIS but in the ability to accommodate a variety of data about land and its vulnerability and management. Precision of the model is limited by spatial resolution of data, assumptions concerning land management relationships, and lack of specific knowledge of the actual location and adoption of specific practices. It could be asserted that all of the usual caveats apply, as to other GIS applications, that with more or better resolution data the outputs would somehow be better. However, better precision of model output data may not make a substantial difference to decision making in the region.

The purpose of the LUIM, as described here, is to produce outputs that can provide special focus for actions to minimise risk of degradation to on-site and off-site assets. The LUIM application really only finds completion when actions on the ground serve to alter practices in a direction that lessens the unsustainable land use. The steps beyond LUIM are necessarily those involving ground-truth and engagement with land managers, so that the model outputs are tested by comparison with the real condition of the land, and practices are adapted to protect the soil assets where they are genuinely under threat. Greater precision in model outputs might increase efficiency in selecting areas for action. However, there is a danger that greater precision is mistaken for accuracy, and in this way, the outputs become clumsy prescriptive mandates for land use and practices.

Specific assumptions and limitations inherent to the information produced using the LUIM are:

1. Output of the LUIM is in the form of relative ratings based on subjective, not measured, values. While this is very relevant for discrimination of end members of classes (the best and the worst), the intermediate classes should be treated with intelligence if the output is to be used for any deeper quantitative analysis. In this respect the output of LUIM serves prioritization needs in identifying the areas where there is most and least likely to be a soil management problem.

2. Data and analysis used to generate the likelihood maps are considered reliable at 1:100,000 scale but these maps should not be regarded as showing actual condition of soil assets as this is unknown.

3. The use of current land use to determine soil asset / land value is a limitation in that it does not account for the potential of any parcel to be used for higher-value primary production.

4. The risk maps should be used circumspectly due to the data limitations listed in points 1-3. Each data layer developed for the LUIM application should be reviewed to ensure appropriate use of accurate and reliable data in the modelling of risk.

5. Not all land uses in the region have been analysed in the current LUIM. Further land uses can be incorporated at a later date.

6. Other degradation issues (nutrient decline, salinity, acid-sulfate soils, organic-matter decline, soil-biota decline, coastal-dune erosion) that have not been modelled could be incorporated in future depending on need and availability of data.

7. Without collecting any further biophysical data, the LUIM can be used to run scenarios of land-use or land management change.

8 Priority setting

The initial priorities for action are based on the risk rating of the 'Land Asset' for the on-site risks for soil erosion. The Land Use Impact Model (LUIM) outputs have identified key land areas at risk of soil erosion across the WGCMA region. Priorities will be based on the high to very high risk areas illustrated using gully and tunnel erosion in Figure 24.

8.1 Priority soil erosion risk – integrating land and water assets: targeting using soil erosion Priority Management Areas

The areas of priority have also been linked to the West Gippsland River Health Strategy (RHS), which considers water as the primary asset (Figure 25). The modelling has linked soil erosion risk to off-site impacts. The LUIM modelling process has produced data on the area of each sub-catchment at risk for each erosion type (Figures 16, 18, 20 and 22). Table 12 summarises the areas of erosion risk rated as high to very high for each sub-catchment.

River Health Areas have been amalgamated to form SEMP Priority Management Areas (PMAs), as shown in Figure 26 below, and future actions will be focused in these management areas. These actions have been developed in the PMAs described in Section 9 Targets, Monitoring, Evaluation and Reporting.

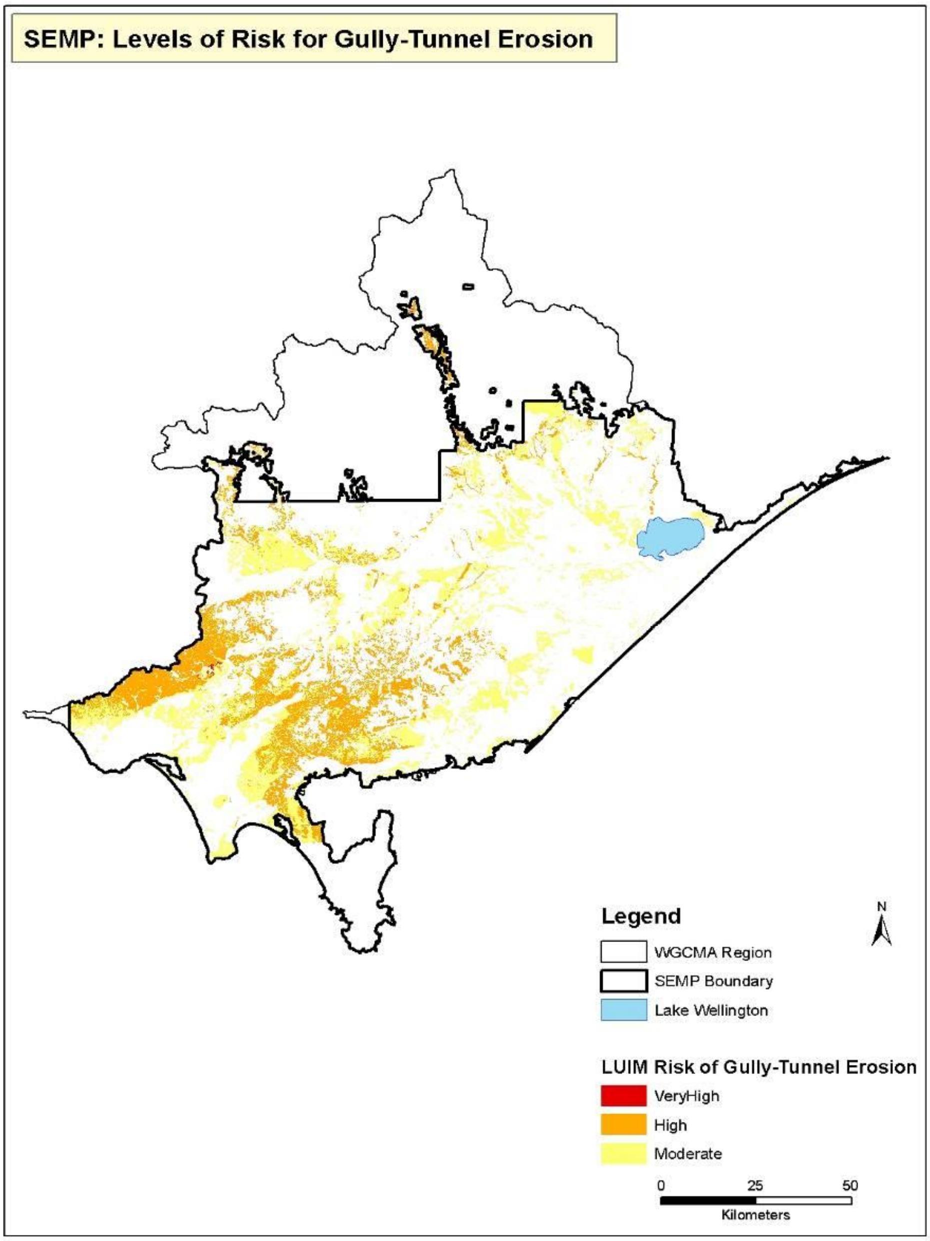

Figure 24: Prioritisation: management areas in relation gully and tunnel erosion risk

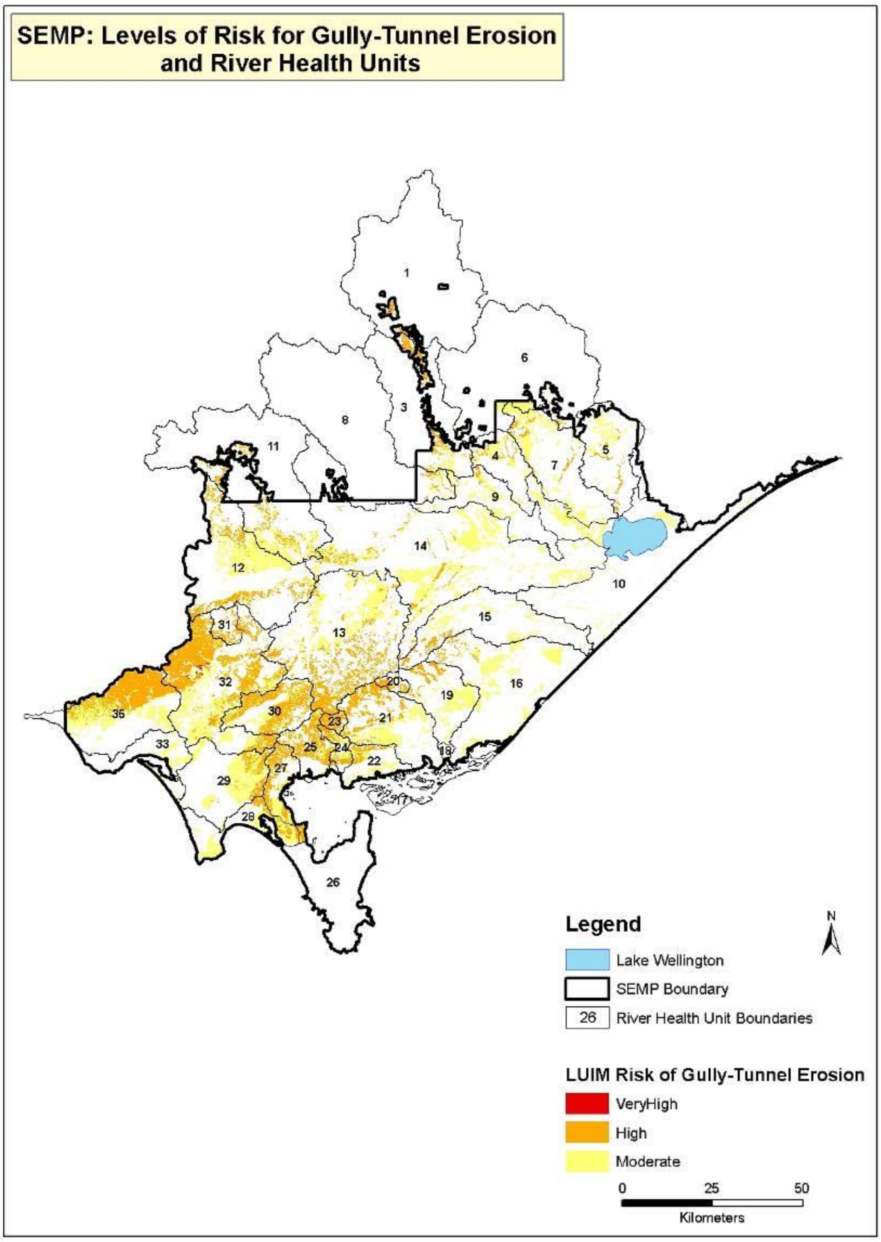

Figure 25: Levels of risk for gully and tunnel erosion and River Health Units

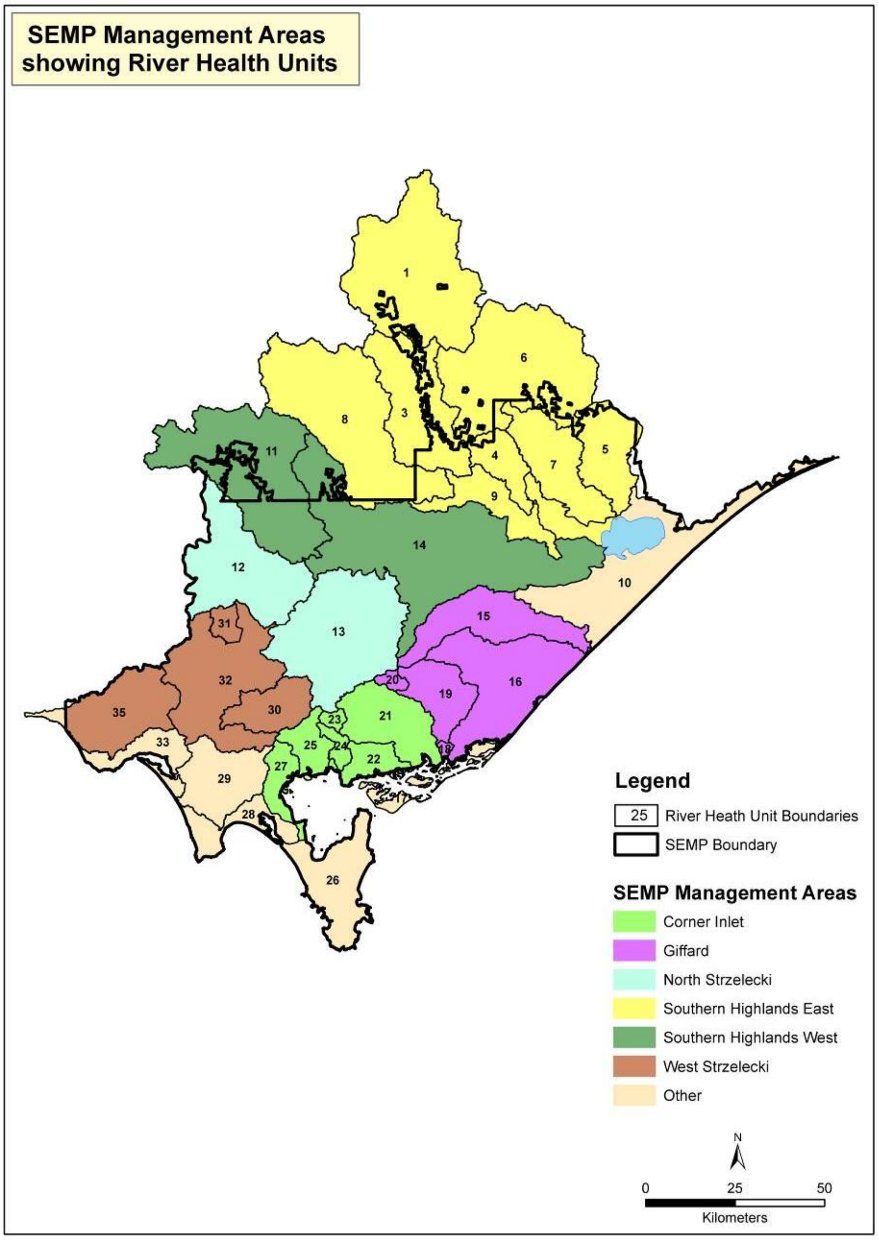

Figure 26: SEMP Management Areas showing River health areas

8.2 Extent across the West Gippsland catchment: priority soil erosion "type" risk

Utilising the risk maps (Figure 16, Figure 18, Figure 20 and Figure 22), approximately 24% of the region is at high or very high risk of gully and tunnel erosion, while sheet and rill make up 3% of the risk, and wind erosion less than 1% and landslips only 0.4% . The LUIM indicates the relative risk of the different erosion types considered across West Gippsland by the 'total ha' figures in Table 11 below. This indicates that West Gippsland has a much higher risk of gully and tunnel erosion (134,980 ha at risk) than of all other erosion types (total of 18,040 ha).

The areas can be grouped into like areas, i.e. PMAs, for improved planning and setting of resource condition targets (RCTs) and management action targets (MATs). Table 11 provides a list of logical groupings based on the risk assessment of sub catchments developed by LUIM as earlier illustrated in Figures 25 and 26.

Table 11: Summary of Priority Management Areas from Figure 26

Priority Management Areas	Area of high to very high erosion risk (All types) Ha.
1. West Strzelecki (Tarwin West & East / Powlett Rivers)	57,940 ha
2. North Strzelecki (Moe / Narracan / Morwell / Traralgon rivers)	28,350 ha
3. Corner Inlet (Corner Inlet Rivers and streams)	27,530 ha
4. Southern Highlands West (La Trobe River)	11,110 ha
5. Southern Highlands East (Thomson, Macallister, Avon, Perry)	11,960 ha
6. Giffard (Merrimans Creek / Giffard / Tarra)	8,250 ha
7. Other sub catchments	5,690 ha

Based on the geographic location of the risk, key PMAs have been developed and prioritised for action. Appendix 8 shows the methodology of grouping sub-catchments from Table 11 and Table 12. Of the above PMAs, three have been selected and given priority over others for action based on the hectares at risk and include the management areas of West Strzelecki, North Strzelecki and Corner Inlet, as illustrated in Figure 26.

Future use of the PMAs will be an important part of setting Resource Condition Targets (RCTs) and Management Action Targets (MATs) as well as providing a framework for monitoring, evaluation and reporting processes as part of the plan development.

8.3 Priority setting using water as the asset

Since the risk values relate to a geographic area it is possible to overlay erosion risk with RHS sub-catchments. The relationship between onsite soil-erosion risk and offsite river heath are expressed in Table 12. Hence it is possible to prioritise based on more than one asset class; land and water. For the purpose of this plan and related actions, the targets will be based on the land asset class.

The column of total 'high to very high' erosion risk; in Table 11, is the sum of all the erosion types; some areas may be counted more than once if they are susceptible to more than one type of erosion process. This column gives a priority rating to the overall erosion risk, (but the values cannot be taken as the absolute erosion risk). When calculating the management action targets, therefore, the values for 'gully and tunnel' erosion risk have been used.

Sub-catchments sorted by total area of high to very high erosion risk.

Table 12: Sub-catchments sorted by total area of high to very high erosion risk.

RHS Sub-Catchment Number	Sub-catchment name	Gully/tunnel high – very high ha	Landslip high – very high ha	Sheet/Rill high – very high ha	Wind high – very high ha	Total high – very high ha	RHS management program
32	Tarwin River (west branch)	28300	410	1240	0	29950	A
13	Morwell River and Traralgon Creek	15600	10	1750	0	17360	A
35	Upper Powlett River	16000	50	300	90	16440	C
30	Tarwin River (east branch)	10900	590	60	0	11550	N
12	Moe River	7900	0	3090	0	10990	C
21	Albert River	6800	440	660	0	7900	C
25	Franklin River	6300	320	120	0	6740	A
14	Lower La Trobe River	4200	0	1930	0	6130	A
27	Stockyard Creek	5700	0	390	0	6090	N
3	Middle Macalister River	3700	50	1530	0	5280	A
11	Upper La Trobe River	4400	0	580	0	4980	B
29	Lower Tarwin River	3200	0	30	0	3230	C
19	Middle Tarra River	2200	940	50	0	3190	B
23	Upper Agnes River	2300	210	90	0	2600	N
28	Waratah Bay	2100	0	120	10	2230	A
24	Lower Agnes River	2000	170	50	0	2220	N
22	Nine Mile Creek	1700	80	180	20	1980	N
15	Merriman Creek	1700	270	0	0	1970	C
1	Upper Macalister River	1200	0	700	0	1900	N
20	Upper Tarra River	1500	320	50	0	1870	B
8	Upper Thomson River	700	0	930	0	1630	A
7	Lower Avon River	1500	0	20	0	1520	N
16	Bruthen Creek and Giffard plain	1200	10	10	0	1220	C
4	Lower Macalister River	1200	0	0	0	1200	A
5	Perry River	1200	0	0	0	1200	N
6	Upper Avon River	800	0	60	0	860	N
9	Lower Thomson River	510	0	50	0	560	C
100	Kilcunda to Griffith Point	170	0	0	0	170	N
10	Lake Wellington	0	0	30	0	30	A
33	Screw Creek, Pound Creek	0	0	0	30	30	A
17	Corner Inlet and Nooramunga	N	N	N	N	N	A
18	Lower Tarra River	0	0	0	0	0	B
26	Wilson's Promontory	N	N	N	N	N	A

9 Targets, Monitoring, Evaluation and Reporting

Management actions are planned and undertaken to address resource condition. Translation of management actions and change in resource condition, to realistic targets guides plan implementation and provides change in references so that progress can be assessed. This section explains the creation of suitable Resource Condition Targets (RCTs), establishes Management Action Targets (MATs) that are expected to address the RCTs, and provides direction for ongoing monitoring, evaluation and reporting (MER).

9.1 Resource Condition Targets

On the basis of the outputs from the LUIM, a group of long-term (20 year) RCTs has been established. The RCTs are framed as areas in which soil erosive condition will be improved by either reduction in risk levels for erosion processes, or by treatment of active erosion sites. RCTs are set for three erosion processes (sheet and rill, gully and tunnel and landslips) for each of the three priority management areas (PMAs) and for the overall area outside the 3 PMAs of the SEMP region. This acknowledges the existence of erosive risk and actual erosion outside the 3 PMAs and provides contingency for interventions on a needs and/or formal planning basis.

There is a direct correlation between the RCTs expressed as areas, and the MATs planned to address the RCTs. It is anticipated that completing a suite of management actions over a given area will positively influence the soil erosion resource condition over the same area, either by prevention or remediation. Thus over 20 years, the MATs are planned to impact on essentially the same area as that for which RCTs are set. Although the RCTs have a 20-year time-frame, this SEMP covers a 5-year period during which a proportion of the total required MATs can be realistically undertaken. The period when the SEMP is reviewed and possibly renewed will also provide an opportunity to review targets.

Since the outputs from the LUIM have not at this stage been completely ground truthed and the values for some of the LUIM parameters are based on expert opinion, implementation of this plan includes management actions to validate and ground truth the LUIM and the associated resource condition and management action targets. The resource condition targets encompass two main functions: targeted prevention of future erosion and treatment of existing erosion sites.

9.1.1 Prevention and treatment RCTs

The generic format for prevention RCTs is:

By 2028 in the … [PMA or other] management area, improve the erosive condition and reduce by X ha the area with high-very high risk of …… [type] erosion (as classified by the 2007 LUIM) through land management practice change and/or land use change.

The generic format for soil erosion treatment RCTs is:

By 2028 in the … [PMA or contingency] management area, improve the erosive condition and treat and rehabilitate X ha of active …… [type] erosion (after ground truthing of the 2007 LUIM) through appropriate works and related land management/land use change.

Areas for the RCTs have been calculated using outputs from the LUIM and estimates from personnel with expertise and local knowledge in soil erosion. These estimates are that:

- Approximately 30% of the area at high-very high risk from erosion can be successfully managed to reduce risk over 20 years.
- Approximately 5% of the area at high-very high risk from erosion is actually showing active erosion and that all of this area (from the LUIM) can be successfully remediated over 20 years.
- The actual RCT areas calculated from LUIM outputs and the percentage estimates above, with some bias towards the 3 PMAs for prevention, are shown in Table 13. which is derived from Figure 25.

Table 13: Area Targets for Prevention and treatment over 20 years

SEMP Management Area	High-Very High Risk Gully-Tunnel		High-Very High Risk Sheet-Rill		High-Very High Risk Landslip	
	Prevention	Treatment	Prevention	Treatment	Prevention	Treatment
	Ha	Ha	Ha	Ha	Ha	Ha
West Strzelecki	18,000	2,700	600	80	410	50
North Strzelecki	7,500	1,200	1,800	240	10	1
Corner Inlet	8,500	1,300	600	80	480	59
Other	6,000	1,500	1,200	300	300	80
SEMP Boundary Total	40,000	6,700	4,200	700	1,200	190

These regional RCTs are aggregated from targets for each of the management areas. The RCTs for each of the priority management areas are provided in the following tables. From the totals in Table 13 the SEMP regional resource condition targets have been set as shown in Tables 14 to16.

The codes used in Tables 14 to 16 are logical descriptors for generic RCT development; for example ‘P’ relates to Prevention and ‘T’ to treatment. The other parts of the code are descriptors for the priority management areas (WS- West Strzelecki, NS – North Strzelecki, CI – Corner Inlet)

Table 14: SEMP Regional Resource Condition Targets (2007)

Code	SEMP Regional Resource Condition Targets
1P	By 2028 in the SEMP region, improve the erosive condition and reduce by 40,000 ha the area with high-very high risk of gully-tunnel erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
2P	By 2028 in the SEMP region, improve the erosive condition and reduce by 4,200 ha the area with high-very high risk of sheet-rill erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
3P	By 2028 in the SEMP region, improve the erosive condition and reduce by 1,200 ha the area with high-very high risk of landslip (as classified by the 2007 LUIM), through land management practice change and/or land use change.
1T	By 2028 in the SEMP region, improve the erosive condition, treat and rehabilitate 6,700 ha of active gully-tunnel erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
2T	By 2028 in the SEMP region, improve the erosive condition, treat and rehabilitate 700 ha of active sheet-rill erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
3T	By 2028 in the SEMP region, improve the erosive condition, treat and rehabilitate 190 ha of active landslip (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.

Further refinement of the RCTs has been undertaken (shown in Tables 14 and 15) for each of the PMAs with targets set within each of the PMAs for both treatment and prevention of soil erosion. This further focuses the attention to the PMA most at risk.

Table 15: SEMP Resource Condition Targets: Prevention

Code	SEMP Resource Condition Targets: Prevention
	West Strzelecki Management Area
1P-WS	By 2028 in the West Strzelecki management area, improve the erosive condition and reduce by 18,000 ha the area with high-very high risk of gully-tunnel erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
2P-WS	By 2028 in the West Strzelecki management area, improve the erosive condition and reduce by 600 ha the area with high-very high risk of sheet-rill erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
3P-WS	By 2028 in the West Strzelecki management area, improve the erosive condition and reduce by 410 ha the area with high-very high risk of landslip (as classified by the 2007 LUIM), through land management practice change and/or land use change.

Table 15: SEMP Resource Condition Targets: Prevention (cont'd)

	North Strzelecki Management Area
1P-NS	By 2028 in the North Strzelecki management area, improve the erosive condition and reduce by 7,500 ha the area with high-very high risk of gully-tunnel erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
2P-NS	By 2028 in the North Strzelecki management area, improve the erosive condition and reduce by 1,800 ha the area with high-very high risk of sheet-rill erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
3P-NS	By 2028 in the North Strzelecki management area, improve the erosive condition and reduce by 10 ha the area with high-very high risk of landslip (as classified by the 2007 LUIM), through land management practice change and/or land use change.
	Corner Inlet Management Area
1P-CI	By 2028 in the Corner Inlet management area, improve the erosive condition and reduce by 8,500 ha the area with high-very high risk of gully-tunnel erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
2P-CI	By 2028 in the Corner Inlet management area, improve the erosive condition and reduce by 600 ha the area with high-very high risk of sheet-rill erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
3P-CI	By 2028 in the Corner Inlet management area, improve the erosive condition and reduce by 480 ha the area with high-very high risk of landslip (as classified by the 2007 LUIM), through land management practice change and/or land use change.
	Other Areas of SEMP Region
1P-O	On a contingency and needs basis and by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition and reduce by 6,000 ha the area with high-very high risk of gully-tunnel erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
2P-O	On a contingency and needs basis and by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition and reduce by 1,200 ha the area with high-very high risk of sheet-rill erosion (as classified by the 2007 LUIM), through land management practice change and/or land use change.
3P-O	On a contingency and needs basis by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition and reduce by 300 ha the area with high-very high risk of landslip (as classified by the 2007 LUIM), through land management practice change and/or land use change.

Table 16: SEMP Management Area Risk Treatment Resource Condition Targets

Code	SEMP Management Area Risk Treatment Resource Condition Targets
	West Strzelecki Management Area
1T-WS	By 2028 in the West Strzelecki management area, improve the erosive condition, treat and rehabilitate 2,700 ha of active gully-tunnel erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
2T-WS	By 2028 in the West Strzelecki management area, improve the erosive condition, treat and rehabilitate 80 ha of active sheet-rill erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
3T-WS	By 2028 in the West Strzelecki management area, improve the erosive condition, treat and rehabilitate 50 ha of active landslip (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
	North Strzelecki Management Area
1T-NS	By 2028 in the North Strzelecki management area, improve the erosive condition, treat and rehabilitate 1,200 ha of active gully-tunnel erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
2T-NS	By 2028 in the North Strzelecki management area, improve the erosive condition, treat and rehabilitate 240 ha of active sheet-rill erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
3T-NS	By 2028 in the North Strzelecki management area, improve the erosive condition, treat and rehabilitate 1 ha of active landslip (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
	Corner Inlet Management Area
1T-CI	By 2028 in the Corner Inlet management area, improve the erosive condition, treat and rehabilitate 1,300 ha of active gully-tunnel erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
2T-CI	By 2028 in the Corner Inlet management area, improve the erosive condition, treat and rehabilitate 80 ha of active sheet-rill erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
3T-CI	By 2028 in the Corner Inlet management area, improve the erosive condition, treat and rehabilitate 59 ha of active landslip (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
	Other Areas of SEMP Region
1T-O	On a contingency and needs basis and by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition, treat and rehabilitate 1,500 ha of active gully-tunnel erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
2T-O	On a contingency and needs basis and by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition, treat and rehabilitate 300 ha of active sheet-rill erosion (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.
3T-O	On a contingency and needs basis and by 2028, in areas outside the three priority management areas, maintain options to improve the erosive condition, treat and rehabilitate 80 ha of active landslip (after ground truthing of the 2007 LUIM), through appropriate works and related land management/land use change.

9.2 Management actions

The management action options for soil erosion are described and justified in the previous section. On the basis of these options, specific management actions have been established that are considered effective for addressing the RCTs, based on many years of experience by practitioners and landholders. Nevertheless, the causal relationships between the management actions and their likely impact on the resource condition, in both scale and effectiveness, warrant local testing and validation. The implementation of this plan offers scope for controlled experimental design for such validation.

The suite of proposed management actions is provided in the Table 17, organised into the five categories of Resource Assessment (A), Planning (P), Capacity Building (C), On-ground Works (O) and Statutory Functions (S). They are all ultimately expected to positively influence the erosive condition of the soil. management actions for on-ground works and some statutory functions are ‘direct’ interventions in natural systems – they act directly on some aspect of the environment. Human capacity building is usually ‘indirect’ in its affect, and aims to influence people’s behavior such that they improve on resource condition. Planning and resource assessment management actions are generally ‘preparatory’ in their potential influence on resource condition and RCTs. Planning management actions create and review plans for future interventions, and resource assessment MAs generate knowledge that may be used in planning and subsequently in capacity building and/or on-ground works.

There are a number of actions and interventions that can be utilised to manage, reduce or eliminate the impact of soil erosion. These may focus on either prevention of soil erosion or on repair and remediation of degraded areas.

The selection of management actions will depend on a range of factors peculiar to the soil erosion issue being addressed, and may vary with the severity of the erosion, the assets being impacted and the land use at the site.

The main options currently available to manage soil erosion include a range of on-ground works, planning options, resource assessment, capacity building, regulation and market-based instruments.

It is likely that a combination of actions will be required in any given area to achieve the desired outcome. For example, a landslip can be managed by the development of land class fencing, exclusion of grazing, drainage of the site and revegetation with native species.

It is possible that some issues cannot be solved using different management options within a land use category: it may be necessary to change the land use.

Table 17: SEMP Management Actions

Code	Scale: Local (L) Regional(R)	Management Action	Rationales /Assumptions
Resource Assessment/Investigation			
A1	R	Conduct soil survey field work and collect information that will contribute to the regional soils data used in the LUIM.	Increasing the extent and quality of soil information will improve the input data for the LUIM, and hence its output quality.
A2	R	Collect further relevant land use information to refine/validate existing land use information and to provide new information on land use e.g. separation of grazing intensities for pastures.	More accurate land use information will improve the input data for the LUIM, and hence the outputs from the model.
A3	R	Review asset value information of the LUIM in the context of potential change to onsite values and of erosion related offsite values.	Absolute and relative values used in the LUIM are likely to change over time. Establishing means of monitoring any such input changes and their affects on LUIM outputs is vital for the ongoing development and use of LUIM.
A4	L	In high-very high risk areas of the 3 priority management areas, undertake field work surveys and data collection to map the locations, extent and severity of all existing erosion types.	This work will provide validation of the estimates made from LUIM of the extent of existing soil erosion.
A5	L	In conjunction with the Water Quality Plan collect and/or review baseline data on soil loss, sources and sinks of sediment in the 3 priority management areas.	This aims to provide quantification of sediment movement, and understanding of sedimentation processes for adaptive management.
A6	R	In planning for prevention and remediation of soil erosion, incorporate a plan for suitable experimental designs that will enable the expected results of remediation and land management/land use practice change to be tested in a controlled scientific manner.	Tacit knowledge and expert opinion suggest that the proposed management actions are effective in managing for soil erosion. However, it is important to properly validate this causality and the SEMP offers an opportunity to do this.

Code	Scale: Local (L) Regional(R)	Management Action	Rationales /Assumptions
		Planning	
P1	R	Run the updated LUIM (based on resource assessment), and use the model to predict erosion outcomes with specific land use changes and land management practice changes e.g. land use change to forestry in suitable areas.	An effective use of a valid and reliable LUIM will be to realistically predict improvements to erosion risk and likelihood levels, with changes in land management/land use, across defined areas.
P2	R	Review SEMP targets in the basis of outputs from LUIM development.	The targets in the SEMP are based on the results of the current LUIM. Undertaking validation procedures for the LUIM may promote review of targets.
P3	R	Run the updated LUIM (based on resource assessment), and use the model to predict erosion outcomes with specific land use changes and land management practice changes e.g. land use change to forestry in suitable areas.	An effective use of a valid and reliable LUIM will be to realistically predict improvements to erosion risk and likelihood levels, with changes in land management/land use, across defined areas.
P4	R	Review SEMP targets in the basis of outputs from LUIM development.	The targets in the SEMP are based on the results of the current LUIM. Undertaking validation procedures for the LUIM may promote review of targets.
P5	R	In conjunction with local government, review Local Government Authorities (LGAs) planning schemes' overlays relating to soil erosion risk in the context of outputs from the LUIM and other available data.	LGA have an important role in contributing to soil erosion outcomes, and new layers will enhance their planning capacity.
P6	R	Encourage and support the use of Market-based Instruments (MBIs) that include actions that will reduce the risk of and/or treat, soil erosion.	Soil erosion has not to date been an explicit component of MBIs.
P7	L	In the suite of existing landholder Property Management Planning programs, establish ways to effectively incorporate soil erosion management for high risk areas.	Soil erosion management could become a more explicit component of PMPs. It is assumed that the total target area will be subject to PMPs over 20 years.
P8	L	Integrate soil erosion interventions and targets with other NRM programs/targets for multiple outcomes.	Integrated planning and implementation is an efficient way of utilizing resources, and minimising duplication.

Code	Scale: Local (L) Regional(R)	Management Action	Rationales /Assumptions
Capacity Building			
C1	R	Undertake a knowledge/skills audit of critical stakeholders to determine current levels of capability in relation to soil erosion.	It is anticipated that there are different levels of understanding within groups/agencies and individuals in relation to soil erosion processes, remediation and extent. It is important to ascertain this variation.
C2	R	Support NRM agencies in developing staff capacity in relation to planning schemes and soil erosion issues.	Building this capacity will lead to an increased understanding of erosion processes, prevention and remediation.
C3	R	Undertake a knowledge/skills audit of critical stakeholders to determine current levels of capability in relation to soil erosion.	It is anticipated that there are different levels of understanding within groups/agencies and individuals in relation to soil erosion processes, remediation and extent. It is important to ascertain this variation.
C4	R	Support NRM agencies in developing staff capacity in relation to planning schemes and soil erosion issues.	Building this capacity will lead to an increased understanding of erosion processes, prevention and remediation.
C5	R	Prepare suitable information/materials for new lifestyle landholders about responsibilities, management and support, especially in relation to prevention and remediation of soil erosion.	Experience suggests that suitable information for new lifestyle landholders is very important in managing soil erosion.
C6	L	Develop or locate suitable soil erosion demonstration sites in high risk areas, initially within the area of the three PMAs.	Experiential learning and understanding of soils will be critical to on-farm improvements being realised.
C7	L	Conduct awareness-raising events, including field days for landholders on the topics of soil erosion prevention and remediation.	Experiential learning and understanding of soils will be critical to on-farm improvements being realised.
C8	L	Offer extension site visits to individual landholders for consultations, discussion of support, and planning for soil erosion management.	Experiential learning and understanding of soils will be critical to on-farm improvements being realised.

Code	Scale: Local (L) Regional(R)	Management Action	Rationales /Assumptions
On-ground Works			
O1	L	In high risk areas, fence to Land Classes for improved land management.	Assume that the total high-very high risk target area can be fenced to land classes.
O2	L	Protect high erosion risk areas by fencing for stock exclusion.	Assume that 15% of the total high-very high risk target area will warrant stock exclusion, and that 10% of this area will be riparian zone.
O3	L	Establish off-stream water points in high erosion risk areas.	Assume that for every 3 ha of riparian zone fenced, an off-stream water point will be required.
O4	L	Revegetate (after fencing) with indigenous species, guided by ecological vegetation classes (EVCs), in high erosion risk areas.	Assume that 2% of the total high-very high risk target area will warrant revegetation.
O5	L	Protect remnant vegetation from ongoing degradation in high erosion risk areas.	Assume that in each of the 3 PMAs, 10 ha per year is a realistic target for protection of remnant vegetation.
O6	L	Establish improved perennial pastures in high erosion risk areas.	Assume that 10% of the total high-very high risk target area will warrant establishment of improved perennial pasture.
O7	L	Establish grass filter strips and/or revegetation buffers (by waterways) in high erosion risk areas.	Assume that across the 3 PMAs, 5 ha per year is a realistic target for establishing grass buffer strips (mainly in horticultural areas).
O8	L	Improve pasture and grazing management in high erosion risk areas.	Assume that 25% of the total high-very high risk target area will warrant improved grazing management.
O9	L	Improve tillage practice and management for erosive minimisation in high erosion risk areas.	Assume that 7% of the total high-very high risk target area will warrant improved tillage practices.
O10	L	Undertake earthworks, structural works and use of physical aids to remediate erosion sites or treat very high risk sites.	Assume that a realistic target for on-ground works is 10 sites per year over the total SEMP area, if funding is available.
O11	L	Revegetate active erosion sites guided by EVCs, as part of remediation work.	Assume that approximately 15% of the total active erosion areas can be revegetated.
O12	L	As appropriate, protect remediated erosion areas by fencing for stock exclusion.	Assume that approximately 15% of the total active erosion areas can be fenced and revegetated.

Code	Scale: Local (L) Regional(R)	Management Action	Rationales /Assumptions
Statutory Functions			
S1	R	Compliance of dam design and construction with Southern Rural Water guidelines.	Use of these statutory tools will be help in circumstances which require a compliance response.
S2	R	Agencies implement Catchment and Land Protection Act, Planning and Environment Act, Environment Protection Act and regulations that relate to soil erosion.	Use of these statutory tools will be help in circumstances which require a compliance response.
S3	R	Monitor extractive industries to ensure industry codes of practice are followed.	Only applicable to industries that have a code of practice related to soil erosion.
S4	R	Meet statutory requirements to provide technical advice for planning applications in high erosion risk areas within timelines.	Assume that some proportion of work undertaken will be part of a referrals process at a catchment-wide scale. Provision is on a planned basis and funded up front.
S5	R	Provide technical advice to aid compliance with voluntary Codes of Practice that relate to soil erosion, such as Code of Practice for Feedlots.	Assume that some proportion of work undertaken will be part of a referrals process at a catchment-wide scale. Provision is on a planned basis and funded up front.

9.2.1 Resource Assessment (A)

To enable relevant and useful management actions to be developed, selected, applied and evaluated, sufficient information and mapping resources must be available. There are knowledge gaps in West Gippsland for many soil-health issues, and soil erosion is not well understood, as discussed in Appendices 1 and 2.

Filling key information gaps will be important in reviewing the management actions and resource condition targets that achieve the aims of this SEMP and the RCS.

Currently there is no soil mapping for public land at a scale suitable for inclusion in the SEMP. Furthermore, there is little data on a range of important specific soil characteristics in the survey of Sargeant and Imhof (2006) which has meant that expert advice has been used rather than field-collected data.

Application of the LUIM provides information on erosion risk but does not indicate the current extent of soil erosion to enable a meaningful cost-benefit analysis to be carried out for management of soil erosion. A regional survey, especially in the high and very high risk areas for gully, tunnel and landslip erosion, is required to enable the current extent of these erosion types to be established, and thus to verify the accuracy of the information produced by the LUIM. This will provide a benchmark for monitoring and evaluation.

Other baseline data that needs to be collected includes the sources and sinks of sediment in the catchments, in order to determine the movement of sediment and its impact on assets throughout the catchments, rivers and estuaries. Some data is available from studies and modelling carried out in the catchments of the Gippsland Lakes. Unfortunately most is not specific to soil erosion but relates mainly to water quality and nutrient management.

There is little information relating to the South Gippsland catchments and even less that is specific to soil erosion at a broad scale. Obtaining this baseline data would help to specify effective resource-condition targets and enable improved targeting of high-priority areas by the identification of key sources and sinks of sediment, and its impact on high-value assets.

The LUIM has developed risk maps using a range of different data sources. The modelling outputs could be improved by reviewing the data sources and their limitations, removing the limitations, then running the model with updated information. An example is the 'land use' layer, developed from satellite imagery but limited to a fixed range of land uses. The layer was manually improved with input from regional industry experts within DPI, but could be further refined by the inclusion of improved land-use data.

Similarly, the LUIM could be used to study the effects on soil erosion risk of a change in land use. For example, there are proposals in West Gippsland to increase the area of plantations in response to an increased demand for wood product from the paper manufacturing industry. Scenario testing with the LUIM could identify worst-case and best-case locations for this industry in terms of soil erosion risk.

The information collected to inform the asset-value table in the LUIM was developed through a workshop with natural resource management professionals, and the land and production WGCMA portfolio group. There is currently no standard objective process for developing this information. Consequently, there is an inconsistency with other plans and strategies developed for the WGCMA region and similar strategies and plans across Victoria. When a standard format is developed it should be used to inform the model so that the outputs are consistent with other plans and strategies.

Water monitoring programs associated with the West Gippsland RHS and the WQAP provide some information on soil erosion. Although the various data collected in these programs do not define the sources of sediment or quantify soil erosion, they can be used to identify off-site impacts. Areas identified as 'high risk' in the SEMP should be targeted for intensified water monitoring programs to integrate the aims and activities of SEMP, RHS and WQAP.

9.2.2 On-ground works (O)

Revegetation

Clearing of native vegetation has resulted in increased erosion risk in many parts of West Gippsland. Cultivation or other removal of vegetative cover also resulted in increased soil erosion. Vegetation cover helps to anchor soil and provide protection from wind and water erosion. In this regard perennial pastures (native or exotic) qualify as vegetation cover. Therefore, one of the key management practises for addressing soil erosion is revegetation of degraded and high-risk sites to maximise the instability.

Revegetation with trees and shrubs will help to reduce the likelihood of landslips by reducing soil moisture levels and by providing physical stability due to the extensive network of roots, compared to revegetation with pasture

The choice of vegetation will depend on the circumstances of each site. The intentions of the landowner, in terms of post-remediation land use, will direct this choice. Formal farm planning and utilising the land to its land class are planning options to help make these decisions on land use.

Re-establishment of native eco-systems may be appropriate in areas not intended for or suited to agriculture whereas the establishment of permanent perennial pastures may be more appropriate in areas suited to agricultural production. For example, revegetation could mean establishing perennial pasture in high-risk areas supporting horticulture, to provide permanent ground cover between crops, which will then reduce the erosion risk. Revegetation with native vegetation generally excludes agricultural land use. Such sites are fenced to exclude stock and then revegetated using local-provenance native species.

Revegetation can have multiple outcomes. Revegetation of streamside areas can provide a mechanism to filter sediment from overland flows of water that would otherwise carry it to waterways and can also provide wildlife habitat, shade and shelter, and bank stability.

Revegetation with native vegetation is an opportunity to achieve outcomes such as increased biodiversity, salinity management, shade, shelter and desired amenity values. Farm forestry as a revegetation method, can also utilise degraded areas and areas of high erosion risk to achieve timber production.

Protection of Remnant Vegetation

Protection of remnant vegetation is a high priority listed in the RCS and it is an objective of the West Gippsland Native Vegetation Plan (West Gippsland Catchment Management Authority, 2003). Victoria’s Native Vegetation Management Framework also places a high priority on protection of native vegetation, with many vegetation classes listed as endangered and thus having a high value for protection.

Protection of remnant vegetation is a key management practice to prevent soil erosion, particularly in the identified high risk erosion areas. Protection of the land surface with native vegetation will generally afford a better level of protection than cleared land. Revegetation of degraded land is a much more difficult and costly option than protection of existing vegetation in high risk areas.

The selection of areas and management actions for on-ground works to prevent soil erosion should consider the protection of native vegetation as a high priority. Prevention of soil erosion by protecting native vegetation has multiple outcomes including improving local biodiversity values.

Stock-Exclusion Fencing

Unrestricted stock access in riparian zones is a cause of severe soil erosion, especially on stream banks. This erosion is a major source of sediment into streams and could account for over 80% of the sediment loads entering the Gippsland Lakes (Wilkinson *et al.*, 2005). Stock access to drainage lines and degraded areas such as sites of tunnel and gully erosion, exacerbates the impact of soil erosion.

Stock increase erosion by physically loosening and shifting soil by hoof impact, by channelling of water along their tracks and by the removal of vegetative cover. In particular, channelling of water flows in the high-rainfall environment of West Gippsland can initiate tunnel and gully erosion. This combination of circumstances facilitates the movement of sediment to drainage lines and waterways.

Landholders often rely on permanent streams and gully dams for stock water. On-ground works, which include stock exclusion from these sources of water, often also require the establishment of alternative watering points such as troughs or off-stream dams.

Stock-exclusion fencing is one of the most cost-effective and simple solutions available to prevent soil erosion. It is often used in conjunction with revegetation to provide a higher level of protection from soil erosion and also to provide biodiversity and other benefits. Fencing is often an outcome of farm planning that encourages farming to land class and retiring areas of high erosion risk.

Land Class Fencing

Land-class fencing helps manage the risk of soil erosion by enabling the land manager to match management practices, especially grazing or cultivation regimes, to different parts of the landscape that have contrasting land capabilities and soil erosion hazards.

Land-class fencing has become a key aspect of land management planning programs such as Environmental Management Systems (EMS) and Environmental Best Management Practice (EBMP). Formal Farm Planning is a management action for achieving outcomes of the Water Quality Action Plan (WQAP) and the West Gippsland Salinity Management Plan (WGSMP).

In these programs, land class fencing of a property aims to separate different land classes or parts of the farm landscape to both achieve optimum production and minimise the risk of land degradation. For example, pasture on a steep slope will require a different grazing regime to pasture on flat land to achieve optimal production whilst minimising erosion risk at different times of the year.

Well-managed pastures on steep slopes, depending on the aspect, will respond better to autumn and winter grazing due to the good drainage properties of the slopes, in contrast to pastures on flat land that may have a higher productivity in the summer months due to good moisture retention properties. These areas will be more resilient to higher grazing pressure with a lower risk of erosion than the steep land.

Land-class fencing is usually implemented after the development of a farm plan or in line with best-practice guidelines for the property. Land-class fencing will usually be done in conjunction with revegetation and other land-management improvements to achieve protection from soil erosion and reduce erosion on higher-risk areas of the farm.

Earthworks and Structures

Earthworks and structures have a place in the prevention of soil erosion and in the management of degraded sites that are too severely degraded to be repaired by stock exclusion and revegetation. The measures utilised depend on the erosion type, soil type, slope and severity of the erosion. Works include the establishment of contour banks, permanent grassed buffer strips across and at the base of slopes, use of rock structures to mitigate the erosive power of flowing water, diversion banks and trickle flow pipes to stabilise gully and tunnel erosion. Other types of earthworks can include the use of heavy machinery to break up and reconsolidate gullies and tunnels, and to stabilise landslips prior to the establishment of permanent vegetative cover.

Earthworks and structures need to be carefully designed and sited to minimise the risk of failure. Earthworks generally need to be carried out in the autumn when the soil has retained some moisture, but before the winter rains and cold temperatures set in. For example, poorly designed tracks and roads can be a source of sediment that may be eroded from the road surface or adjoining drains and culverts. Important design considerations include careful placement of the tracks, use of non-erodible materials, good compaction, adequate drains and culverts, and discharge characteristics.

Earthworks and structures which prevent water from entering high risk sites can be an important method of preventing soil erosion. For example, construction of diversion banks and grassed waterways can be used to divert water from high risk areas. Preventative measures can be a necessary adjunct to the repair of a degraded site.

9.2.3 Planning (P)

Shire Planning Schemes

Municipal Planning Schemes are developed by local government under the Planning and Environment Act (1987) to set provisions and conditions that relate to the use, development, protection or conservation of any land. Planning schemes provide for the protection of natural and man-made resources, the maintenance of ecological processes and encourage sustainable development practices.

Planning schemes include zones and overlays to help describe areas and define actions that are or are not allowed in particular areas to manage development of the land.

Environmental Significance Overlays (ESOs) are used to identify areas where development may be impacted by environmental constraints and to ensure that any development allowed is compatible with identified environmental values. ESOs can relate to water catchments, coastal areas, areas susceptible to soil erosion and land with other environmental issues.

Some LGAs also have an Erosion Management Overlay (EMO) that specifically relates to areas prone to soil erosion. Baw Baw and South Gippsland Shires have Erosion Management Overlays whilst Bass Coast and Wellington Shires and La Trobe City do not. The purpose of this overlay is to protect areas prone to erosion from inappropriate development by setting conditions that minimise land disturbance.

The schedules attached to these overlays specify the activities that can be carried out and those that require a planning permit. The schedules specify application requirements and decision guidelines to be considered, and can provide for specific conditions to be applied for the development of land.

The information produced through the modelling of erosion risk by the LUIM could inform the updating of the overlays relating to soil erosion risk and the associated schedules. The efficiency of processing planning applications could be improved by the development of standard conditions that better reflect the objectives of the RCS and provide consistency across West Gippsland.

Declared Water Supply Catchments

Many catchments supplying water for domestic, irrigation or other purposes in Victoria are protected by declaration under the Catchment and Land Protection Act 1994. There are 20 of these declared catchments in West Gippsland, all of which have significant values as assets to supply high quality water mainly for domestic use.

9.2.4 Capacity Building (C)

A key component of achieving practice change is the delivery of training and education programs to influence land management change. Such programs will be an important part of erosion prevention and remediation and need to be targeted to both the managers of the land and the extension providers.

This plan will assist stakeholders involved in delivery of extension programs to target high-risk areas. It also provides information relating to key management options available for implementation.

Effective program delivery requires extension providers and land planners to have a high level of technical knowledge. Capacity building will include an audit of current skills and then up-skilling practitioners to achieve a high standard for delivery of programs to manage soil erosion risk in a local context.

The use of best management practices needs to be implemented for a range of practices, including effective pasture and fertiliser management, management of steep land, stock management in dry conditions, road and track construction, cultivation practices in horticultural areas, and management of degraded land.

The Soil Erosion Management Plan outlines the high priority risk areas where management actions should be implemented. This information needs to be delivered to the land managers in these areas via a range of extension programs. Extension programs can be delivered to landholder groups including Landcare and industry groups, and will include EMS and other best management practice and farm planning programs.

Other extension activities to be delivered include:

- Provide of technical information on erosion risk to land planners including those in state and local government departments,
- Review current notes and develop information brochures to provide technical information on land management and soil erosion in West Gippsland where it is deficient.
- Provide of technical information and deliver of EMS, best management practice and farm planning programs.
- Relate productivity and prevention of soil erosion to activities such as maintaining healthy pastures, best practice grazing management and maintaining good soil structure.
- Present field days and other events to inform land managers about soil erosion and other land degradation issues.
- Target ‘new’ landholders, including lifestyle landholders to provide information on improving land management including soil erosion in partnership with other stakeholders.
- Establish demonstration sites in high risk areas to demonstrate best management practice for erosion control and prevention.
- Develop links with other stakeholders involved in natural resources management to achieve multiple outcomes that include soil erosion objectives. Links could be made with salinity, biodiversity, river management, agricultural production groups and farm forestry programs to achieve multiple outcomes.

9.2.5 Statutory functions (S)

The main Parliamentary Acts that relate to soil and land management include:

The *Catchment and Land Protection Act 1994*, which establishes the Proclaimed Catchments and describes the general duties of landholders to avoid land degradation, minimise soil erosion and protect water resources. Authorised officers have the capacity to issue notices for works to be carried out to protect soil where land degradation causes damage to land of another landholder or to water resources.

The *Planning and Environment Act 1987*, which establishes the planning framework of the local government planning schemes that set conditions for developments in environmentally sensitive areas. These conditions are enforceable.

Environment Protection Act 1970, which enables prosecution for pollution and contamination, including sedimentation of water resources.

Other regulations, codes of practice and policies apply to forestry practices, feedlots and other intensive industries, extractive industries, dam building and stormwater management. The Code of Practice for Timber Production 2007 is enforceable by the Department of Sustainability and Environment, Vicforests and local government. Other voluntary Codes of Practice can be applied as conditions in planning applications for development projects making non-compliance a breach of the planning approval.

9.2.6 Market -based instruments

Market-based Instruments (MBIs) are ‘tools’ that use a range of market-like approaches to influence land management practices. These instruments can be price based, like tenders, grants, rebates, subsidies and taxes, or they can be market focused like EMS programs that provide a label and price premium for products that meet strict environmental conditions.

These tools provide valuable incentives to land managers to effect land management change where it may not otherwise occur and are a valuable part of extension programs. Having a broad suite of options to offer land managers will encourage a higher rate of uptake of new ideas and especially encourages remedial projects to be implemented.

Traditionally grant schemes have provided incentives for landholders to carry out remedial works on their land. Programs like the Federal Government Natural Heritage Trust and National Landcare Program have invested millions of dollars in natural resources management programs in West Gippsland in the past 15 years. The State Government has a range of assistance programs targeting soil erosion and other land degradation issues.

Grant schemes do not capture any cost efficiency opportunities as they are generally allocated on a fixed cost basis but are usually simple and low cost to implement and administer.

factor in the efficiency of the work in dollar cost per benefit output. Bush Tender and Carbon Tender are examples of tender schemes. These schemes encourage innovation, allow more flexibility in activities carried out and can also leverage private investment in NRM. Auction schemes are used in other states to reduce stream bank erosion, salinity and improve water quality.

The Australian Government currently has a tax rebate scheme for landcare activities and water facilities, whereby certain capital expenditure associated with Landcare works, land-class fencing and water facilities are tax deductible in a single year. In some cases there are also rebates available to landholders that have a permanent conservation covenant on their title. There are also Local Government schemes that offer rate rebates for initiatives that improve land management on individual farms.

The MBIs can be used to achieve land use change to reduce erosion risk and can be targeted to address a land degradation issue. This plan will enable improved targeting of MBIs to the highest risk areas to achieve better value for money.

9.2.7 SEMP regional management action targets

The management actions described above are translated into regional management action targets whose timeframes are either the period of the SEMP (up to 5 years), or 20 years, a period that corresponds to that of the RCTs. Some of the regional MATs are wholly regional in nature (e.g. P01), while the implementation of other regional MATs is planned discretely in each of the three SEMP priority management areas - these regional MATs, thus have subsidiary local MATs that aggregate to constitute the regional MATs. Those with linked local MATs are shown in Table 18, and the local MATs themselves are provided in Table 20.

Table 18: SEMP Regional Management Action targets

Code	Regional Management Action Target	Linked Local MATs	Priority
A01	As part of a 5-yearly LUIM review, use regional soil survey field work and related information that has been collected during implementation of the SEMP.		Low
A2	As part of a 5-yearly LUIM review, maintain and update ongoing land use information that has been assembled during implementation of the SEMP.		Medium
A03	As part of a 5-yearly LUIM review, reconsider asset value information of the LUIM in the context of potential changes to onsite values and of erosion related offsite values.		Medium
A04	By 2011 in high-very high erosion risk areas of each of the three PMAs priority management areas, undertake field work surveys and data collection to map the location, extent and severity of all existing erosion types.	Local	High
A05	By 2011 in each of three PMAs, and in conjunction with the regional Water Quality Action Plan, collect and/or review baseline data on soil loss, and sources and sinks of sediment.	Local	High
A06	By 2010 and working with informed consenting landholders in suitable locations, establish experimental designs that will enable the expected results of relevant prevention and treatment practices to be tested in a controlled scientific manner.		Medium
P01	As part of a 5-yearly review incorporate LUIM data updates based on resource assessment reviews, run the updated LUIM, and use the model to predict erosion likelihood and risk outcomes, with a range of potential scenarios.		High
P02	As part of a 5-yearly review, reconsider the SEMP targets on the basis of outputs from the LUIM updates, developments and use of the model.		Medium
P03	By 2013 review existing Special Area Plans for Proclaimed Water Supply Catchments, with a focus on their considerations of soil erosion. Recommend any suitable improvements to such plans, and consider any relevant changes as part of the 5-yearly LUIM review.		Medium
P04	By 2011, undertake negotiations to develop, as a pilot, a Special Area Plan for one Proclaimed Water Supply Catchment without such a plan. Use this experience to recommend process for other catchments without plans.		Medium
P05	By 2011, in one local government area, review the LGA planning schemes' overlays relating to soil erosion in the context of outputs from the LUIM and other available data. Use this experience to recommend process for work with other LGAs.		Medium

Code	Regional Management Action Target	Linked Local MATs	Priority
P06	During the course of the SEMP, encourage and support the use of MBIs that include actions that will reduce the risk of and/or treat, soil erosion.		High
P07	In the high-very high erosion risk areas of each of the three PMAs, establish ways to effectively incorporate soil erosion management into existing landholder Property Management Planning programs, and implement such plans over a 20 year period.	Local	High
P08	As feasible during the course of the SEMP, integrate soil erosion interventions and targets with other NRM programs/targets for multiple outcomes, in the three PMAs. There should be at least one project per management area by 2010	Local	High
C01	By 2009 and using a range of methods, ascertain stakeholders' current levels of understanding of soil erosion processes and remediation.		High
C02	During the course of the SEMP, provide biannual training courses to build capacity in regional agencies for understanding of soil erosion issues.		Medium
C03	By 2009, review existing extension materials about soil erosion to assess their suitability for use in the implementation of the SEMP.		High
C04	During the course of the SEMP create, if needed, new information/materials for the range of extension work considered necessary for prevention and treatment of soil erosion in the SEMP region.		High
C05	As early as appropriate in SEMP implementation, prepare and/or access suitable information/materials for new lifestyle landholders, about responsibilities, management and support, in relation to prevention and treatment of soil erosion.		Medium
C06	By 2010 in high-very high erosion risk areas of each of the three PMAs, locate and commence use of suitable soil erosion demonstration sites that will become a long-term resource.	Local	Medium
C07	By 2014 in high-very high erosion risk areas across the three PMAs, conduct an average of 9 awareness-raising events per year, including field days for landholders on the topics of soil erosion prevention and remediation.	Local	High
C08	By 2014 in high-very high erosion risk areas across the three PMAs, offer an average of 22 extension site/property visits per year to individual landholders for consultations, discussion of support, and planning for soil erosion management.	Local	Medium
O01	By 2028 in high-very high erosion risk areas of each of the three PMAs, fence to land classes for improved land management, in the identified areas.	Local	Medium
O02	By 2028 in high-very high erosion risk areas of each of the three PMAs, protect by fencing for stock exclusion, approximately 15% of the identified areas.	Local	High
O03	By 2028 in high-very high erosion risk areas of each of the three PMAs, establish approximately 200 off-stream water points.	Local	High
O04	By 2028 in high-very high erosion risk areas of each of the three PMAs, revegetate (after fencing) approximately 2% of the identified areas.	Local	High
O05	By 2028 in high-very high erosion risk areas of each of the three PMAs, identify and protect an average of 30 ha per year of remnant vegetation from ongoing degradation.	Local	High

Code	Regional Management Action Target	Linked Local MATs	Priority
O06	By 2028 in high-very high erosion risk areas of each of the three PMAs, establish improved/perennial pastures over approximately 10% of the identified areas.	Local	High
O07	By 2028 in high-very high erosion risk areas across the three PMAs, establish grass filter strips and/or revegetation buffers (by waterways) that total approximately 100 ha.	Local	Medium
O08	By 2028 in high-very high erosion risk areas of each of the three PMAs, improve pasture and grazing management across approximately 25% of the identified areas.	Local	Medium
O09	By 2028 in high-very high erosion risk areas of each of the three PMAs, improve tillage practice and management for erosion minimisation across approximately 10% of the identified areas	Local	High
O10	By 2028 in high-very high erosion risk areas of each of the three PMAs, undertake earth and structural works, and use physical aids to remediate erosion sites or treat very high risk sites - 200 sites in total.	Local	High
O11	By 2028 in high-very high erosion risk areas of each of the three PMAs, revegetate active erosion sites (guided by EVCs) as part of remediation work, over approximately 15% of identified areas.	Local	High
O12	By 2028 in high-very high erosion risk areas of each of the three PMAs, as necessary protect remediated erosion areas by fencing for stock exclusion, over approximately 15% of identified areas.	Local	High
S01	During the course of the SEMP, ensure processes are in place and followed for compliance with farm dam design and construction guidelines/regulation.		High
S02	By 2009 and in conjunction with DSE, review the options for, and use of, regulatory tools that apply to soil erosion processes.		Low
S03	During the course of the SEMP, establish procedures to ensure compliance with extractive industry codes of practice.		Low
S04	During the course of the SEMP, meet statutory requirements to provide technical advice for planning applications in high erosion risk areas, within timelines and funding arrangements.		High
S05	During the course of the SEMP, provide technical advice to aid compliance with voluntary codes of practice that relate to soil erosion, (e.g. Code of Practice for Feedlots).		Medium

9.2.8 SEMP local management action targets for priority management areas

The LUIM indicates that the likelihood of the three different types of soil erosion are not necessarily apparent in separate localities; i.e. a proportion of high-very high risk gully-tunnel areas will also contain areas at high-very high risk of sheet-rill erosion and/or landslip. Also many of the management actions are not erosion-type specific and are appropriate for the three erosion processes. Thus in calculating annual targets for management action quantities from LUIM outputs, the total area used is the gully-tunnel area plus 50% of the combined sheet-rill and landslip areas. This allows for contiguity of the three erosion types, and is shown in Table 19. Although the treatment areas are generally expected to be included in the prevention areas, the LUIM treatment areas are also shown in Table 19.

Table 19: Calculation of Areas from which to base MATs for Prevention and Treatment over 20 years

SEMP Management Area	Targets for Prevention and Treatment over 20 years							
	High-Very High Risk Gully-Tunnel		High-Very High Risk Sheet-Rill		High-Very High Risk Landslip		Estimated Total Area for MATs Calculations: Gully-Tunnel +50% (Sheet-Rill + Landslip)	
	Prevent	Treat	Prevent	Treat	Prevent	Treat	Prevention	Treatment
	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha
West Strzelecki	18,000	2,700	600	80	410	50	18,500	2,765
North Strzelecki	7,500	1,200	1,800	240	10	1	8,400	1,320
Corner Inlet	8,500	1,300	600	80	480	59	9,040	1,370
Contingency/Other	6,000	1,500	1,200	300	300	80	6,750	1,690
Total SEMP Boundary	40,000	6,700	4,200	700	1,200	190		

In the table below, the local MATs are written generically and apply to each of the three priority management areas. Quantities are calculated on the basis of the estimated areas above and the assumptions associated with the management actions described in Table 15. Where there are quantities associated with the target, the quantity for each management area is shown in an adjacent cell of the table: WS=West Strzelecki, NS=North Strzelecki, CI=Corner Inlet.

Table 20: Local Management Action Targets

	Local Management Action Target	PMA	Qty	Priority
A04	In high-very high risk areas of the …… PMA, map the locations, extents and severity of existing erosion types by 2011.	WS	√	H
		NS	√	
		CI	√	
A05	In the ……. PMA collect and/or review baseline data on soil loss, and sources and sinks of sediment by 2011.	WS	√	H
		NS	√	
		CI	√	
P07	In the ……. PMA, establish/update Property Management Plans that, over 20 years, incorporate an average of approximately … ha per year of land with high-very high erosive risk.	WS	930	H
		NS	420	
		CI	450	
P08	In the …… PMA during the course of the SEMP, establish projects that integrate soil erosion interventions and targets with other NRM programs/projects/targets for at least one project by 2010.	WS	√	H
		NS	√	
		CI	√	
C06	In the …… PMA by 2010, establish and develop soil erosion demonstration sites in high-very high risk areas.	WS	√	M
		NS	√	
		CI	√	
C07	In the ……. PMA by 2014, conduct 3 soil erosion awareness raising events (including field days) per year.	WS	3	H
		NS	3	
		CI	3	
C08	On a responsive and needs basis, in the …… PMA by 2014, conduct at least … property site visits per year that focus on planning and management for soil erosion.	WS	10	M
		NS	5	
		CI	7	
O01	In high-very high risk areas of the …… PMA, fence to Land Classes an average of … ha per year by 2028.	WS	930	M
		NS	420	
		CI	450	
O02	In high-very high risk areas of the…… PMA, establish stock exclusion by fencing for an average of … ha per year by 2028.	WS	140	H
		NS	65	
		CI	78	
O03	In high-very high risk areas of the …… PMA, establish an average of .. off-stream	WS	5	

	Local Management Action Target	PMA	Qty	Priority
	watering points per year by 2028.	NS	2	H
		CI	3	
O04	In high-very high risk areas of the …… PMA, revegetate (after fencing) an average of…. ha per year with indigenous species guided by EVCs, by 2028.	WS	20	H
		NS	9	
		CI	11	
O05	In high-very high risk areas of the …… PMA, protect an average of 10 ha per year of remnant vegetation, by 2028.	WS	10	H
		NS	10	
		CI	10	
O06	In high-very high risk areas of the …… PMA, establish an average of … ha of improved/perennial pastures per year, by 2028.	WS	93	H
		NS	42	
		CI	45	
O07	In high-very high risk areas of the …… PMA, establish grass filter strips/revegetation buffers that contribute to an average of 5 ha per year over the 3 priority management areas, by 2028.	WS	5	M
		NS		
		CI		
O08	In high-very high risk areas of the …… PMA, improve pasture and grazing management over an average of … ha per year, by 2028.	WS	230	M
		NS	105	
		CI	115	
O09	In high-very high risk areas of the …… PMA, improve tillage practice and management over an average of … ha per year, by 2028.	WS	93	H
		NS	42	
		CI	45	
O10	In high-very high risk areas of the …… PMA, undertake earthworks and/or install structures to remediate soil erosion sites or treat incipient high risks, at an average of …… sites per year by 2028.	WS	5	H
		NS	2	
		CI	3	
O11	In high-very high risk areas of the …… PMA, revegetate active erosion sites (guided by EVCs) as part of remediation work, over an average of … ha per year by 2028.	WS	21	H
		NS	10	
		CI	12	
012	In high-very high risk areas of the …… PMA, as necessary protect remediated erosion areas by fencing for stock exclusion, over an average of … ha per year by 2028.	WS	21	H
		NS	10	
		CI	12	

Figure 27: MAT OO4: Revegetation of high risk erosion areas on a farm

10 Conclusion

This plan has:

- Identified the priorities for future investment in Soil Erosion across the catchment (excluding public Land in the Northern parts).
- Identified areas of highest soil-erosion risk.
- Identified other soil-health issues.
- Identified priority assets threatened by soil erosion and established spatial relationships.
- Identified priority land management areas for management actions.
- Identified key management actions for soil erosion.
- Identified knowledge gaps for future research and resource assessment as part of the Management Action Targets (MATs).
- Developed a framework for monitoring and evaluation using Land Use Impact Model (LUIM) model.
- Produced a document which will inform continued development toward a soil health strategy for West Gippsland.
- Provided an adaptive management approach which will allow model predictions to be confirmed and will allow improvements to be made to the management action targets into the future.

A key outcome of this plan will be to establish an effective and efficient monitoring program which will further utilise the modelling capability of LUIM. An ongoing review process against the priority management action targets needs to be completed, preferably annually, as part of the MATs set in the relevant section as part of the Regional Catchment Investment Planning process. Future work in assessing best management land use options will have to be explored as to the key sensitivity or triggers for each of the erosion types.

The plan has attempted to assess multiple priorities for action based on both the on-site risk of soil erosion and off-site consequences to water quality.

This study has defined high priority areas and issues within an evidence-based plan of management actions and targets. Investment can now be appropriately coordinated across the region for soil erosion control. It should also be stated that a holistic approach to solving a range of land and water asset issues should be considered and recognise that reducing the risk of soil erosion can achieve multiple outcomes from investment.

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Appendix 1 - Soil erosion processes

Erosion is the gradual wearing away of the earth's surface. The process includes the separation of soil particles from the parent soil and their removal by wind, water or gravity, followed by deposition at another location. This process of soil redistribution is continuous and it shapes the surface of the land into the landscapes we see today. However, this process can and has been accelerated by human activity. Human activity often has its greatest impact on soil erosion when vegetation is removed. The soil surface is then more exposed to the energy of rain, running water, gravity and wind, with nothing but its own structure preventing soil from moving down the slope (often into a waterway) or being blown away.

Water erosion

Soil erosion by water is the process of detachment of particles from the soil by water, their transport off-site and their eventual deposition. The process occurs as a series of events of varying duration, extent and intensity. Sediments may be re-worked and re-deposited many times within the land surface prior to reaching a waterway. The rate of erosion depends on the frequency and severity of rainfall events; soil and land characteristics especially surface characteristics at the micro-scale of soil surface roughness and vegetation cover, and the macro-scale of topography; and how the land is used.

Differentiation of the different forms of water erosion is to a certain extent, based on the practical needs of land and water managers working within the different parts of a catchment. For example, the distinctions between rill, gully and streambank erosion are based on size, location and remediation methods, as much as they are based on soil characteristics, mechanisms and processes.

Figure 28: Sediment load and bank erosion in Eaglehawk Creek

Sheet and rill erosion

Sheet erosion is the removal of a layer of surface soil from the land by raindrop splash and runoff. Rain falling on a soil surface can disrupt the soil aggregates and constituent particles. Where the aggregates are not stable, raindrops can break them into constituent particles. These can be packed into soil surface pores, further reducing the infiltration of water and thus increasing surface run-off and sheet erosion.

Rill erosion results from soil detachment by concentrated surface flows to form small channels in the surface soil. Once rilling begins, it increases rapidly as water continues to concentrate, especially if slopes are long or steep. Rill erosion usually occurs in numerous small channels in association with sheet erosion. Both can be obliterated during normal tillage.

Sheet erosion is often not as visually dramatic as other forms of water erosion. The observer is often unaware of the severity and extent of sheet erosion and so it is ignored. For example, casual observers of tunnel, rill and gully erosion often have a memory or awareness of what once filled the void left by these forms of erosion, whereas sheet erosion usually does not allow such a comparison as the entire surface is lower. Only when the surface soil is totally removed to expose dissimilar subsoil or bare rock, does the casual observer appreciate the catastrophe.

The risk of sheet and rill erosion is particularly high where loose soil lays on top of undisturbed or compacted subsoil, and is exposed to storms. Typically, sheet and rill erosion occurs during seedbed preparation. Unprotected soil on batters, gutters and landscaped surfaces often suffers sheet and rill erosion. Therefore, cultivated paddocks, gutters, unpaved roads, farm tracks and construction sites have generated large amounts of sediment from sheet and rill erosion.

Figure 29: Rill erosion in cultivated paddock in the Strzelecki Ranges

Gully Erosion

Gully erosion begins when soil is removed by running water to cause the formation of channels sufficiently large that they disrupt normal farming and can't be filled in during normal cultivation or are in areas too steep for cultivation. Channel depth is often used to distinguish rills (<30cm) from gullies (>30cm). The term "ephemeral gullies" may be used to describe an eroded channel where ephemeral flow occurs that is much wider than a rill, but shallow enough to be partially filled by tillage (Figure 32). Gully erosion is more typically associated with drainage lines and intermittent streams and erodes both surface and sub-surface soil layers, where as rill erosion is usually associated with sheet erosion of surface soil.

Figure 30: Ephemeral gullies in a cultivated paddock

Because gully erosion involves the removal of sub-surface soil, the characteristics of the sub-surface strata and the rate and amount of water flow affect gully development. Gullies typically have steep sides and they enlarge through active erosion by scouring by running water, splash from water falling from overhanging surface soils and by slumping of the gully walls. Removal of the gully walls undermines the surface soil, which then collapses. Slumping occurs where the gully wall becomes saturated by the pool of water on the gully floor or directly by rainfall.

Gully formation occurs most readily in soils which have slaking or dispersive clay sub-surface soil, in sandy soils and in soils subject to surface crusting. The rate of progress of gully depth and headward movement depends on the length and steepness of the slope, the force of water drops or flowing water and the degree of vegetative cover of the soil. Hence, remediation must tackle the gully development by disrupting the existing channel, protecting the new soil surface with vegetation cover and directing water away from the channel line.

Large gullies are difficult and costly to repair, so early intervention is very strongly recommended. Maximum soil loss occurs on sites cleared and disturbed for agriculture, urban development, road development, mining, forest harvesting or cropping.

Tunnel erosion

Tunnel erosion is the removal of sub-surface soil by water while the surface soil horizon remains relatively intact. Thus, the true extent of tunnelling may be hidden under the landscape. Long cavities may form beneath the soil surface that enlarge until the surface soil is not supported and collapses, forming holes from the cavity to the surface.

If intervention does not occur to disrupt the tunnel and reform or revegetate the soil surface, then further surface collapse may occur converting the cavity into an open gully which continues to grow.

Tunnels may range from a few centimetres to several metres in diameter. Tunnel initiation occurs when water enters the second soil horizon along soil cracks or root spaces, concentration of water to a point on the side of a gully, or through the digging action of animals. Dispersive and slaking subsoils are particularly susceptible to tunnel erosion because they break down into readily transportable particles which are then transported along the soil profile thus creating a tunnel.

Streambank erosion

Streambank erosion is the removal of soil from streambanks, or, through the movement of livestock along unprotected banks.

The soils on stream banks are often developed from floodplain sediments and are highly erodible. Undercutting and saturation slumping are common mechanisms of streambank erosion. It typically occurs during periods of high stream flow.

Revegetation and stock exclusion are important control measures for management of stream bank erosion. Erosion rates of streambanks can be reduced by 95% by revegetation of a 40 metre riparian zone along streambanks.

Figure 31: Stream bank erosion on the Stockyard Creek

The division between stream bank erosion and gully erosion is artificial to a degree.

The West Gippsland River Health Strategy (2005) details the processes of streambank erosion, management actions and priorities for action, and defines the geographic coverage of stream banks.

Mass movement

Mass movement is the term given to erosion where gravity is the main force. The occurrence of mass movement involves a complex interaction of landform, regolith and depth, rainfall intensity and duration, drainage characteristics and vegetation cover. Human activities such as construction of roads and housing, or vegetation change from forest to pasture can also have a part to play.

Mass movement can result in either landslips, soil creep or subsidence. Where gravity is acting to dislodge and transport surface earth materials, mass movement is called landslips, also referred to as slumping. Soil creep forms small ridges (terracettes) across steep hillsides. Terracettes developed from trampling of hoofed animals are not to be confused with those developed from soil creep. Subsidence refers to the mass movement due to vertical downward movement of sub-surface strata. This may be associated with tunnel erosion, dewatering, mining or earthquakes. Subsidence is not considered here.

Landslips are usually the end result of activities and processes that have taken place over many years prior to the actual failure event. For this reason it is difficult to accurately predict where and when failure will occur. In general, failure occurs when the weight of the earth and vegetative material on a slope exceeds its restraining capabilities. This usually takes place following intense rainfall periods, when the slope weight has been increased dramatically by saturation and an underlying material has been lubricated by water infiltration.

Landslips can involve material moving downslope as a mass, typically having distinct minor scarps within the moving materials and in contact with the ground. Movement can be slow or rapid. The shear zone where failure has occurred is usually a fairly well-defined surface that may be visible or at least accurately inferred. Landslips can be catastrophic by causing damage to houses, infrastructure, rivers and agricultural land. They can be very expensive and sometimes impossible to restore.

Figure 32: Revegetated landslip at Arawata

Wind erosion

Wind erosion is the movement of soil particles by wind. It occurs when the lifting forces of the wind exceeds the gravity and cohesion forces of the particles at the soil surface. In Gippsland it is of most concern in coastal regions where sand may be blown onto roads and public utilities if the coastal landforms have been destabilised.

Destabilisation occurs where the vegetation covering of the dune is disrupted by the actions of burrowing animals such as rabbits and wombats or by human activities of house and road construction, vegetation removal or inappropriate beach access. Movement of the separated particles to a new site then depends on the wind flow close to the ground being turbulent and eddying in different directions. Once erosion starts, the sediment is sorted according to its particle size and weight. Larger particles (>0.5mm) slowly roll and bump across the surface. Smaller particles (0.1-0.5mm) skip up to 50cm high above the surface (this size constitutes the greatest proportion of particles moved during a wind erosion event) and the smallest particles (>0.1mm) may be suspended in the wind and move considerable distances.

Appendix 2 - Assessment of erosion trends

Quantitative assessment

Quantitative determination of soil erosion is a difficult task due to the broad range of variables to be considered.

Quantitative research can be either process-specific, for example, tracer studies of soil loss, in which conclusions are extrapolated to all similar situations, or site-specific, for example, modelling of soil loss from a catchment where effectively all sites are included and the process is inferred from data collected using a multitude of techniques.

It is inappropriate to discuss the pros and cons of various experimental methods and models in this plan, but it is necessary to consider the results of research conducted in the WGCMA region and in similar environments in other parts of Australia.

The severity of soil loss from the forested site on granitic soil at Tanjil Bren was surprising to the authors. However, the 1,842 mm annual rainfall, 16 % slope and the typically erosive nature of the coarse-textured soils that develop on granite may explain this result. In contrast the low erosion observed at Leongatha concurred with the site characteristics i.e., less intense rainfall, (1,100 mm annual rainfall), less erosive soils and under permanent perennial pasture.

The remaining 21 sites can be used as analogues for situations in the WGCMA region, where similarities in climate, landscape, soil and management occur. In particular, there was relatively low soil erosion by wind or water where cultivation did not occur, that is, where soil was protected by a permanent cover of pasture. Not surprisingly at sites where soil was exposed by cultivation, the most serious losses of soil were observed.

Table 21: Net soil loss (t soil ha^{-1} a^{-1}) from transects at 23 sites across Victoria (Lorimer *et al*., 1996) based on the ^{137}Cs method

Site	District	Land use	Geomorphic unit	Principal agent	Mean soil loss along the sampled transect	Average soil loss at sampling stations which eroded	Maximum value of soil loss
1	Swan Hill	Crop/pasture rotation	Low calcareous dunes (Ouyen)	Wind	4.26	7.43	37.07
2	Ouyen	As above	As above	As above	7.73	8.71	48.19
3	Meringur	As above	As above	As above	0.57	1.49	3.49
4	Sutton Grange	As above	Stony undulating plains (Western District)	Water	1.70	1.82	7.67
5	Murrayville	As above	Low calcareous dunes (Ouyen)	Wind	4.17	5.25	17.77
6	Kaniva	As above	Clay plains (Nhill)	Wind, water	4.01	4.01	14.41
7	Horsham	As above	As above	Water , minor wind	0.52	2.67	16.00
8	Toolangi	Horticultural crops in rotation with perennial pasture	Dissected uplands	Water	+0.91[1]	0.90	1.59
9	Yea	Permanent annual pasture	As above	Water	0.90	1.54	7.03
10	Charlton	Crop/pasture rotation	Dissected uplands (Midlands)	Wind	0.89	1.34	5.04
11	St Arnaud	As above	As above	Water	1.41	2.01	6.22
12	Werribee	As above	Undulating plains (Western District)	Water	0.02	0.82	3.19
13	Ballarat	Potatoes in rotation with	As above	Water	4.89	5.19	25.67

Site	District	Land use	Geomorphic unit	Principal agent	Mean soil loss along the sampled transect	Average soil loss at sampling stations which eroded	Maximum value of soil loss
		pasture					
14	Stawell	Permanent annual pasture	Dissected uplands (Midlands)	Water	0.00	0.55	1.70
15	Trentham	Horticultural and grain crops in rotation with pasture	Undulating plains (Western District)	Water	1.92	2.22	5.60
16	Colbinabbin	Crop/pasture rotation	Dissected uplands (Midlands)	Water	3.06	3.06	12.31
17	Tallangatta	Permanent pasture	Dissected uplands	Wind and water	+0.04	0.18	0.84
18	Benalla	Unimproved pasture	As above	Water erosion	0.89	2.53	15.48
19	Tanjil Bren	Undisturbed woodland left to regenerate after 1939 fires	As above	As above	1.90	2.57	31.49
20	Leongatha	Permanent perennial pasture	Dissected fault block	As above	0.60	0.60	1.99
21	Yea Transect A	Permanent pasture	Dissected uplands	As above	0.36	0.56	2.73
21	Yea Transect B	As above	As above	As above	+0.90 (net gain)	0.76	5.55
22	Silvan	Permanent perennial pasture	As above	As above	0.68	1.78	7.03
23	Silvan	Perennial pasture to 1971 then horticultural crops	As above	As above	Not reported	3.35	56.41

Estimation of soil erosion by water using mini-subcatchments

Several research reports have focussed on nutrient run-off from grazed pastures in small catchments (less than 3.6 ha), in West Gippsland (Greenhill, *et al*., 1983ab; Nash and Murdoch, 1997; Nash *et al*., 2005). While the objective of these reports was not to report sediment movement from pastures to waterways, they do provide important information on this process.

In the past, it has been perceived that high-rainfall pastures treated with high rates of fertiliser are the main source of nutrients contaminating waterways and that sediment in run-off is the main carrier.

These reports indicate that most of the P in run-off from well managed permanent perennial pastures is likely to be in the form of reactive P rather than P carried by sediment. In fact, sediment yield from such pastures is minimal (D Nash, pers. comm.).

There are no similar studies that can provide information on soil erosion for other major land-uses and landscapes in West Gippsland, such as land used for horticulture, or from riverine plains where soil is exposed by cultivation or other soil disturbance.

Previous field trials demonstrating the impact of earth structures and buffer strips on soil loss from horticulture (Abbot and Ashton, 1991; Hirst *et al*., 1992) have only collected anecdotal data. This data indicated that sediment movement from exposed cultivated soil can be substantial even for robust soils such as the Red Ferrosols typically used for potato farming in West Gippsland.

Small area studies such as the above, are limited in scale, both spatially and temporally. Such studies are also limited in the kind of erosion processes that can be studied, that is, sheet and rill erosion. Tunnel erosion, gully erosion, wind erosion and landslips have not been quantified. Usually, these are studied at a larger spatial scale and at longer time scales, especially when the erosion process of interest is episodic.

Estimation of soil erosion at catchment scales

Prosser *et al*., 2001 reviewed Australian research on erosion and sediment transport in the rivers of Australia.

They concluded that the main source of sediment in most catchments is from stream bank erosion. Much of the sediment from the erosion of hill-slopes, gullies and channels, is stored in stream beds.

Their review found that erosion increased with disturbance of the landscape during clearing for agricultural development, although, in general, gully erosion in south-eastern Australia has declined since the rapid growth of gullies from initial clearing during European colonisation.

A number of studies using a combination of modelling, tracers and inference have been and are continuing to be used to provide more detailed information on soil erosion in the catchments of the WGCMA region (Wilkinson *et al*., 2005) and in neighbouring regions (for example, Sargeant, 1977; Hughes *et al*., 2003; Wallbrink *et al*., 2003). These research activities are on-going and are yet to reach unequivocal conclusions.

Sednet, a catchment hydrology model, has been widely used to predict sediment supply to a number of waterways, for example, the Western Port Bay basin (Hughes *et al*., 2003; Wilkinson *et al*., 2003) and the Gippsland Lakes (Wilkinson *et al*., 2005). Model outputs (Hughes *et al*., 2003) are supported by tracer studies to confirm sediment sources (Wilkinson *et al*., 2003).

Wallbrink *et al*. (2003) concluded that gully erosion and channel bank erosion have been major contributors to sediment load in the eastern part of Western Port Bay catchment, that is from landscapes shared by WGCMA region. They also concluded that surface erosion contributed sediments from steep land in the Bass River catchment.

A draft report (Wilkinson *et al*., 2005) on sediment entering the Gippsland Lakes made a preliminary conclusion that over 90% of suspended sediment entering these waters, is from stream bank erosion. It also concluded that a significant proportion of the suspended sediment supplied to the La Trobe and Thomson Rivers is deposited within the catchment on floodplains and in reservoirs.

The draft report states that very little soil eroded from hill-slopes is delivered to the streams. Their modelling predicted that only 5% of sediment would come from hill-slope erosion and that the hill-slope erosion (from sheet, rill and tunnel erosion) was estimated at less than one tonne per ha per year for forested areas, and could be greater than five tonnes per ha per year for steeper farmed areas, both considered quite low on a national scale.

Table 22 shows the relative inputs of sediments from different sources in the western catchments (those flowing into Lake Wellington) of the Gippsland Lakes.

Table 22: Preliminary total catchment budget for suspended sediment flowing into Lake Wellington from the western part of the Gippsland Lakes catchment (from Wilkinson *et al*., 2005)

Suspended sediment budget	Sediment (Kt/yr)	Proportion of total sediment (%)
Hill-slope erosion input to streams	14	6.5
Gully erosion input to streams	10	4.6
Bank erosion input to streams	192	88.8
Total erosion input	216	100
Floodplain and reservoir deposition	116	53.7
Suspended load export to lakes	100	46.3

Table 23: The relative sediment inputs and run-off volumes from the 2 major catchments feeding the Gippsland Lakes (Wilkinson *et al*. 2005)

Catchmen t	Suspended sediment exported to lakes (Kt/yr)	Proportion of total sediment	Run-off volumes (GL/yr)
La Trobe	51	52	997
Thomson	47	48	1104

Semi-quantitative assessment

In-situ observations or remote sensing can be used to assess soil erosion processes to at least give semi-quantitative data. For example, landslips have been assessed using aerial photography (Brumley, 1979). While not producing data on tonnages of soil lost from a site or tonnages of sediment delivered to waterway, semi-quantitative data can enable confident natural resource management decisions to be made.

Landslips in the former Narracan Shire

Landslips have not been assessed across the WGCMA region although Brumley (1979) has reported on landslips in the southern part of the former Shire of Narracan. Brumley's report described and assessed a number of landslips in this area, and published a diagrammatic map of landslips (Figure 35). Brumley's map illustrates the size of individual landslips and the proportion of land affected by landslips in this area. Landslips in other areas of the WGCMA region have not been quantified to the same extent.

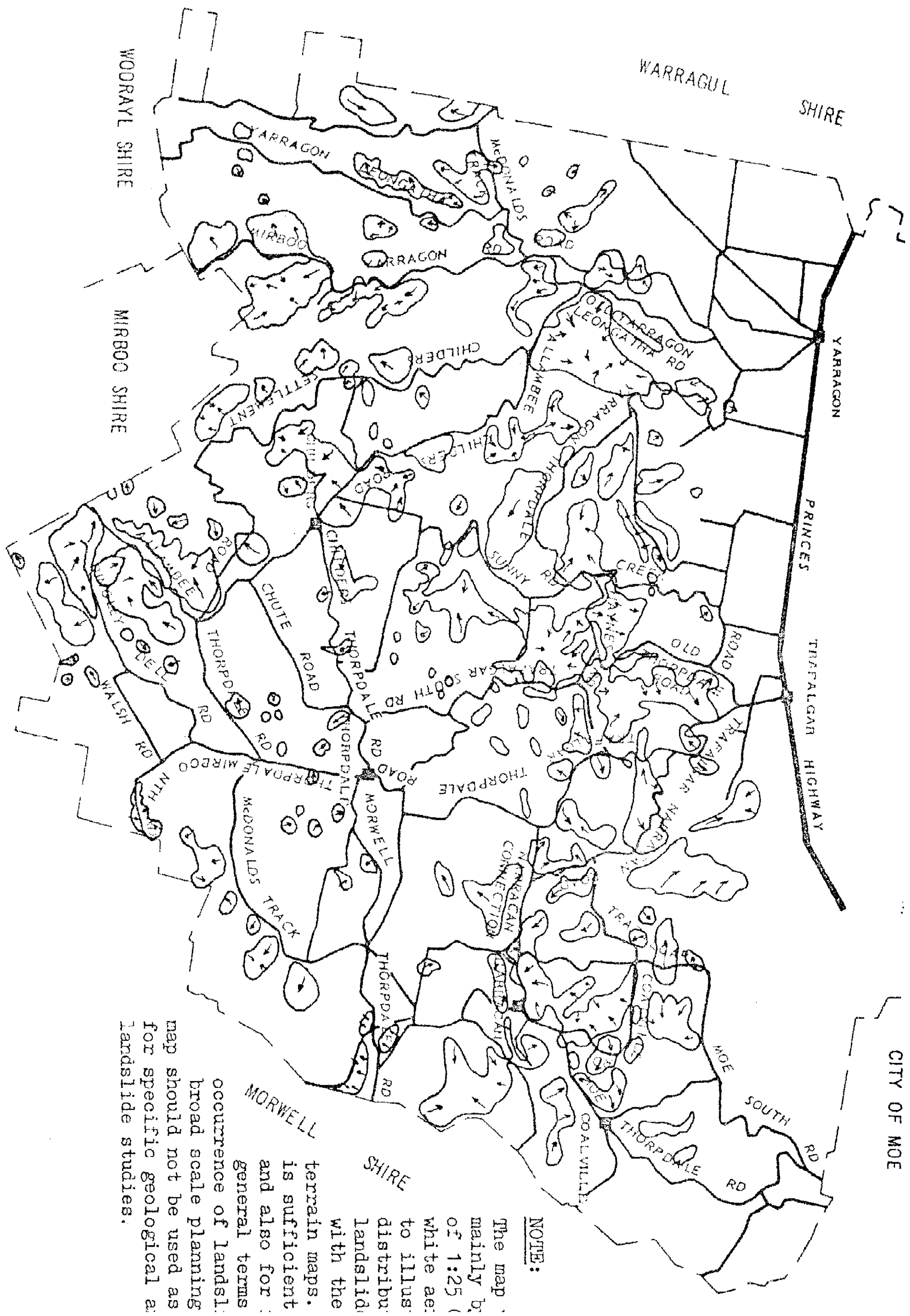


Figure 33: Reproduction of a map of landslips in the southern part of the Shire of Narracan from Brumley (1979)

Qualitative assessment of soil erosion

Several surveys of farmers (Fuller, 1995) and natural resource managers (Department of Natural Resources and Environment, 1997) provide qualitative information on soil erosion. These provide a better geographic coverage than the quantitative studies discussed above. However, to a certain degree, these surveys represent the past since land-use is rapidly changing in the WGCMA region. For example, expansion of opportunistic cultivation such as snow-pea and fodder-crop production and extension efforts such as whole farm planning may have changed land use practises sufficiently to render these inaccurate.

Development of the 1997 Regional Catchment Strategy for the WGCMA region (Department of Natural Resources and Environment, 1997) involved a workshop where natural resource professionals of the Department of Conservation and Natural Resources (DCNR) (predecessor of the Department of Sustainability and Environment) were asked to assess and rate the impact of soil erosion across the freehold land in the WGCMA region. Landslips as a soil erosion process were not assessed nor were soil erosion in public land. Their assessments are reproduced here from scanned images of the published maps (the original digital data was not available) and form the main source of qualitative assessment.

Gully and Tunnel erosion

A survey by Fuller (1995) of full time farmers of South and West Gippsland found that they perceived tunnel erosion and the resulting gully erosion to be the most important "land degradation problem" and it posed the greatest risk. Landslips and streambank erosion were the other two main land degradation problems. Landslips, declining soil structure, stream bank erosion and soil acidification were ranked as lesser risks, in that order. This is in accord with Department of Conservation and Natural Resources staff's perception of gully and tunnel erosion (Department of Natural Resources and Environment, 1997) (Figure 34). The land on the lower slopes of the Moondarra Plateau also has severe tunnel and gully erosion.

This is in accord with DCNR staff's perception of gully and tunnel erosion (Department of Natural Resources and Environment, 1997). The land on the lower slopes of the Moondarra Plateau also has severe tunnel and gully erosion.

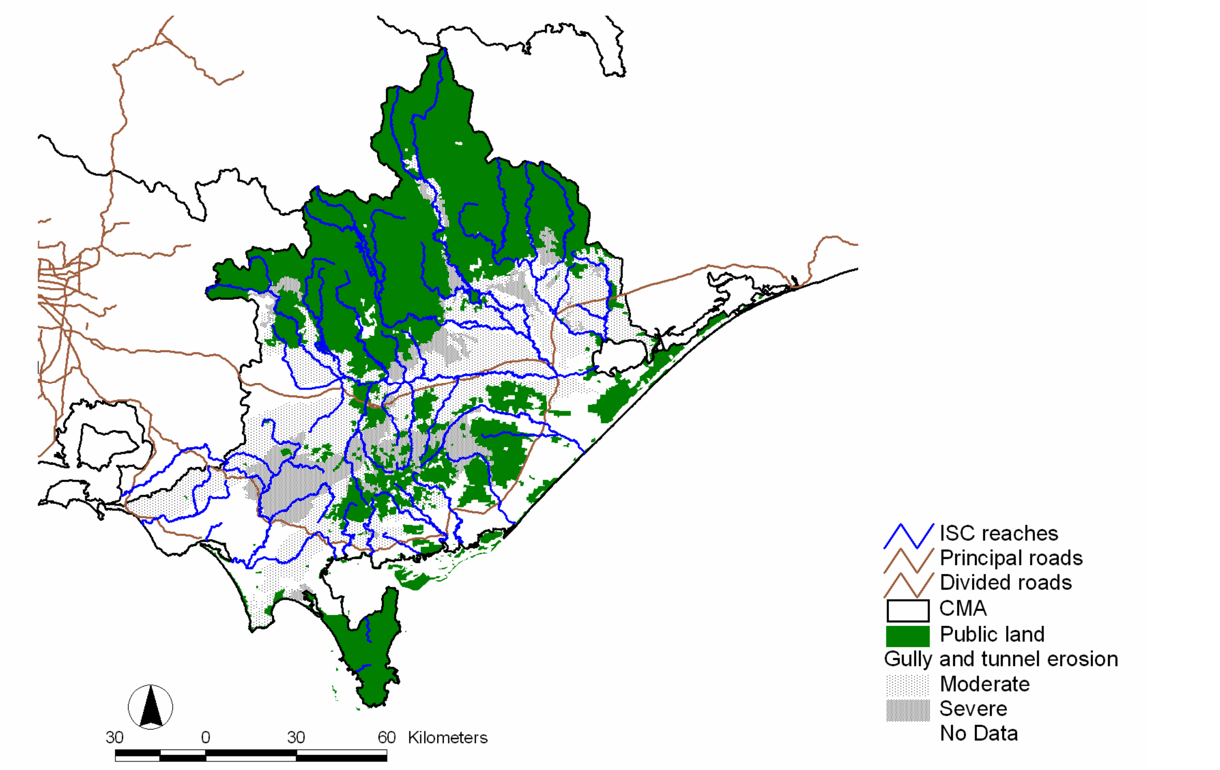


Figure 34: Anecdotal observations and impact ratings by DCNR field staff from 1985 to 1991 of actual gully and tunnel erosion on freehold land. Boundaries are delineated on the basis of landsystem (Rowan, 1990)

Sheet and rill erosion

Sheet and rill erosion was rated as severe in the hills of the Strzelecki ranges, the Moondarra Plateau and along the Avon, Thomson and Macalister Rivers (Figure 35). The Thorpdale potato production areas are included in the severe rating, which would not be the case if these robust soils were not cultivated.

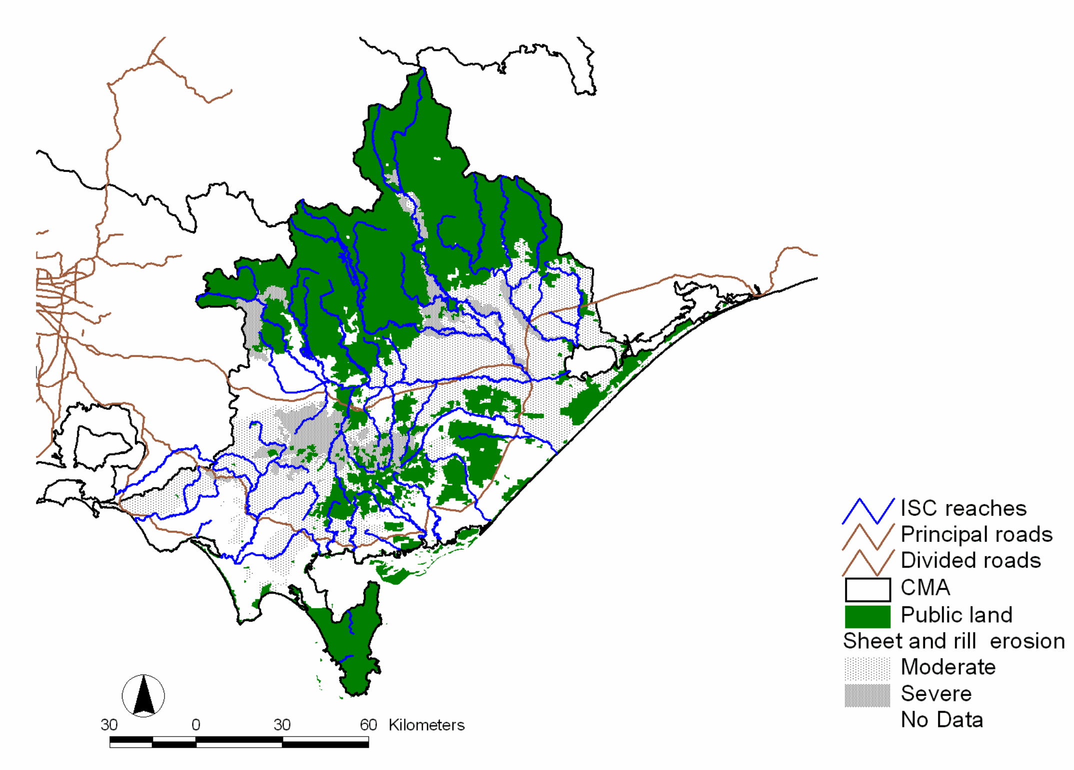


Figure 35: Anecdotal observations and impact ratings by DCNR field staff from 1985 to 1991 of actual sheet and rill erosion on freehold land. Boundaries are delineated on the basis of landsystem (Rowan, 1990)

Wind erosion

Wind erosion was perceived as being limited to the dunefields of the coastal plains. Little quantitative information is available to corroborate this perception.

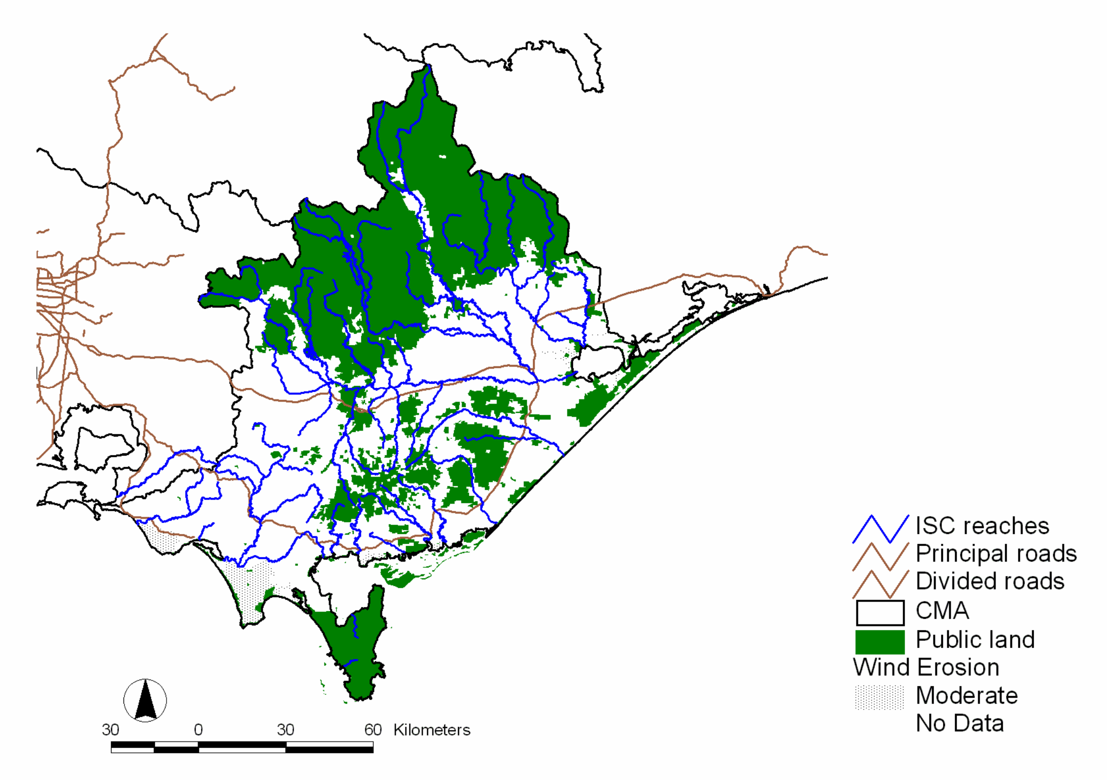


Figure 36: Anecdotal observations and impact ratings by DCNR field staff from 1985 to 1991 of actual wind erosion on freehold land. Boundaries are delineated on the basis of landsystem (Rowan, 1990)

Appendix 3 - Summary of River Health Strategy priority areas

The basis of the West Gippsland River Health Strategy (RHS) is to 'protect the best' so the management programs reflect this objective. Due to the lack of knowledge of the sources of sediment entering waterways, the management actions implemented using this priority method will not necessarily have the expected impact on water quality.

The RHS details three management programs with priorities based on a risk assessment process.

Management Program A: Sub-catchments are defined by highest values at risk of degradation.

Objective: To protect highest value river assets by reducing risks identified within priority Index of Stream Condition (ISC) reaches.

Management Program B: Sub-catchments are defined by Ecologically Healthy River or Representative River status defined in the Victorian RHS. Priority reaches were identified for enhancement or maintenance of this status based on the risk-based approach.

Objective: To enhance or maintain the condition of Ecologically Healthy and Representative River reaches defined in the Victorian RHS.

Management Program C: Reaches within the top 30% of risk which are located outside Management Program A and B sub-catchments.

Management Program N: These are other lower priority catchments that are not categorised under any of the programs listed above.

Appendix 4 - Susceptibility rule data

Susceptibility to sheet and rill erosion

The tables used to assess sheet and rill erosion were modified from Elliott and Leys (1991). The properties which influence soil erodibility (Table 23) were identified and then related to slope, to determine a rating for susceptibility.

Table 24: Erodibility of topsoils

Soil parameters			Soil dispersibility		
Texture group (A1)	Structure grade (A1)	Horizon depth (A1 + A2)	Very Low – Low E3(1), E3(2), E4,E5, E6, E7, E8	Medium – High E3(3), E3(4), E2	Very High E1
Sand	apedal	< 0.2 m	M		
		0.2 - 0.4 m	L		
		> 0.4 m	L		
Sandy loam	apedal	< 0.2 m	M	H	
		0.2 - 0.4 m	L	M	
		> 0.4 m	L		
	weakly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M		
Loam	apedal	< 0.2 m	M	H	
		0.2 - 0.4 m	L	M	
		> 0.4 m	L		
	weakly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M		
	peds evident	< 0.2 m	H	E	
		0.2 - 0.4 m	H		
		> 0.4 m	H		
Clay loam	apedal	< 0.2 m	M	H	
		0.2 - 0.4 m	L	M	
		> 0.4 m	L		
	weakly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M		
	peds evident	< 0.2 m	H	E	
		0.2 - 0.4 m	H	E	
		> 0.4 m	M		

Soil parameters			Soil dispersibility		
Texture group (A1)	Structure grade (A1)	Horizon depth (A1 + A2)	Very Low – Low E3(1), E3(2), E4,E5, E6, E7, E8	Medium – High E3(3), E3(4), E2	Very High E1
Light clay	weakly pedal	< 0.2 m	H	E	E
		0.2 - 0.4 m	M	V	E
		> 0.4 m	M	V	E
	peds evident	< 0.2 m	M	V	E
		0.2 - 0.4 m	M	H	E
		> 0.4 m	M	H	E
	highly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M	V	
Medium to heavy clay	weakly pedal	< 0.2 m	M	H	E
		0.2 - 0.4 m	M	H	V
		> 0.4 m	M	H	V
	peds evident	< 0.2 m	H	E	E
		0.2 - 0.4 m	M	V	E
		> 0.4 m	M	V	E
	highly pedal	< 0.2 m	H	E	E
		0.2 - 0.4 m	M	V	E
		> 0.4 m	M	V	E

L - Low M - Moderate H - High V - Very high E – Extreme

Table 25: Susceptibility of soil to sheet and rill erosion

Slope %	Topsoil erodibility				
	Low	Moderate	High	Very high	Extreme
< 1 %	Very low	Very low	Low	Low	Moderate
1 - 3 %	Very low	Low	Moderate	Moderate	High
4 - 10%	Low	Moderate	Moderate	High	Very high
11 - 32%	Moderate	Moderate	High	Very high	Very high
> 32%	Moderate	High	V-high	Very high	Very high

Susceptibility to gully and tunnel erosion

Susceptibility to gully and tunnel erosion (Table 26) was assessed by scoring soil characteristics from Table 26 and then rating the scores using Table 27, which were modified from Baxter *et al*. (1997).

Table 26: Susceptibility to gully or tunnel erosion: criteria and scores

Criteria	Description	Score
Slope	< 1%	1
	1 – 3%	2
	4 – 10%	3
	11 – 32%	4
	> 32%	5
Sub-soil dispersibility	E1	5
	E2, E3(3), E3(4)	4
	E3(1), E3(2)	3
	E4, E5	2
	E6, E7, E8	1
Depth to rock/hardpan	> 2.0m	1
	1.6 – 2.0m	2
	1.1 – 1.5m	3
	0.6 – 1.0m	4
	0 – 0.5m	5
Subsoil structure	Apedal, massive	1
	Weak fine < 2 mm	3
	Moderate 2 – 10 mm	2
	Coarse > 10 mm	1
	Moderate fine < 2 mm	4
	Moderate 2 – 10 mm	3
	Coarse > 10 mm	2
	Strong fine < 2 mm	5
	Moderate 2 – 10 mm	3
	Coarse > 10 mm	1
	Apedal, single grained	5
Lithology of substrate	Basalt	1
	Volcanic	2
	Rhyodacite	2
	Granite	4
	Alluvium	3
	Colluvium	5
	Tillite	4
	Ordovician sandstone/mudstone	5
	Silurian sandstone/mudstone	4

Table 27: Rating for susceptibility to gully and tunnel erosion

Class	Total score
1. Very low	6 - 10
2. Low	11 - 13
3. Moderate	14 - 17
4. High	18 - 20
5. Very high	21 - 25

Susceptibility to Landslips

Susceptibility to land slips was assessed using rules designed by Ian Sargeant, a regional soils and landscapes expert, which is detailed in Table 28.

Table 28: Susceptibility to land slips

Soil type	Slope class	Susceptibility rating
Basalt soils	slopes up to 10 % slump-earth flows occasionally occur	Low
	slopes between 10 and 40 % slump-earth flows occur often	Moderate
	slopes greater than 40 % slump-earth flows are common	High
Strzelecki soils	slopes up to 20 % slump-earth flows occasionally occur	Low
	slopes between 20 and 40 % slump-earth flows are common	Moderate
	Slopes greater than 40 % slump-earth flows often occur.	High
All other soils		Low

Susceptibility to wind erosion

Susceptibility to wind erosion was assessed using an expert classification. Soil units comprised of sand dunes or dominated by a sandy topsoil, that were known to be susceptible to wind erosion, were classified as moderate or high susceptibility. The other soil units were classified as low susceptibility.

Several rule tables sourced from the literature were trialled in the region, but either did not produce ‘believable’ outputs or data was not available for all the assessment criteria.

Appendix 5 - Management practice classifications for sheet and rill erosion

Table 29: Grazing improved pastures, high-rainfall mixed dairy and beef, low-rainfall beef and sheep, dryland dairy

Grazing rotation	Pasture composition	Renovation method	Influence on sheet or rill erosion
Graze and spell	Perennial	Direct drill	Beneficial
Graze and spell	Perennial	Cultivation	Weakly negative
Graze and spell	Sown annual	Direct drill	Weakly negative
Graze and spell	Sown annual	Cultivation	Weakly negative
Graze and spell	Annual	Direct drill	Weakly negative
Graze and spell	Annual	Cultivation	Weakly negative
Set stock	Perennial	Direct drill	Weakly negative
Set stock	Perennial	Cultivation	Weakly negative
Set stock	Sown annual	Direct drill	Weakly negative
Set stock	Sown annual	Cultivation	Moderately negative
Set stock	Annual	Direct drill	Moderately negative
Set stock	Annual	Cultivation	Moderately negative

Table 30: Permanent cropping

Establishment	Stubble management	Stubble grazed	Influence on sheet or rill erosion
Direct drill	Burnt	Yes	Strongly negative
Direct drill	Burnt	No	Moderately negative
Direct drill	Removed	Yes	Moderately negative
Direct drill	Removed	No	Weakly negative
Direct drill	Retained	Yes	Moderately negative
Direct drill	Retained	No	Weakly negative
Minimum till	Burnt	Yes	Strongly negative
Minimum till	Burnt	No	Moderately negative
Minimum till	Removed	Yes	Moderately negative
Minimum till	Removed	No	Weakly negative
Minimum till	Retained	Yes	Moderately negative
Minimum till	Retained	No	Weakly negative
Conventional till	Burnt	Yes	Strongly negative
Conventional till	Burnt	No	Strongly negative
Conventional till	Removed	Yes	Strongly negative
Conventional till	Removed	No	Weakly negative
Conventional till	Retained	Yes	Strongly negative
Conventional till	Retained	No	Moderately negative

Table 31: Production forests

Coupe revegetation	Coupe planning	Production roads	Non production roads	Influence on sheet or rill erosion
Yes	No	Yes	No	Moderately negative
Yes	No	No	No	Strongly negative
Yes	Yes	Yes	No	Weakly negative
Yes	Yes	No	No	Moderately negative

Table 32: Timber plantations

Deep ripping	Mounding	Access roading	Weed control	Influence on sheet or rill erosion
Yes	Yes	Yes	Broad acre	Beneficial
Yes	Yes	Yes	Strip	Beneficial
Yes	Yes	Yes	Spots	Beneficial
Yes	Yes	No	Broad acre	Moderately negative
Yes	Yes	No	Strip	Moderately negative
Yes	Yes	No	Spots	Moderately negative
Yes	No	Yes	Broad acre	Moderately negative
Yes	No	Yes	Strip	Moderately negative
Yes	No	Yes	Spots	Moderately negative
Yes	No	No	Broad acre	Moderately negative
Yes	No	No	Strip	Moderately negative
Yes	No	No	Spots	Moderately negative
No	Yes	Yes	Broad acre	Moderately negative
No	Yes	Yes	Strip	Moderately negative
No	Yes	Yes	Spots	Moderately negative
No	Yes	No	Broad acre	Moderately negative
No	Yes	No	Strip	Moderately negative
No	Yes	No	Spots	Moderately negative
No	No	Yes	Broad acre	Moderately negative
No	No	Yes	Strip	Moderately negative
No	No	Yes	Spots	Moderately negative
No	No	No	Broad acre	Moderately negative
No	No	No	Strip	Moderately negative
No	No	No	Spots	Moderately negative

Table 33: Irrigated horticulture

Cultivation method	Irrigation method	Influence on sheet or rill erosion
Up down slope	Solid set sprinkler	Moderately negative
Up down slope	Travelling irrigator	Strongly negative

Table 34: Irrigated dairy

Irrigation method	Grazing rotation	Pasture composition	Renovation method	Influence on sheet or rill erosion
Spray	Graze and spell	Perennial	Direct drill	Beneficial
Spray	Graze and spell	Perennial	Cultivation	Weakly negative
Spray	Graze and spell	Sown annual	Direct drill	Weakly negative
Spray	Graze and spell	Sown annual	Cultivation	Weakly negative
Spray	Graze and spell	Annual	Direct drill	Weakly negative
Spray	Graze and spell	Annual	Cultivation	Weakly negative
Spray	Set stock	Perennial	Direct drill	Weakly negative
Spray	Set stock	Perennial	Cultivation	Weakly negative
Spray	Set stock	Sown annual	Direct drill	Weakly negative
Spray	Set stock	Sown annual	Cultivation	Weakly negative
Spray	Set stock	Annual	Direct drill	Weakly negative
Spray	Set stock	Annual	Cultivation	Weakly negative
Flood	Graze and spell	Perennial	Direct drill	Beneficial
Flood	Graze and spell	Perennial	Cultivation	Weakly negative
Flood	Graze and spell	Sown annual	Direct drill	Weakly negative
Flood	Graze and spell	Sown annual	Cultivation	Weakly negative
Flood	Graze and spell	Annual	Direct drill	Weakly negative
Flood	Graze and spell	Annual	Cultivation	Weakly negative
Flood	Set stock	Perennial	Direct drill	Weakly negative
Flood	Set stock	Perennial	Cultivation	Weakly negative
Flood	Set stock	Sown annual	Direct drill	Weakly negative
Flood	Set stock	Sown annual	Cultivation	Weakly negative
Flood	Set stock	Annual	Direct drill	Weakly negative
Flood	Set stock	Annual	Cultivation	Weakly negative

Table 35: Horticulture

Cultivation method	Crop establishment	Influence on sheet or rill erosion
Up down slope	Direct drill	Weakly negative
Up down slope	Minimum till	Moderately negative
Up down slope	Conventional tillage	Strongly negative

Table 36: Grazing of native vegetation

Grazing management	Influence on sheet or rill erosion
Yes	Beneficial
No	Moderately negative

Table 37: Irrigated improved pastures

Irrigation method	Grazing rotation	Pasture composition	Renovation method	Influence on sheet or rill erosion
Solid set sprinkler	Graze and spell	Perennial	Direct drill	Beneficial
Solid set sprinkler	Graze and spell	Perennial	Cultivation	Weakly negative
Solid set sprinkler	Graze and spell	Sown annual	Direct drill	Weakly negative
Solid set sprinkler	Graze and spell	Sown annual	Cultivation	Weakly negative
Solid set sprinkler	Graze and spell	Annual	Direct drill	Weakly negative
Solid set sprinkler	Graze and spell	Annual	Cultivation	Weakly negative
Solid set sprinkler	Set stock	Perennial	Direct drill	Weakly negative
Solid set sprinkler	Set stock	Perennial	Cultivation	Weakly negative
Solid set sprinkler	Set stock	Sown annual	Direct drill	Weakly negative
Solid set sprinkler	Set stock	Sown annual	Cultivation	Moderately negative
Solid set sprinkler	Set stock	Annual	Direct drill	Moderately negative
Solid set sprinkler	Set stock	Annual	Cultivation	Moderately negative
Travelling irrigator	Graze and spell	Perennial	Direct drill	Weakly negative
Travelling irrigator	Graze and spell	Perennial	Cultivation	Moderately negative
Travelling irrigator	Graze and spell	Sown annual	Direct drill	Weakly negative
Travelling irrigator	Graze and spell	Sown annual	Cultivation	Moderately negative
Travelling irrigator	Graze and spell	Annual	Direct drill	Weakly negative
Travelling irrigator	Graze and spell	Annual	Cultivation	Moderately negative
Travelling irrigator	Set stock	Perennial	Direct drill	Moderately negative
Travelling irrigator	Set stock	Perennial	Cultivation	Moderately negative
Travelling irrigator	Set stock	Sown annual	Direct drill	Moderately negative
Travelling irrigator	Set stock	Sown annual	Cultivation	Strongly negative
Travelling irrigator	Set stock	Annual	Direct drill	Strongly negative
Travelling irrigator	Set stock	Annual	Cultivation	Strongly negative

Table 38: Irrigated permanent cropping

Solid set sprinkler	Crop establishment	Stubble grazed	Stubble management	Influence on sheet or rill erosion
Solid set sprinkler	Direct drill	Yes	Burnt	Strongly negative
Solid set sprinkler	Direct drill	Yes	Removed	Moderately negative
Solid set sprinkler	Direct drill	Yes	Retained	Moderately negative
Solid set sprinkler	Direct drill	No	Burnt	Moderately negative
Solid set sprinkler	Direct drill	No	Removed	Weakly negative
Solid set sprinkler	Direct drill	No	Retained	Weakly negative
Solid set sprinkler	Minimum till	Yes	Burnt	Strongly negative
Solid set sprinkler	Minimum till	Yes	Removed	Moderately negative
Solid set sprinkler	Minimum till	Yes	Retained	Moderately negative
Solid set sprinkler	Minimum till	No	Burnt	Moderately negative
Solid set sprinkler	Minimum till	No	Removed	Weakly negative
Solid set sprinkler	Minimum till	No	Retained	Weakly negative
Solid set sprinkler	Conventional	Yes	Burnt	Strongly negative
Solid set sprinkler	Conventional	Yes	Removed	Strongly negative
Solid set sprinkler	Conventional	Yes	Retained	Strongly negative
Solid set sprinkler	Conventional	No	Burnt	Strongly negative
Solid set sprinkler	Conventional	No	Removed	Moderately negative
Solid set sprinkler	Conventional	No	Retained	Moderately negative
Travelling irrigator	Direct drill	Yes	Burnt	Strongly negative
Travelling irrigator	Direct drill	Yes	Removed	Strongly negative
Travelling irrigator	Direct drill	Yes	Retained	Strongly negative
Travelling irrigator	Direct drill	No	Burnt	Strongly negative
Travelling irrigator	Direct drill	No	Removed	Moderately negative
Travelling irrigator	Direct drill	No	Retained	Moderately negative
Travelling irrigator	Minimum till	Yes	Burnt	Strongly negative
Travelling irrigator	Minimum till	Yes	Removed	Strongly negative
Travelling irrigator	Minimum till	Yes	Retained	Strongly negative
Travelling irrigator	Minimum till	No	Burnt	Strongly negative
Travelling irrigator	Minimum till	No	Removed	Moderately negative
Travelling irrigator	Minimum till	No	Retained	Moderately negative
Travelling irrigator	Conventional	Yes	Burnt	Strongly negative
Travelling irrigator	Conventional	Yes	Removed	Strongly negative
Travelling irrigator	Conventional	Yes	Retained	Strongly negative
Travelling irrigator	Conventional	No	Burnt	Strongly negative
Travelling irrigator	Conventional	No	Removed	Strongly negative
Travelling irrigator	Conventional	No	Retained	Strongly negative

Appendix 6 - Management practice classifications for gully and tunnel erosion

Table 39: Permanent cropping

Establishment	Influence on gully and tunnel erosion
Direct drill	Weakly negative
Minimum till	Weakly negative
Conventional till	Moderately negative

Table 40: Grazing native vegetation

Grazing management	Influence on gully and tunnel erosion
Yes	Beneficial
No	Moderately negative

Table 41: Hardwood plantations and softwood plantations

Deep ripping	Mounding	Influence on gully and tunnel erosion
Comply	Yes	Beneficial
Comply	No	Moderately negative
Not comply	Yes	Moderately negative
Not comply	No	Moderately negative

Table 42: Horticulture and irrigated horticulture

Cultivation	Influence on gully and tunnel erosion
Up down slope	Moderately negative

Table 43: Irrigated crop/pasture rotation, irrigated permanent cropping

Crop establishment	Influence on gully and tunnel erosion
Direct drill	Weakly negative
Minimum till	Weakly negative
Conventional till	Moderately negative

Table 44: Production forests

Revegetation	Influence on gully and tunnel erosion
Yes	Beneficial
No	Strongly negative

Table 45: Dryland dairying and irrigated dairying

Headworks	Fencing and revegetation	Downstream riparian works	Influence on gully and tunnel erosion
Yes	Yes	Yes	Beneficial
Yes	Yes	No	Weakly negative
Yes	No	Yes	Moderately negative
Yes	No	No	Moderately negative
No	Yes	Yes	Weakly negative
No	Yes	No	Moderately negative
No	No	Yes	Moderately negative
No	No	No	Strongly negative

Table 46: Irrigated improved fertilised pastures

Fencing and revegetation	Earthworks	Drainage	Headworks	Influence on gully and tunnel erosion
Yes	Yes	Yes	Yes	Beneficial
Yes	Yes	Yes	No	Weakly negative
Yes	Yes	No	Yes	Weakly negative
Yes	Yes	No	No	Moderately negative
Yes	No	Yes	Yes	Weakly negative
Yes	No	Yes	No	Moderately negative
Yes	No	No	Yes	Moderately negative
Yes	No	No	No	Strongly negative
No	Yes	Yes	Yes	Beneficial
No	Yes	Yes	No	Weakly negative
No	Yes	No	Yes	Weakly negative
No	Yes	No	No	Moderately negative
No	No	Yes	Yes	Weakly negative
No	No	Yes	No	Moderately negative
No	No	No	Yes	Moderately negative
No	No	No	No	Strongly negative

Table 47: High rainfall mixed dairy/beef, low rainfall mixed sheep/beef

Fencing and revegetation	Earthworks	Drainage	Headworks	Influence on gully and tunnel erosion
Yes	Yes	Yes	Yes	Beneficial
Yes	Yes	Yes	No	Weakly negative
Yes	Yes	No	Yes	Weakly negative
Yes	Yes	No	No	Moderately negative
Yes	No	Yes	Yes	Weakly negative
Yes	No	Yes	No	Moderately negative
Yes	No	No	Yes	Moderately negative
Yes	No	No	No	Strongly negative
No	Yes	Yes	Yes	Beneficial
No	Yes	Yes	No	Weakly negative
No	Yes	No	Yes	Weakly negative
No	Yes	No	No	Moderately negative
No	No	Yes	Yes	Weakly negative
No	No	Yes	No	Moderately negative
No	No	No	Yes	Strongly negative
No	No	No	No	Strongly negative

Appendix 7 - Management practice classifications for wind erosion

Table 48: Permanent cropping, horticulture, irrigated horticulture, irrigated crop/pasture rotation, irrigated permanent cropping

Establishment	Stubble management	Stubble grazed	Influence on wind erosion
Direct drill	Burnt	Yes	Strongly negative
Direct drill	Burnt	No	Moderately negative
Direct drill	Removed	Yes	Weakly negative
Direct drill	Removed	No	Weakly negative
Direct drill	Retained	Yes	Weakly negative
Direct drill	Retained	No	Beneficial
Minimum till	Burnt	Yes	Strongly negative
Minimum till	Burnt	No	Moderately negative
Minimum till	Removed	Yes	Weakly negative
Minimum till	Removed	No	Weakly negative
Minimum till	Retained	Yes	Weakly negative
Minimum till	Retained	No	Beneficial
Conventional till	Burnt	Yes	Strongly negative
Conventional till	Burnt	No	Strongly negative
Conventional till	Removed	Yes	Strongly negative
Conventional till	Removed	No	Moderately negative
Conventional till	Retained	Yes	Weakly negative
Conventional till	Retained	No	Weakly negative

Table 49: Grazing of native vegetation

Grazing management	Influence on wind erosion
Yes	Beneficial
No	Weakly negative

Table 50: Timber plantations

Weed control	Influence on wind erosion
Broadacre	Strongly negative
Strips	Beneficial
Spot sites	Beneficial

Table 51: Horticulture, irrigated horticulture, irrigated crop/pasture rotation, irrigated permanent cropping

Crop establishment	Influence on gully and tunnel erosion
Direct drill	Weakly negative
Minimum till	Weakly negative
Conventional till	Moderately negative

Table 52: Grazing improved pastures, high rainfall mixed dairy/beef, low rainfall beef/sheep, dryland dairy

Grazing rotation	Pasture composition	Renovation method	Influence on sheet or rill erosion
Graze and spell	Perennial	Direct drill	Beneficial
Graze and spell	Perennial	Cultivation	Weakly negative
Graze and spell	Sown annual	Direct drill	Moderately negative
Graze and spell	Sown annual	Cultivation	Moderately negative
Graze and spell	Annual	Direct drill	Moderately negative
Graze and spell	Annual	Cultivation	Moderately negative
Set stock	Perennial	Direct drill	Weakly negative
Set stock	Perennial	Cultivation	Weakly negative
Set stock	Sown annual	Direct drill	Moderately negative
Set stock	Sown annual	Cultivation	Strongly negative
Set stock	Annual	Direct drill	Moderately negative
Set stock	Annual	Cultivation	Strongly negative

Table 53: Production forests

Revegetation	Influence on gully and tunnel erosion
Yes	Beneficial
No	Strongly negative

Appendix 8 - Summary of Sub Catchment Groupings into Management Areas.

Table 54: Areas of land rated as high or very high erosion risk, for erosion process, sub-catchment and management unit

Sub catchment name	Gully / tunnel high - very high (ha)	Landslip high - very high (ha)	Sheet / Rill high - very high (ha)	Wind high - very high (ha)	Total high / very high (ha)
Group 1. West Strzelecki					
Tarwin River (west branch)	28300	410	1240	0	29950
Upper Powlett River	16000	50	300	90	16440
Tarwin River (east branch)	10900	590	60	0	11550
Total	55200	1050	1600	90	57940
Group 2. North Strzelecki					
Morwell River and Traralgon Creek	15600	10	1750	0	17360
Moe River / Narracan Creek	7900	0	3090	0	10990
Total	23500	10	4840	0	28350
Group3. Corner Inlet					
Albert River	6800	440	660	0	7900
Franklin River	6300	320	120	0	6740
Stockyard Creek	5700	0	390	0	6090
Upper Agnes River	2300	210	90	0	2600
Lower Agnes River	2000	170	50	0	2220
Nine Mile Creek	1700	80	180	20	1980
Total	24800	1220	1490	20	27530
Group 4. Southern Highlands - West					
Lower La Trobe River	4200	0	1930	0	6130
Upper La Trobe River	4400	0	580	0	4980
Total	8600	0	2510	0	11110
Group 5. Southern Highlands - East					
Middle Macalister River	3700	50	1530	0	5280
Upper Macalister River	1200	0	700	0	1900
Lower Macalister River	1200	0	0	0	1200
Upper Thomson River	700	0	930	0	1630
Lower Thomson River	510	0	50	0	560
Lower Avon River	1500	0	20	0	1520
Upper Avon River	800	0	60	0	860
Perry River	1200	0	0	0	1200
Total	10810	50	3290	0	14150

Sub catchment name	Gully / tunnel high - very high (ha)	Landslip high - very high (ha)	Sheet / Rill high - very high (ha)	Wind high - very high (ha)	Total high / very high (ha)
Group 6. Giffard					
Merriman Creek	1700	270	0	0	1970
Middle Tarra River	2200	940	50	0	3190
Upper Tarra River	1500	320	50	0	1870
Bruthen Creek and Giffard plain	1200	10	10	0	1220
Total	6600	1540	110	0	8250
Group 7. Other					
Waratah Bay	2100	0	120	10	2230
Lower Tarwin River	3200	0	30	0	3230
Kilcunda to Griffith Point	170	0	0	0	170
Lake Wellington	0	0	30	0	30
Screw Creek, Pound Creek	0	0	0	30	30
Corner Inlet and Nooramunga	N	N	N	N	N
Lower Tarra River	0	0	0	0	0
Wilson's Promontory	N	N	N	N	N
Lower Powlett	0	0	0	0	0
Tom Creek	0	0	0	0	0
Total	5440	0	180	0	5690

Appendix 9 - Soils of West Gippsland

West Gippsland has a great diversity of soil types that reflect differences in parent material, topography, climate, biomass and time. The following provides a summary of the major soils in West Gippsland and is sourced from soil mapping undertaken by Ian Sargeant and Mark Imhof (http://www.dpi.vic.gov.au/dpi/vro/wgregn.nsf/pages/wg_soil).

This appendix includes maps depicting the distribution of the major soil orders, based on the Australian Soil Classification, in the West Gippsland region. More detailed soil/landform mapping (at 1:100 000 scale) (Isbell 1995) is available on the Victorian Resources Online website at:
http://www.dpi.vic.gov.au/dpi/vro/wgregn.nsf/pages/wg_soil_detailed

A Brief Description of the Major Soil Groups in West Gippsland

In the West Gippsland Region the major Soil Orders have been grouped according to their geology:

- Palaeozoic Sediments
- Cretaceous Sediments
- Tertiary Volcanics
- Tertiary Sediments
- Quaternary Sediments

Palaeozoic sediments

Soils developed on rolling to steep hills on Palaeozoic (Devonian and Silurian) sediments are generally Yellow and Brown Kurosols as well as Tenosols. They are usually strongly acid throughout and occur on steep slopes with weathered parent material usually encountered above one metre depth. These areas are mainly forested foothills and slopes of the highlands. Much of these areas are publicly owned and in water catchment areas. Some parts are cleared for pasture.

Cretaceous sediments

The Strzelecki's are a range of low hills formed by uplift of Cretaceous sediments. These uplands are strongly dissected with moderate (10-32%) to steep (32-56%) slopes. The soils developed on these hills are typically Brown and Grey Dermosols and are characterised by a lack of strong texture contrast. They are strongly acid throughout the profile. Weathered bedrock usually occurs before one metre depth. On the steeper slopes, less well developed soils (Tenosols) can occur. As the erosion rates are high on the steeply sloping land, the Strzelecki soils are considered to be relatively young. This landscape originally supported a dense forest. Tunnel erosion is a hazard associated with vegetation clearing on the steep slopes. Grazing (beef and dairy), hardwood and pine forestry are the dominant land uses associated with these soils, although some cropping occurs on less steep land. Parts of an earlier land surface remain on the down-throw sides of the Bass Fault, particularly on the Heath Hill Block. The slopes here are more gentle (3-10%) and the soils on Cretaceous sediments are older and have marked texture contrast between the surface and subsoil. These Kurosols are generally strongly acid throughout and are less fertile than the Dermosols – originally supporting a more open forest.

Figure 37: Cretaceous sediments in road cutting

Tertiary volcanics

Deep red friable soils have formed on Tertiary basalts (commonly called *Older Volcanic*s) and are associated with rolling hills in the Warragul and Thorpdale regions where dairying and horticulture (mainly potato cropping) are major industries. These Red Ferrosols are generally strongly acidic throughout, lack strong texture contrast and are high in free iron oxide.

Tertiary sediments

A diversity of soils has developed on Tertiary sedimentary deposits. During the late Tertiary there was significant movement along structures that had been active in the early Tertiary. It was also at this time that the Eastern Highlands reached their maximum height. Accelerated erosion of the highlands occurred and there was extensive sediment deposition, often covering the Cretaceous sediments.

The Tertiary sediments north of the Strzelecki's were deposited as fans and aprons of gravel, sand and clay. In the western part of the region (Warragul district) the soils are typically Yellow and Grey Dermosols. They generally lack strong texture contrast between the surface and subsoil horizons and are acidic throughout the profile. Below the clayey subsoil, the underlying material is quite variable and ranges from sandy clays to cemented sands and gravels. In the eastern part of the region (lower rainfall zone), a stronger texture contrast is evident and the subsoils are often sodic. These soils are commonly Brown and Yellow Sodosols. Soils in the Tarwin Sunklands in southern Gippsland are also more likely to be texture contrast soils. In some areas a zone of variably cemented iron and organic matter compounds, known as 'coffee rock', may also occur below the bleached subsurface horizon at about 40-50 cm. These are known as Podosols.

Quaternary sediments

Soils developed on Pleistocene and recent sediments are usually associated with alluvial plains and valley floors and these occur throughout the region. The most extensive alluvial plains deposited during the Pleistocene Period occur east of Traralgon, north of the La Trobe River and around Yarram. The soils on the oldest alluvial plains are mostly Brown and Yellow Sodosols. These soils are characterised by a strong texture contrast between the surface and subsoil horizons and the subsoil is sodic. Remnants of former stream courses, called prior streams, are still obvious on the youngest Pleistocene alluvial plains around Maffra and Sale. The soils here may or may not have strong texture contrast and are generally Red and Brown Dermosols, Sodosols and Chromosols. The soils are mostly irrigated. Black Dermosols have developed on Recent floodplain sediments in the Maffra region. They lack strong texture contrast and are well structured and permeable. Many of the soils in the valley floors in the Warragul region are Hydrosols which tend to be saturated for a number of months in most years. Along parts of the coastline, siliceous sands have been deposited by wind during the Holocene period. Typically, Podosols have developed in these areas. These sandy soils are strongly acidic and have accumulations of 'coffee rock' in the subsoil.

An overview of the major soil orders represented in West Gippsland:

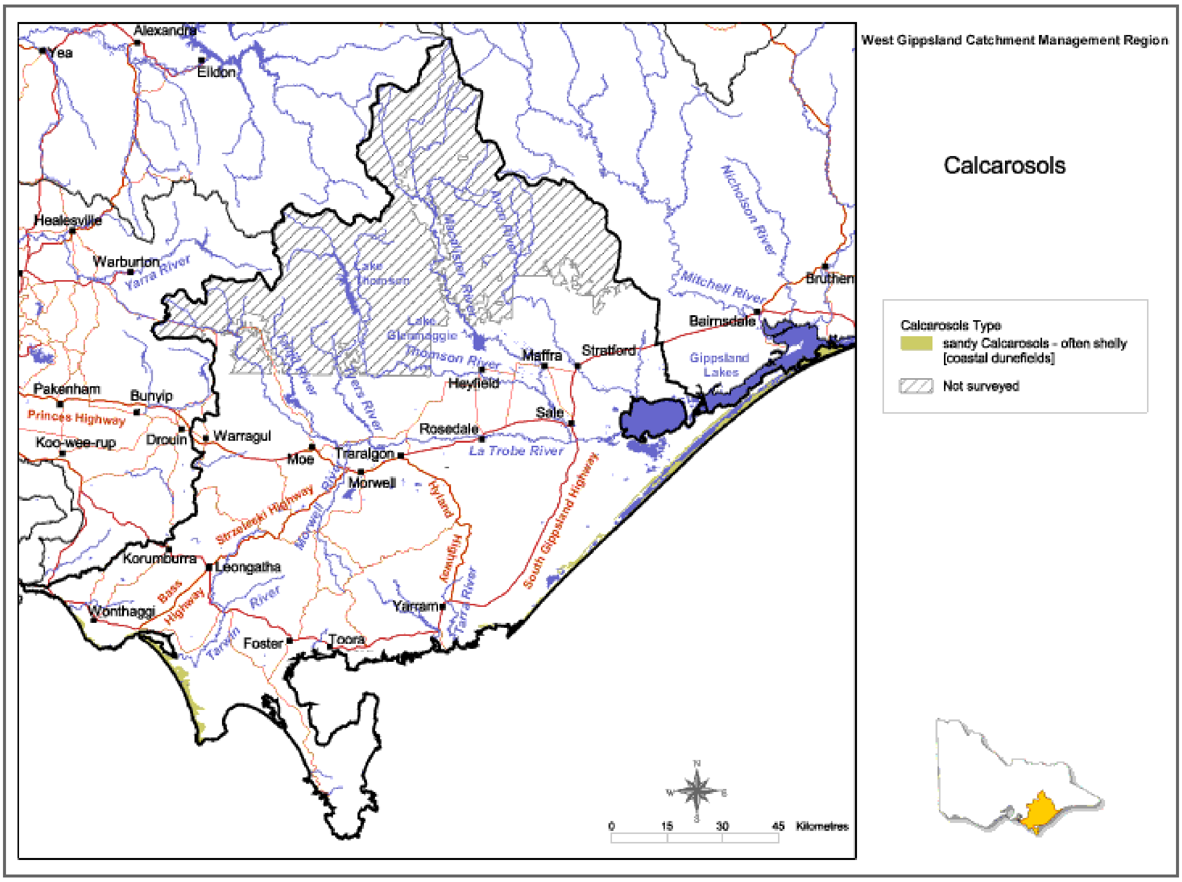
The overview maps of soils in the West Gippsland region, included in this section have been developed from more detailed regional soil/landform mapping (Sargeant and Imhof) as available on the Victorian Resources Online website. They show areas where soil classes are most likely to occur within the region and should only be used as a general indication of their distribution. Note that other soil types may also occur within these mapped areas. Also, some areas (e.g. forested areas in the north of the region) have been largely unsurveyed and the distribution of soil types is not well known.

Calcarosols

A Calcarosol's soil profile is calcareous throughout and generally has a negligible or gradual increase in clay content with depth.

Calcarosols only occur on coastal dunefields within the West Gippsland region. They are sandy throughout and often contain shell fragments.

Figure 38: Distribution of calcarosols soils in West Gippsland



Chromosols

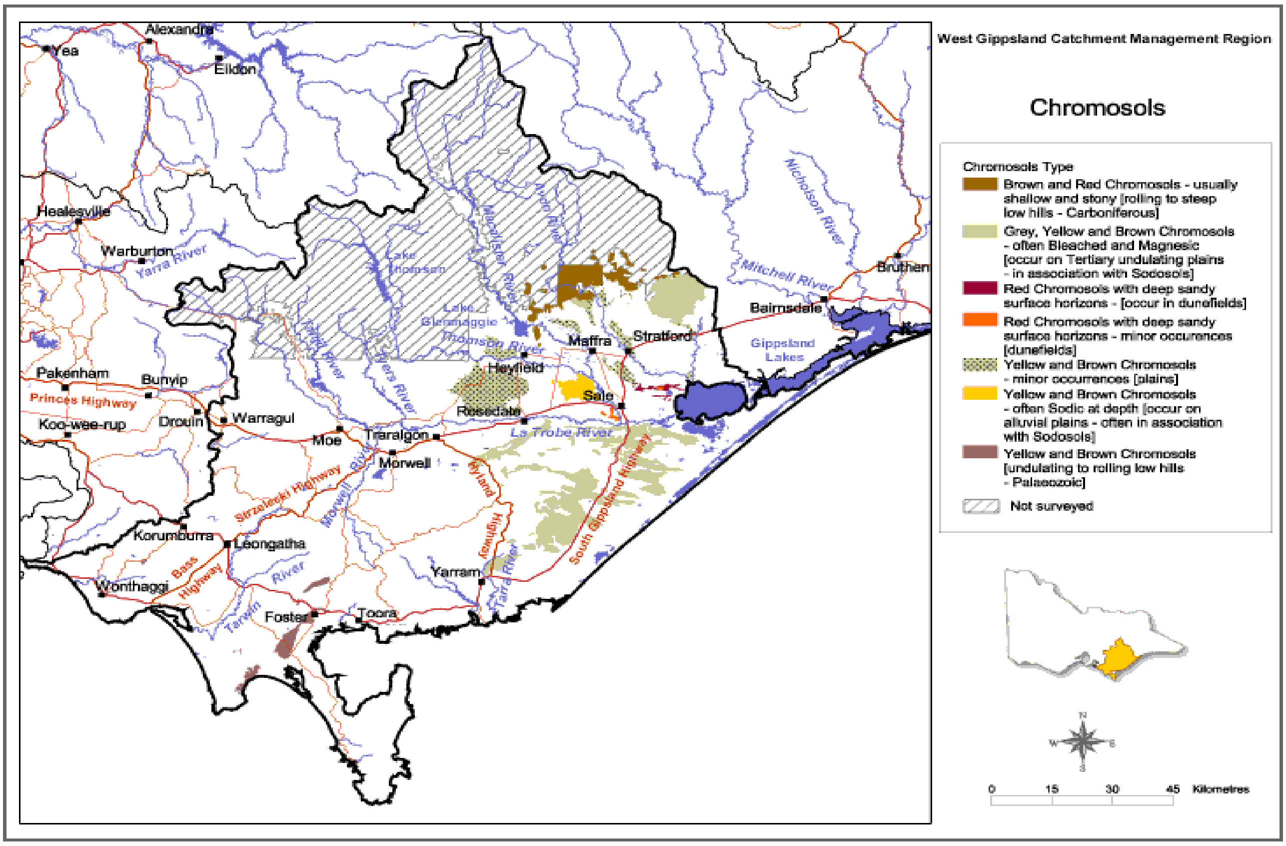


Figure 39: Distribution of chromosols in West Gippsland

Chromosols (Australian Soil Classification) have a strong texture contrast between the loamy surface (A) horizons and the clayey upper subsoil (B2) horizon. The subsoil is also not strongly acid i.e. pH of greater than 5.4 (water) and not sodic.

Figure 40: Brown Chromosol near Nambrok

Chromosols are not widespread in the agricultural areas of West Gippsland. They are most common in the western part of the region and are often associated with Sodosols.

Dermosols

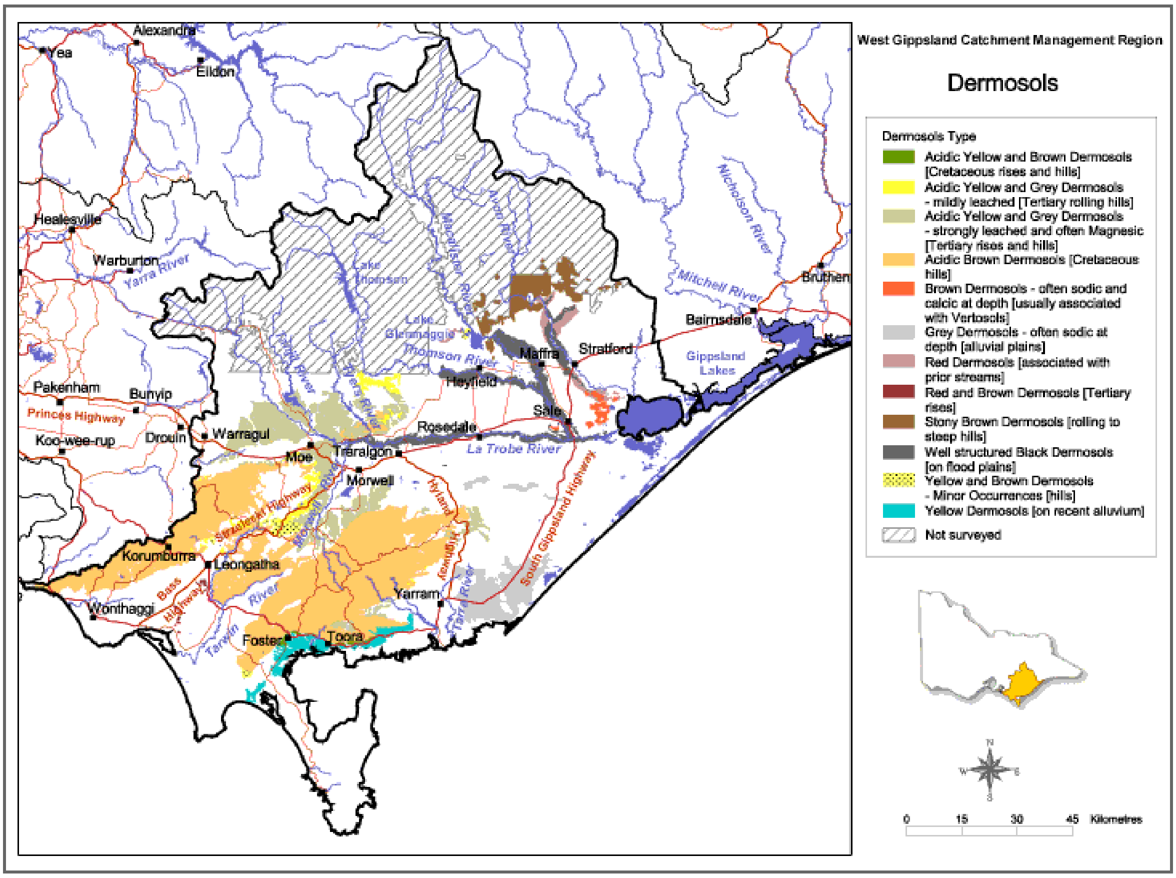


Figure 41: Distribution of dermosols in West Gippsland

Dermosols (Australian Soil Classification) are soils lacking strong texture contrast between surface (A) horizons and the upper subsoil (B21) horizon.

Figure 42: Brown Dermosol in Strzelecki hills near Fish Creek

Acidic Brown and Grey Dermosols have developed on the strongly dissected South Gippsland hills. They are characterised by a lack of strong texture contrast, and are strongly acid throughout the profile. Weathering Cretaceous sandstones and mudstones usually occurs before 1.5 metre depth.

North of the South Gippsland uplands are low hills and undulating rises comprising Tertiary sediments which were deposited as fans and aprons of gravel, sand and clay derived from the Central Highlands. The soils on these Tertiary hills and rises are typically Yellow and Grey Dermosols. They are generally strongly leached, lack strong texture contrast between the surface and subsoil horizons and are acidic throughout the profile. Below the clayey subsoil, the underlying material is quite variable and ranges from sandy clays to cemented sands and gravels

Figure 43: Grey Dermosol near Willow Grove

Figure 44: Black Dermosol near Cowwarr

Black Dermosols have developed on Recent sediments associated with the Thomson, Macalister and Avon floodplains. They lack strong texture contrast and are very well structured and permeable. These can be excellent cropping soils.

Ferrosols

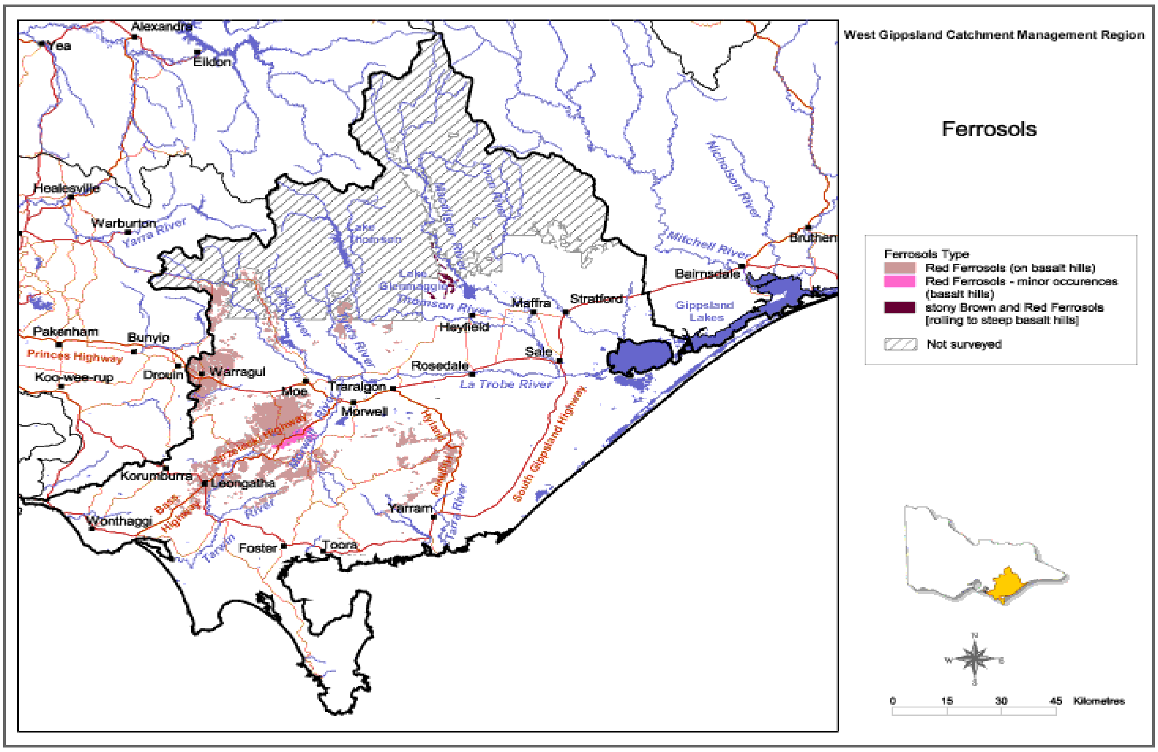


Figure 45: Distribution of ferrosols in West Gippsland

Ferrosols (Australian Soil Classification) are soils lacking strong texture contrast between surface (A) horizons and the upper subsoil (B21) horizon. These soils are also characterised by relatively high levels of free iron oxide (i.e. free iron oxide content greater than 5%). Several Suborders can be separated, based on the colour of the major part of the subsoil (e.g. into Red, Brown, Yellow, Grey and Black groups). Mainly Red Ferrosols have been described in Gippsland.

Figure 46: . Profile of Red Ferrosol near Warragul

Ferrosols are common in the central parts of the West Gippsland region. They are deep red friable soils that have formed on Tertiary basalts (commonly called Older Volcanics) and are associated with rolling hills in the Warragul and Thorpdale regions where dairying and horticulture (mainly potato cropping) occur. These Red Ferrosols are generally strongly acidic throughout, lack strong texture contrast and are high in free iron oxide.

Minor occurrences of stony Brown and Red Ferrosols occur on rolling to steep basalt hills west of Lake Glenmaggie.

Hydrosols

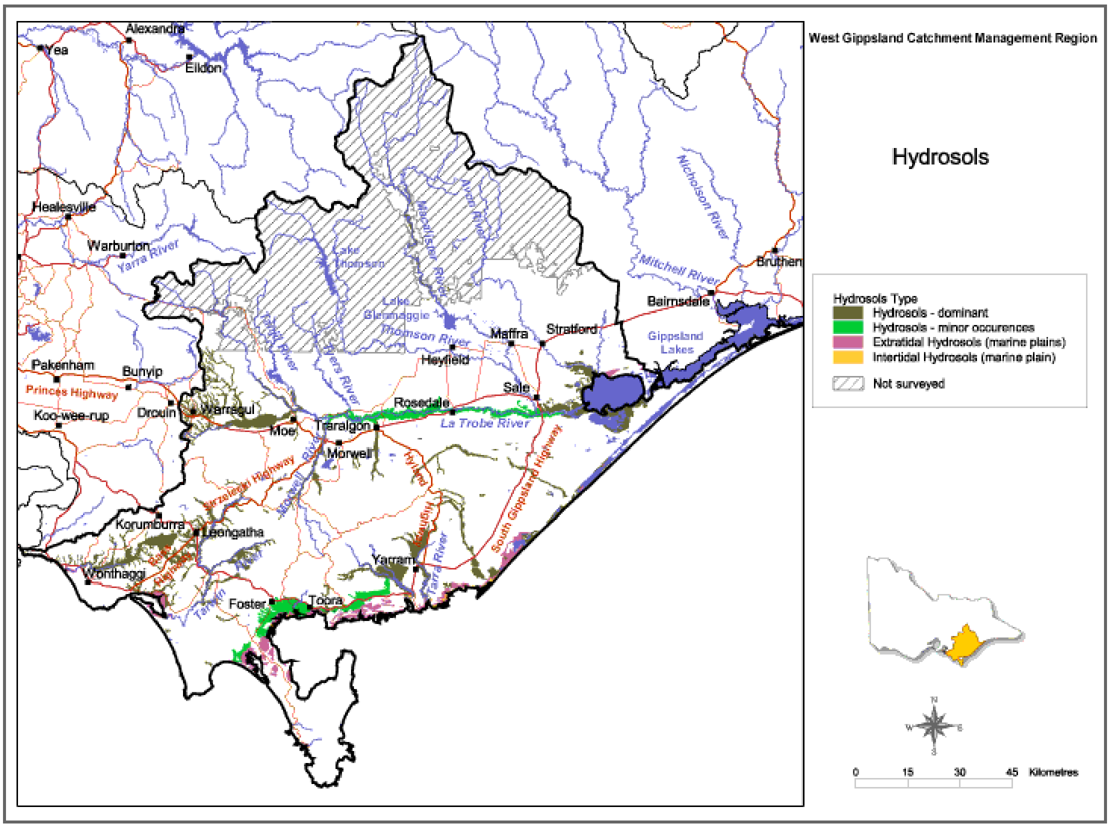


Figure 47: Distribution of Hydrosois in West Gippsland

Hydrosols (Australian Soil Classification) cover a wide range of soils that are seasonally or permanently saturated (for at least 2-3 months per year).

Many of the soils in the valley floors across the region are Hydrosols. These tend to be Dermosolic in nature (in that apart from their seasonal saturation, fulfil the requirements of a Dermosol). Extratidal and Intertidal Hydrosols also occur along the coast in the southern parts of the region.

Figure 48: Figure Dermsolic hydrosol Warragul

Kandosols

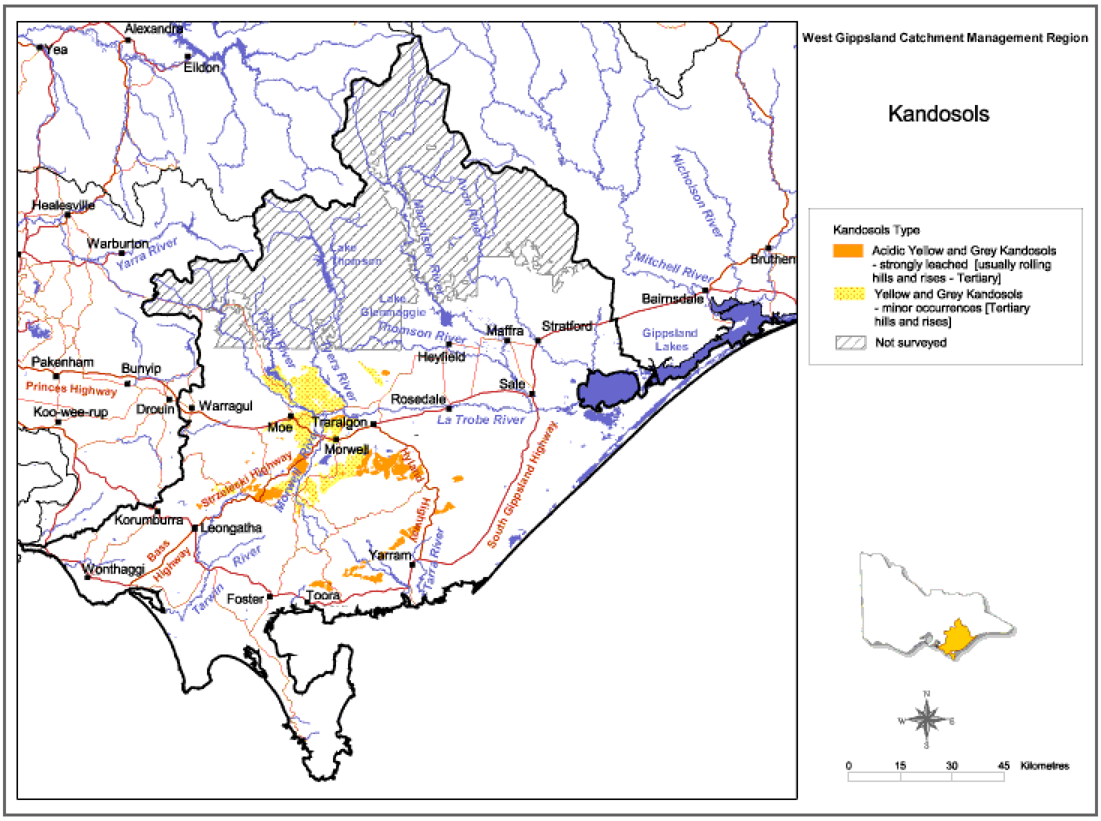


Figure 49: Distribution of kandosols in West Gippsland

Kandosols lack strong texture contrast between the surface (A) horizons and subsoil (B) horizons. They are also characterised by having massive (i.e. structureless) or only very weakly structured subsoils that are often 'earthy' in appearance. Some part of the weakly developed B horizon must have a clay content of more than 15%. Kandosols are usually well drained, permeable soils and often have low fertility.

Kandosols are not common in West Gippsland. These strongly leached soils are most likely to occur on Tertiary hills and rises to the south-west and south-east of Morwell. These represent relatively old landscapes.

Kurosols

Kurosols have a strong texture contrast between loamy surface (A) horizons and clayey subsurface (B) horizons. The subsoils are strongly acid (i.e. pH 5.4 or lower). Kurosols can be separated on the basis of the colour of the upper 20 cm of the subsoil into Red, Brown, Yellow, Grey and Black groups. Further separation is largely made on the basis of additional soil chemical properties.

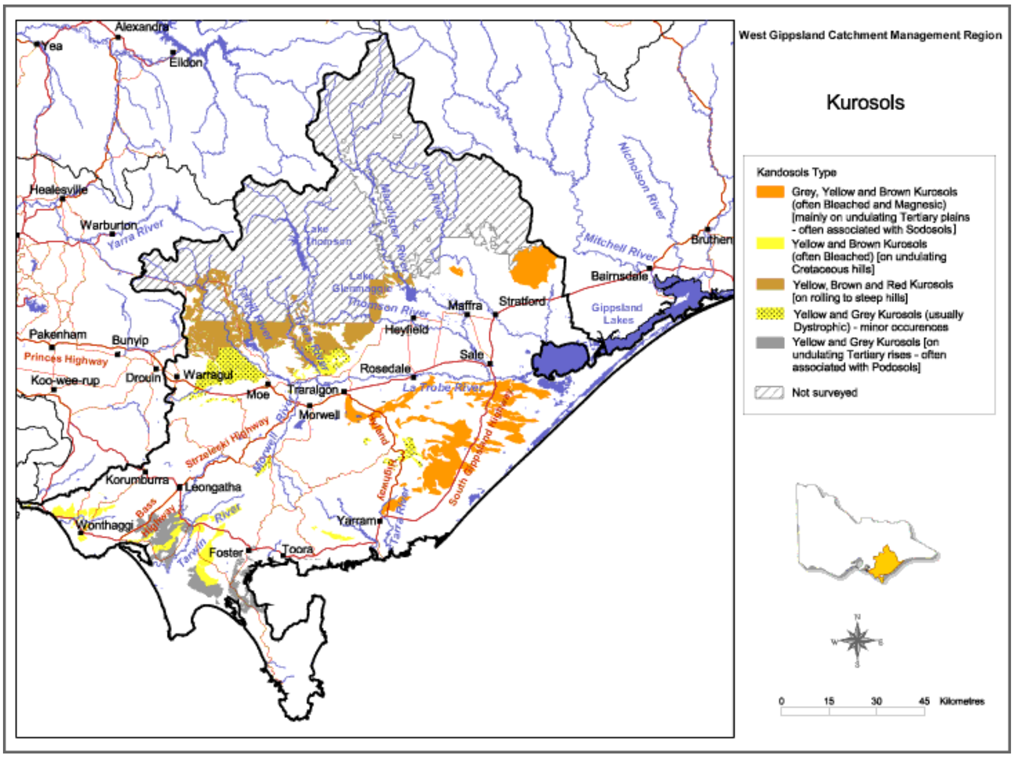


Figure 50: Distribution of Kurosois in West Gippsland

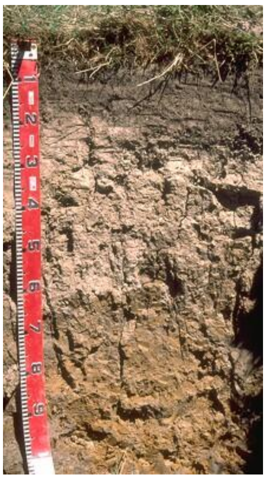


Figure 51: Brown Kurosol near Fish Creek

Kurosols generally occur in higher rainfall parts of the region and have largely developed on Palaeozoic sediments with some on the Cretaceous and Tertiary sediments.

Podosols

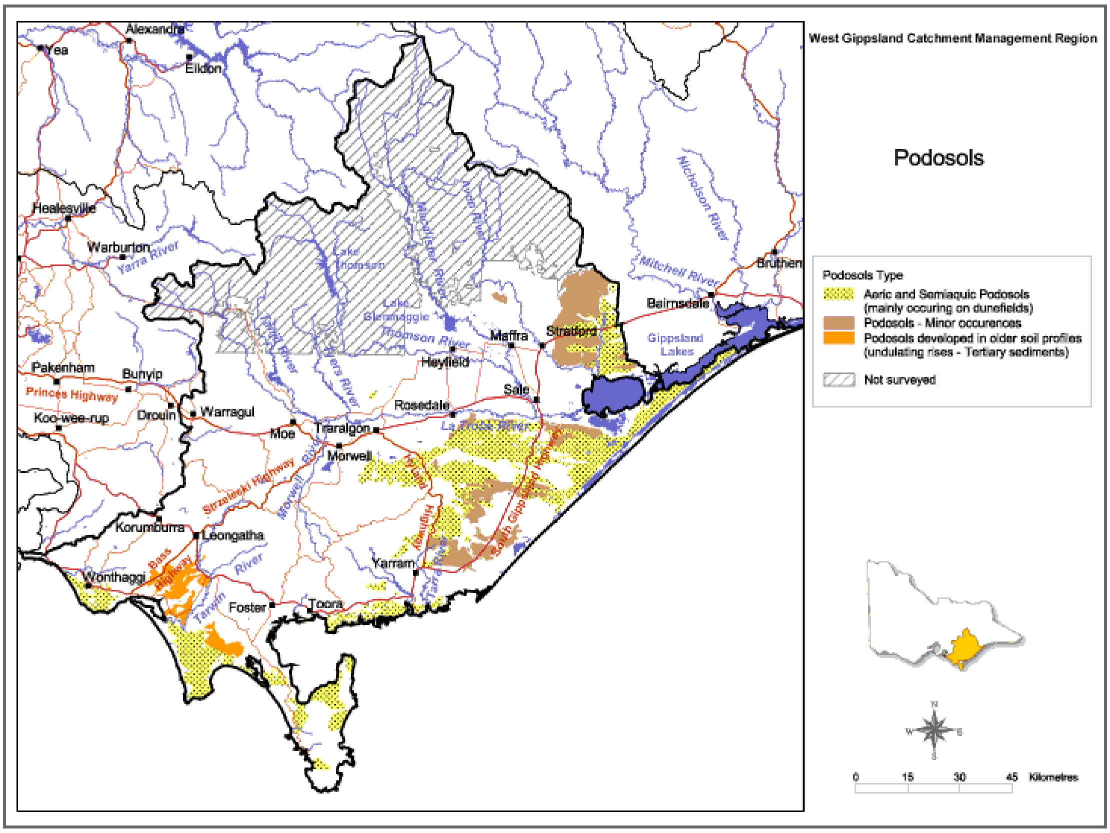


Figure 52: Distribution of Podosois in West Gippsland

Podosols are mainly sandy soils with accumulations of organic materials and aluminium (with or without iron compounds) in subsoil horizons.

Along parts of the coastline, siliceous sands have been deposited by wind during the Holocene period. Typically, Aeric Podosols have developed in these dunes. These deep sandy soils are strongly acidic and have accumulations of 'coffee rock' in the subsoil.

Figure 53: Aeric podosol at Bald Hills

South of Leongatha, Podosols occur (along with other soils) on Tertiary and early Pleistocene sediments. These have been formed within the surface horizons of older soil profiles (e.g. Kurosols).

Figure 54: Semiaquic Podosol formed within an earlier Grey Kurosol near Inverloch

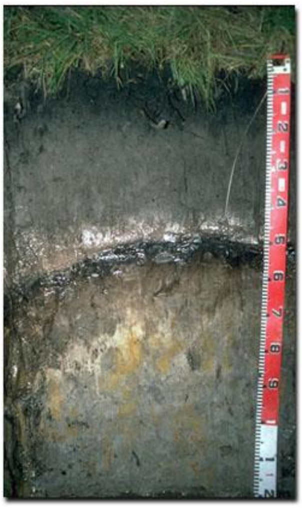


Figure 55: Aquic Podosol at Bald Hills Reserve

Podosols occur on French Island, around Nyora and on inland dunefields and sand plains across southern and eastern parts of the region. Aeric Podosols generally occur on well drained dunes and Aquic Podosols generally occur in poorly drained lower-lying areas.

Rudosols

Rudosols are soils with negligible (rudimentary) pedological development, apart from minimal development of a surface (A) horizon. They are often shallow soils when developed on rocky hills. Deep Rudosols occur on geologically recent sand dunes where there has been insufficient time for a soil profile to develop.

Rudosols have developed on steep rocky areas at Wilsons Promontory and on steep hills north of Maffra. They also occur on sand dunes in southern parts of the region.

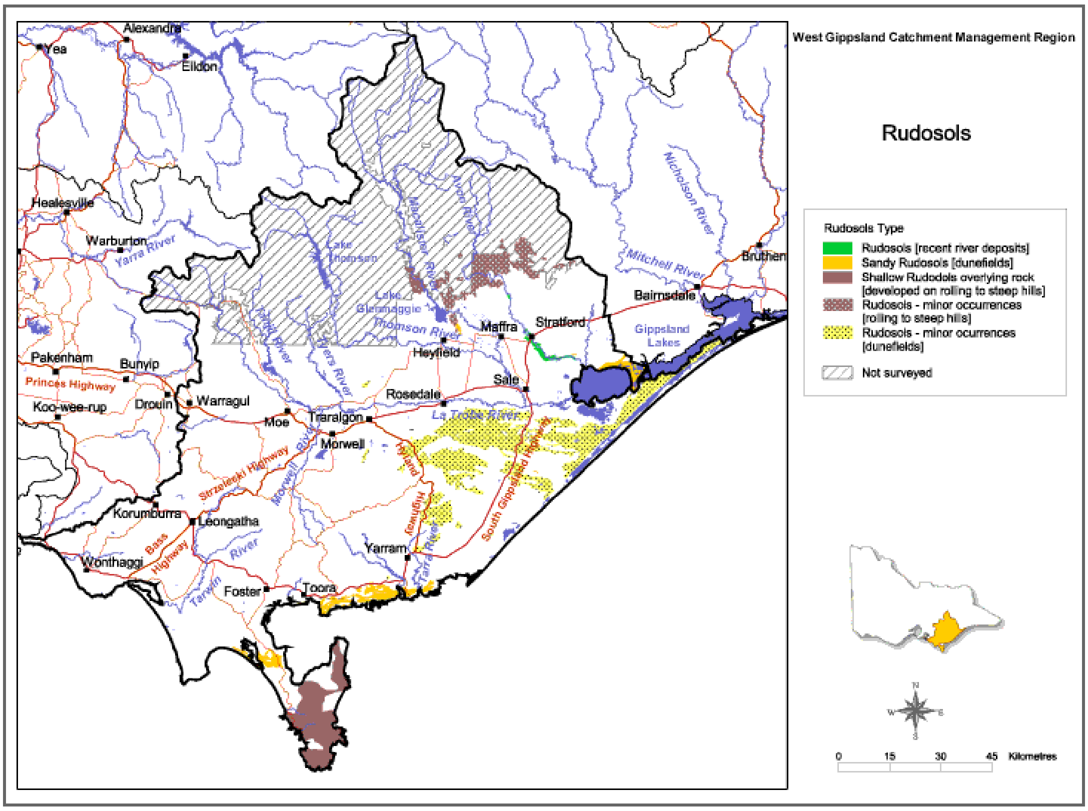


Figure 56: Distribution of rudosols in West Gippsland

Sodosols

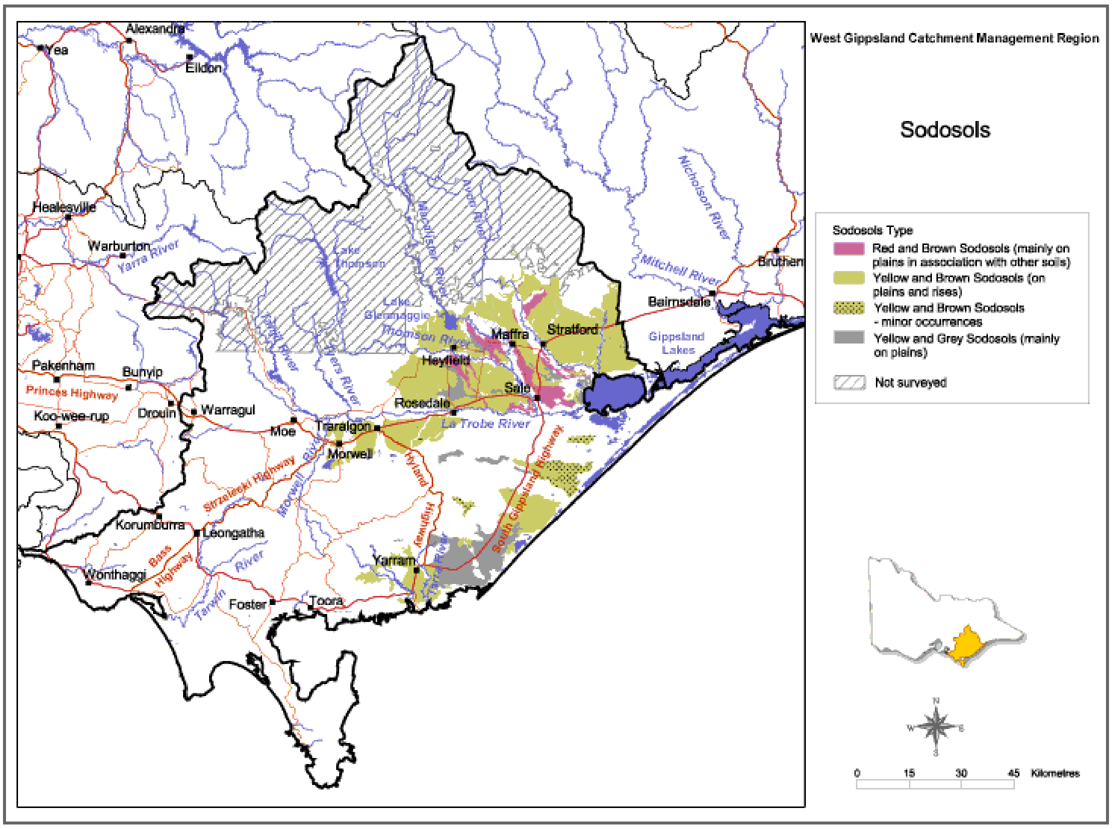


Figure 57: Distribution of sodosols in West Gippsland

Sodosols (Australian Soil Classification) have a strong texture contrast between loamy surface (A) horizons and clayey subsurface (B) horizons. The subsoils are sodic (i.e. exchangeable sodium percentage is 6 or greater) and not strongly acid (i.e. pH 5.5 or lower).

Sodosols can be separated on the basis of the colour of the upper 20 cm of the subsoil into Red, Brown, Yellow, Grey and Black groups. Further separations are made largely on the basis of the soil's chemical characteristics.

Sodosols are most common in the eastern (lower rainfall zone) part of the region. They occur on Tertiary sediments and on the extensive alluvial plains and river terraces deposited during the Pleistocene Period - east of Traralgon, north and south of the La Trobe River and around Yarram. The soils on the oldest alluvial plains are mostly Brown and Yellow Sodosols.

Figure 58: Yellow Sodosol that occurs on older terraces near Briagolong

Tenosols

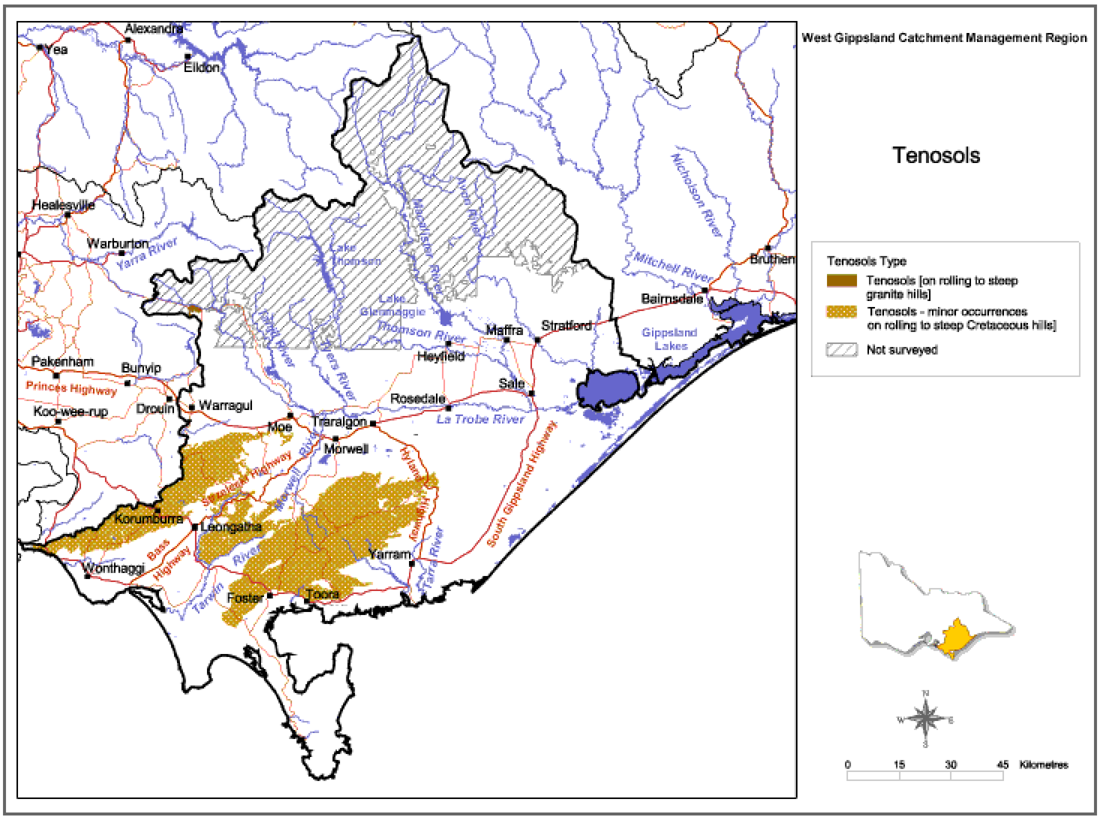


Figure 59: Distribution of Tenosols in West Gippsland

Tenosols (Australian Soil Classification) are characterised by weakly developed soil profiles, which are often shallow.

Figure 60: Shallow Tenosol in Strzelecki's near Bass Hill

The main Tenosol group recognised in the West Gippsland region are Orthic Tenosols. These soils are of minor occurrence in the region and can be found on the steeper and drier north to north-westerly facing slopes of the Strzelecki ranges. These soils may merge into Kandosols as the clay content can be slightly higher than specified as the upper limit for Tenosols (i.e. 15%). Tenosols can also occur in hilly granitic terrain, and on sandplains (in association with Podosols).

Vertosols

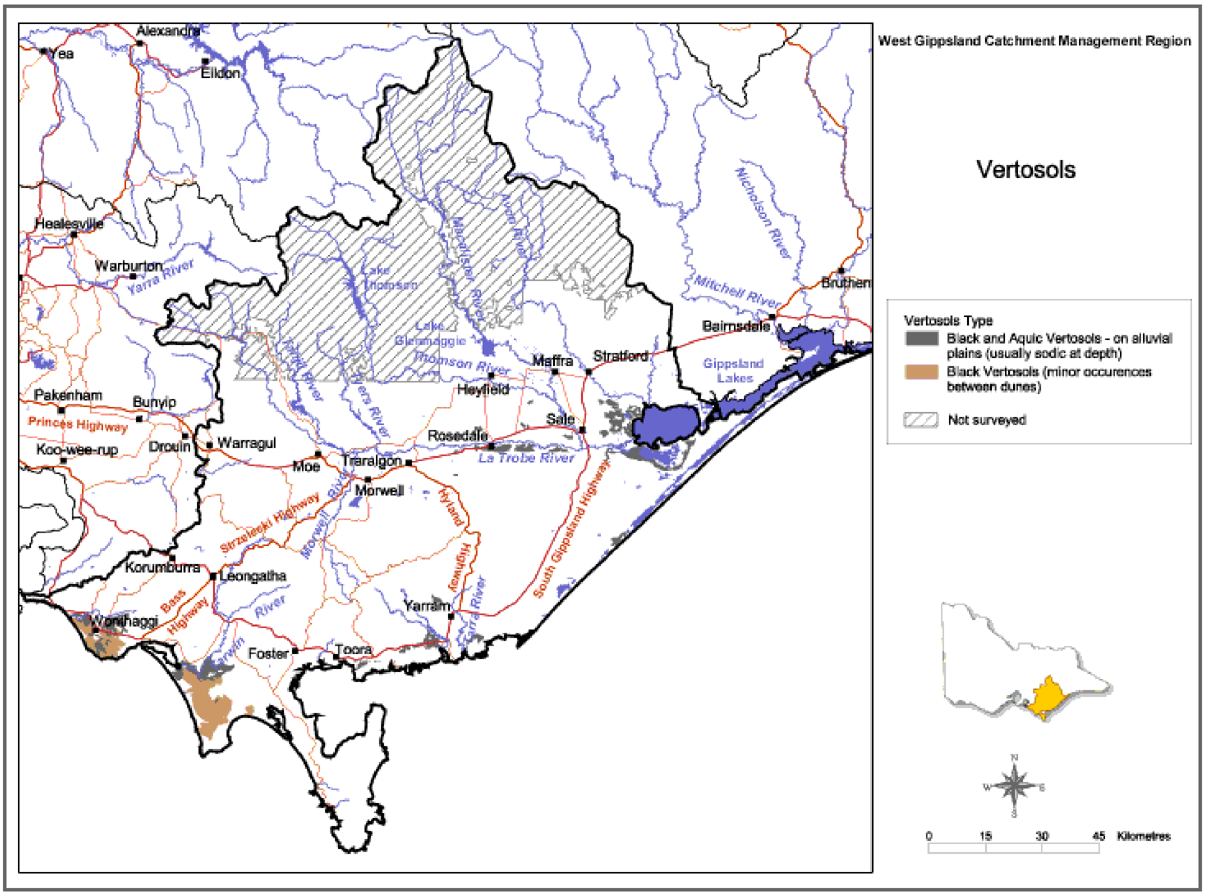


Figure 61: Distribution of Vertosols in West Gippsland

Vertosols (Australian Soil Classification) are clay soils that display shrinking and swelling during wetting and drying cycles. They exhibit strong cracking when dry and at depth have slickensides and/or lenticular peds.

Figure 62: Black Vertosol on the Jack River flats

Vertosols are usually associated with floodplains in the Tarwin and La Trobe valleys. They can also occur in inter-dune swales in the Wonthaggi region.

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