Landscapes of the South East

An educational guide for the landscapes of the South East of South Australia

Australian Government

National Landcare Program

Natural Resources South East

This project is supported by Natural Resources South East through funding from the Australian Government's National Landcare Program.

The South East Natural Resources Management (SE NRM) Board acknowledges and respects the traditional owners of the Region's ancestral lands. The SE NRM Board acknowledges the elders past and present and respects the deep feelings of attachment and relationship of Aboriginal peoples to country.

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About This Education Resource

This pack can be used as a resource for students as well as a teaching aid for educators to assist in developing lesson plans and units of work. It provides background information on the regions landscapes, including how they have changed over time and how current farming practices have been developed based on how these landscapes functioned in the past.

The information is intended to provide a starting point for projects and learning regarding the natural landscapes of the South East region.

Links to further resources, such as online fact sheets and websites are provided throughout the document. The document will be most beneficial when used in its electronic format, which can be accessed here.

Introduction

The South East Natural Resources Management (SE NRM) region has many unique landforms and distinctive natural characteristics originating from a long, complex geological history. Characterised by a series of 'stranded' dune ranges that rise between 20 and 50 metres above the flat plains called interdunal plains. These plains can be inundated by water over winter and dry out over summer. They host a variety of internationally recognised wetland systems including the Ramsar listed Bool and Hacks Lagoons and part of the Coorong and Lower Lakes wetlands. Amongst the varied landscapes of the region is an extensive network of limestone sinkholes and caves, including the world heritage listed Naracoorte Caves.

The region contains very few surface water sources such as streams or rivers, with the majority of the regions community and industry relying on under-ground water resources. These groundwater resources accumulate over time as water from rain, rivers, lakes, wetlands and other sources of surface water migrate through the earth's surface, where it is stored in porous rock (known as an aquifer). This groundwater in the South East is an exceptionally valuable asset to the region.

Although only 13 percent of native vegetation cover remains (Foulkes et al, 2003), the region has a diverse range of flora and fauna. Habitats across the landscape include heathy woodlands and forests, grassy woodlands, dry heathlands and mallee, scattered trees, open water swamps, wetlands and rising springs occur across the region. The coastline is largely undeveloped and has therefore retained distinctive natural features such as stunning coastal lakes and vast limestone cliffs. The marine environment is a high energy system and is unique for its significant biodiversity and high productivity. Large sections of the coastline are protected under the *National Parks and Wildlife Act 1972*, with the scenery and beaches proving a major attraction for visitors to the region.

Contents

Geology of the South East

How did the South East form?

The South East Natural Resources Management (SE NRM) region has many unique landforms and distinctive natural characteristics that have originated from a long, complex geological history (a map summarising these can be found in Appendix 2).

158 million years ago

The separation and movement of Gondwanaland into the Australian and Antarctic continents, which initiated about 158 million years ago, saw the development of the southern seaway (the Southern Ocean) and the resultant formation of the south east coastline of Australia.

As Antarctica began to pull away from southern Australia, sequences of sand and silt were deposited in an elongate depression, known as the Otway Basin, which formed as the two new land masses began to fracture and drift apart. Stretching from Kingston SE to the Mornington Peninsula in Victoria, the western most portion of interest here is known as the Gambier Embayment. Since that time, there have been a number of major depositional events that have led to the development of the South East landscape as it is known today.

66-148 million years ago

The basement rocks that underlie the western portion of the basin were deposited during the lower and upper Cretaceous (145 – 100 and 100 – 66 million years ago respectively) which was laid down both during and after separation. They typically comprise sandstone, siltstone, mudstone and shale and were likely formed in a depositional environment of rivers and lakes (fluvial). Basement rocks of the eastern portion are much older (refer to Appendix 1 for further detail).

55-48 million years ago

The Dilwyn formation overlies the Cretaceous sediments, containing a sequence of interbedded sands, gravels and carbonaceous silicate muds (clays) and silts formed some 55 to 48 million years ago (Palaeocene/Eocene), primarily through deltaic fluvial depositional processes. The Dilwyn formation is credited with providing the region with an extensive confined aquifer system. This is accessed for irrigation, stock and domestic purposes, thanks to a thick clay aquitard that is found at the top of the unit.

40-15 million years ago

Flint occurs in the Gambier limestone as nodular masses at shallow depth. Erosion of the limestone by the sea along a 30 kilometre stretch of cost from Port MacDonnell then NW to Carpenter Rocks has concentrated extensive flint deposits along the beaches. A small industry supplying limited Australian demand operated between the 1880s and 1985.
Source: SA Department of State Development website.

The final separation of Australia from Antarctica allowed circum-Antarctic Ocean currents to form (approximately 40 million years ago) enabling the developing Southern Ocean to advance over much of southern South Australia and Victoria.

Following this the Gambier limestone was deposited between 38 and 15 million years ago (Oligocene/Miocene), which is perhaps the most significant of the recent deposits, due to its contribution to the regions identity as the 'Limestone Coast'. In contrast to the older and deeper sediments (which were primarily terrestrial deposits) the Gambier limestone was deposited in open water marine conditions.

The resultant limestone that was deposited has many forms, from soft and marly, to fossiliferous, containing abundant marine derived lace coral fossils as well as clams, snails and seas urchins. The Gambier limestone acts as a shallow unconfined aquifer that is seasonally recharged, becomes extensively exposed in the south of the region and is used as a popular building material. In some places the limestone has become dolomitized (magnesium and calcium carbonate) which is most notably present at the Tantanoola Caves. Here rock is exposed above the natural soil surface thanks to uplift associated with the Tartwaup fault.

What shaped our current landforms?

15-10 million years ago

Towards the close of the Miocene (15 to 10 million years ago) global tectonic events caused major fluctuations in sea level which resulted in the exposure and erosion of the Gambier limestone in the north of the region; terrestrial depositional regimes eventually returned, with recent sediments (<1.8 million years) comprising silts and sands of aeolian and fluvial origin (Parilla sand), and lacustrine and marginal-marine origin (Coomandook and the Bridgewater and Padthaway Formations, later discussed).

1.5 million years ago

Other major events of regional geological significance include volcanic activity. The Mount Burr range, which includes some 15 volcanic centres, dating back to around 1.5 million years ago and the most recent activity of the Mount Gambier and Mount Schank volcanics dated at around 4,600 years. Volcanic activity has caused a gentle uplifting of the region, contributing to the development of fertile soils in surrounding areas and is the source of abundant potable water for the township of Mount Gambier (via the Blue Lake).

1 million years ago

By far the most visible geological feature of the South East is the series of relic coastal dune ranges (Bridgewater formation) that run parallel to the current coastline in a north westerly orientation (Fig 1). The dunes are separated mostly by low-lying inter dunal corridor plains (called the Padthaway Formation) that are relatively young in age (less than 1 million years) and form the land surface that is currently farmed. Appendix 4 provides further detail regarding the soil types of these two formations.

There are 21 relic coastal dunes occurring in 13 distinct ranges across the coastal plain from Robe to Naracoorte. The east and west Naracoorte ranges are the oldest (>800,000 years) and have the highest elevation of the set, thanks to natural uplift, volcanic activity and interaction with the Kanawinka fault. Across the Naracoorte Plain, the next set of dunes include the Stewart and Harpers Range, followed by the Woolumbool, Peacock, and Bakers Ranges (Fig 1).

The Avenue Plain, which extends southward to the fertile Conmurra and Millicent cropping regions, is flanked by the East and West Avenue ranges, which were formed approximately 400,000 and 340,000 thousand years ago respectively.

The dunes aren’t all aged in succession though. Evidence suggests that the sea retreated and then inundated back over the East Dairy range (which has been dated at 300,000 years) to then form the Reedy Creek range further inland, approximately 220,000 years ago. There was also a dune found offshore in about 50 to 100 metres of water formed during the last glacial period (20,000 years ago). This underwater dune system forms an important habitat for crayfish, supporting a thriving commercial fishing industry.

Dunes in the South East are generally spread two to ten kilometres apart and are around 20 to 50 metres high. Typically made of deep sand, overlying calcrete (which has developed in-situ through soil forming processes) and older limestone deposits (calcarenite) that were beach and wind derived. The limestone has also been subject to dissolution from mildly acidic soil water, which has led to the formation of extensive cave systems and sink holes scattered throughout the region.

The interdunal plains (the flats in between the dunes) are typically made up of a sheet of clay rich loamy topsoil, which is around 10 to 40 centimetres thick. This overlays the lacustrine and lagoonal deposits of limestone, dolomite and clay of the Padthaway Formation.

Much of the land now used for agriculture, horticulture, viticulture and forestry throughout the South East is the result of the Bridgewater and Padthaway Formations (Appendix 4 contains further detail regarding the soil of these formations). The exception to this is the Gambier limestone that is exposed on the surface throughout the area extending from Tantanoola to Port MacDonnell.

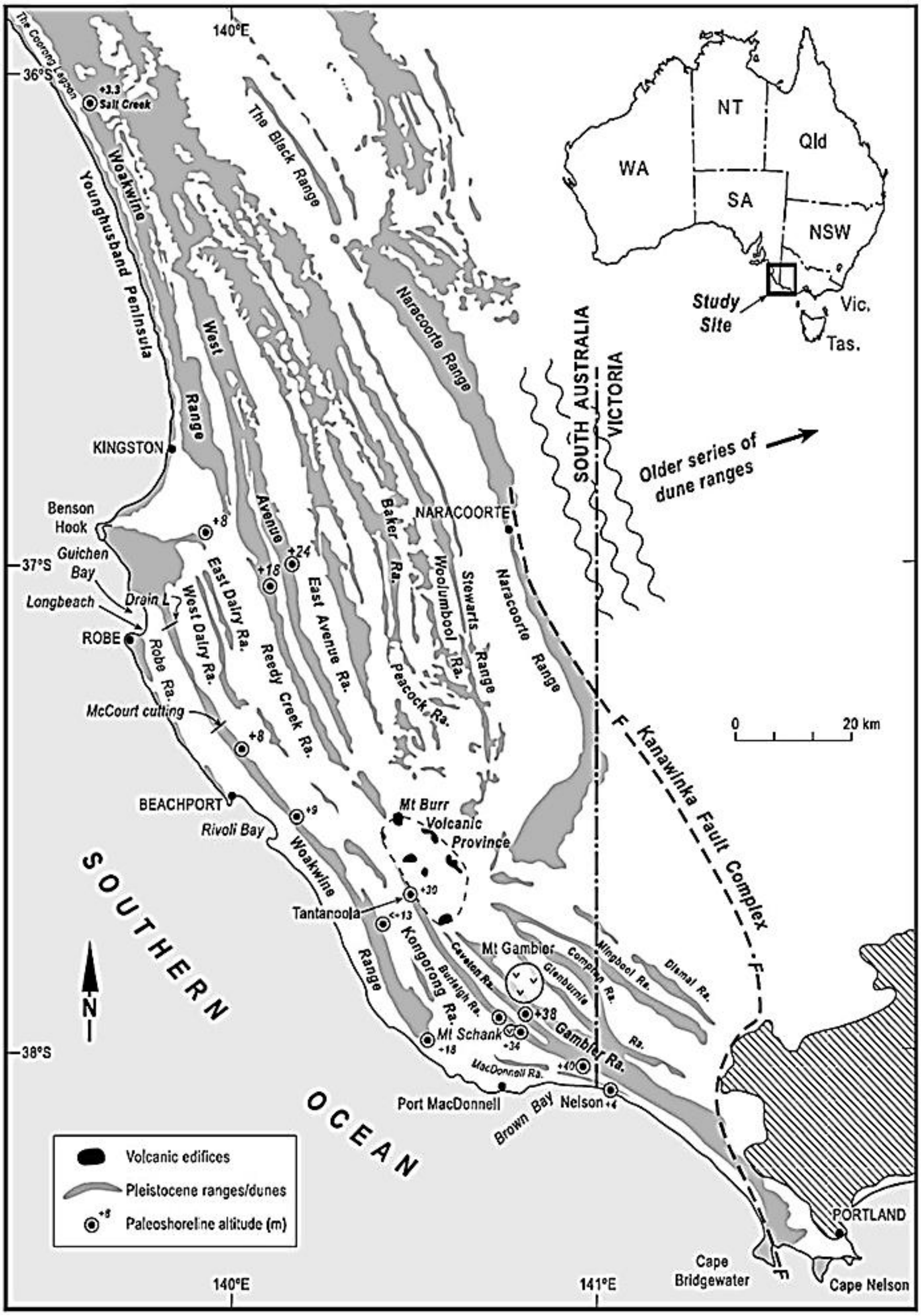


Figure 1. Relic coastal dune ranges of the South East, running parallel to the coastline.

Timeline of geological events in Limestone Coast

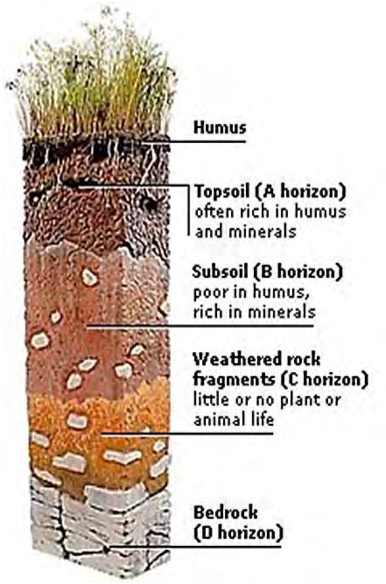
Years ago	***Geological event***
158 million	Formation of Gondwanaland
40 million	Separation of Gondwanaland from Antarctic continent
20 million	Laying down of Gambier limestone deposits
2-5 million	Lifting of Naracoorte Ranges along Kanawinka Fault
1.5 million	Volcanic eruptions in Mount Gambier
1 million	Beginning formation of dunal systems and infilling
20,000	Last dune system currently offshore in 50 – 100 metres of water
4.600	Last volcanic activity around Mount Gambier

Evolution of the dunal systems in the Limestone Coast

Years ago	***Geological event***
940,000	Hynam Dunes
800,000	Naracoorte Range
430,000	West Avenue Range
300,000	Reedy Creek Range
210,000	Robe / Beachport
120,000	Woakwine Range
20,000	Offshore system, 50-100 metres deep
Current	Young Husband Peninsula (Coorong)

How does geology shape farming practices?

Past geological events have had a big influence on current farming practices in the region. Processes such as weathering lead to the formation of different soil types in different areas. Soil profiles (such as the image to the right) show an assortment of layers combining to make up the characteristics of the soil, this can vary at any given location.



Soil layers are formed through processes such as physical, chemical and biological weathering and a process called deposition. Different soils are named after their deposition processes, such as:

- *colluvial soil*– particles are transported by gravity
- *alluvial soil* – particles are moved via running water
- *glacial soil* - heavy ice masses push glacial soils around
- *aeolian soil*- formed through wind moving soil particles

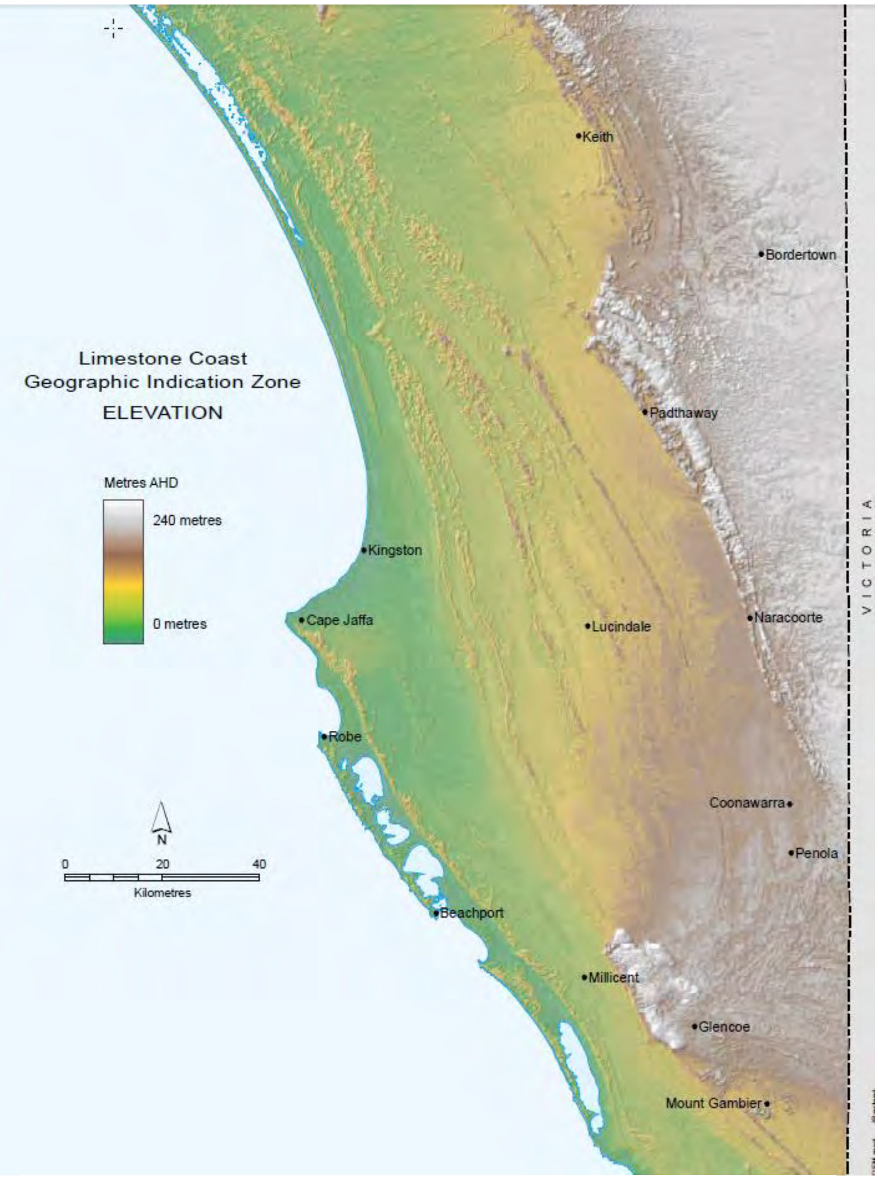


Figure 2. Elevation of the Limestone Coast region

These processes have all worked together over time to form the elevation and aspect of the regions farming land. Figure 2 shows the regions elevation from the ranges in the east to the ocean in the west and from the northern Mallee country to the southern volcanic areas.

Elevation and aspect, in conjunction with dunal systems influence how water moves through and gathers in the landscape. This determines how and where water ways (such as rivers and streams) and wetlands form, ultimately influencing how farming and industry occur.

Throughout the year climate plays a large part in how the land is managed, especially when combined with varying geological and geographic features. For example, in a wet year the swale area of the system may become very wet and water logged, making it unsuitable for running stock or cropping, due to waterlogging. Conversely, in a dry year these areas can be some of the most productive, holding soil water well into the dry season. Similarly the dunes in a drier season may be less suitable to run stock, as once cover crops are removed dunes can start to move, whereas in a wet winter these areas can provide retreat for stock to graze.

Farming a dune and swale landscape

The figure below (Fig. 3) shows a standard dune and swale landscape. In the South East large swales measuring between two and twenty kilometres have formed as the sea has retreated over time. Clay and silt deposits have formed in these swales on top of the ancient limestone reefs that form the bedrock.

Historically these interdunal swales would have been covered in water, forming seasonal wetlands. The construction of the regions drainage system diverted water from being retained in these areas, allowing them to be utilised for productive farming land, growing pastures and even winter and spring crops in years of drought. Whereas is years of excessive rainfall water can still be retained on some of the lower lying swale areas.

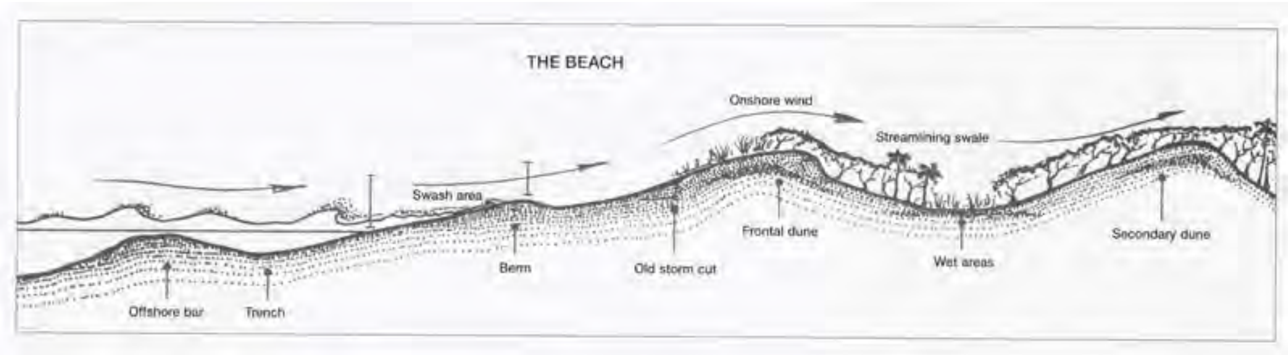


Figure 3. Dune and swale landscapes are traditionally thought of occurring in the coastal zone. However, but due to geological processes these swales can also develop further inland and be over 100's of kilometres long. The South East provides some good examples of this phenomenon. *(source: http://www.anbg.gov.au/photo/vegetation/sand-dunes.html)*

Landholders in the region would often have land on both the flats and the sand dune ranges, allowing stock to be moved to higher country during winter when the ground was wet, and moved back to the swale flats in summer as the ground dried out and pastures flourished.

Fig. 4 shows examples of current farming practices in the dunes and flats landscapes of the South East. The model shows what the community value about the regions landscapes – depicted here as environmental and socio-economic values. It also identifies the environmental and socioeconomic drivers, and the pressures and threats that affect what the community values about this landscapes.

It highlights the focus of recreational pursuits in the coastal zone, and shows the adaptation of farming to the swale or flat areas in the landscape. The implementation of the drainage network significantly altered the landscape of the South East, opening up a lot of land and increasing the productivity and capacity of the area for agriculture and industry. This network has also had a significant impact on the extent and quality of the regions wetlands, with less than five percent of the original area in existence today.

Dunes and Flats

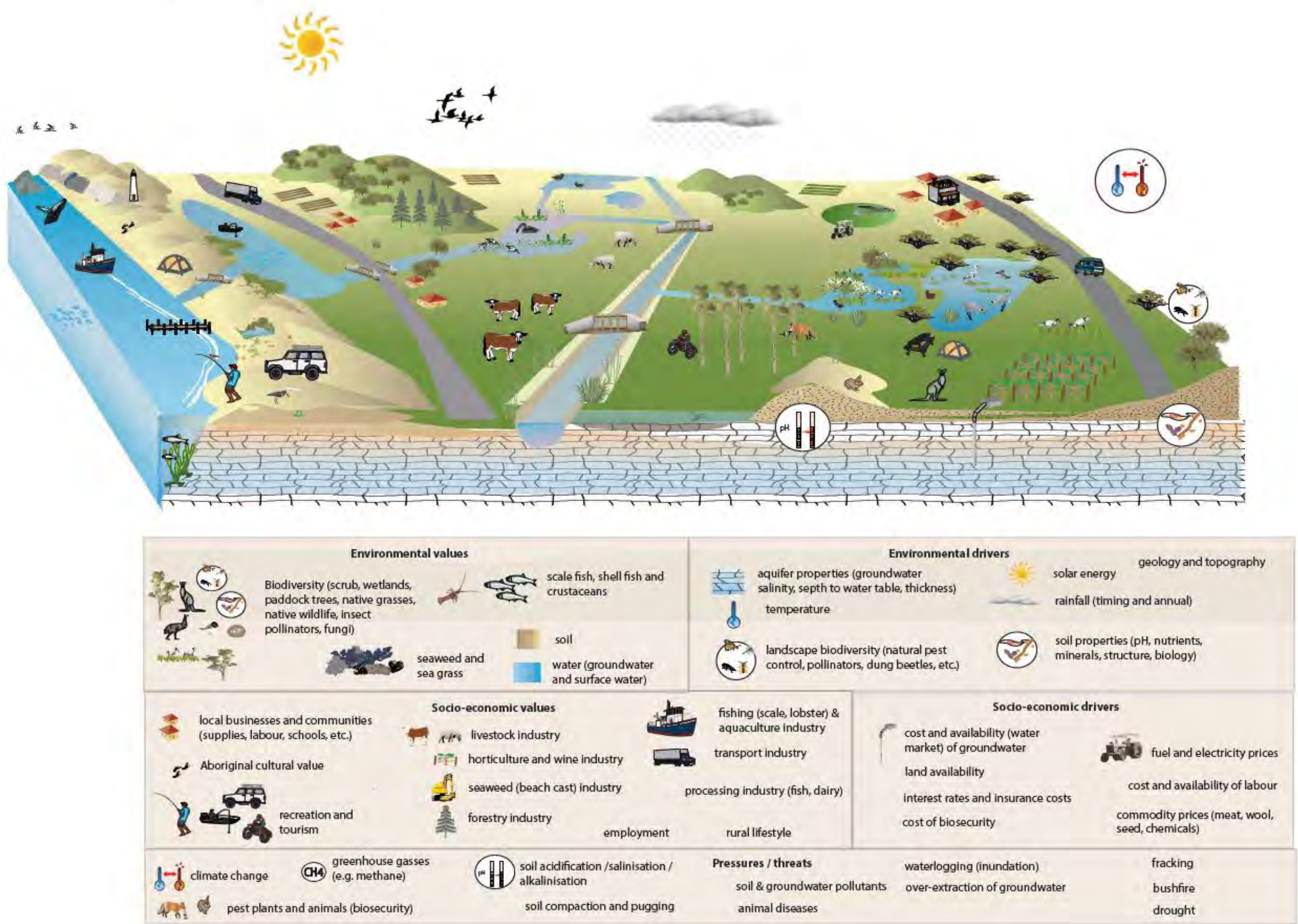


Figure 4. An example of current farming practices in the dunes and flats landscapes of the South East. The model shows what the community value about the regions landscapes.

Photos from region after 60mm of rain fell in 3 days August 2016. A Major challenge to farming in the region is inundated farming land post rainfall events

Climate of the South East

What's the climate like in our region?

The region has a Mediterranean climate and as such experiences natural variability in weather during the year, characterised by hot dry summers and cold wet winters. Climate patterns vary year to year with major climate influences including the:

- El Niño Southern Oscillation (ENSO), the oscillation between El Niño and La Niña conditions which affects rainfall and temperature in eastern Australia; and
- Indian Ocean Dipole (IOD), which affects the climate of Australia and other countries that surround the Indian Ocean Basin, and is a significant contributor to rainfall variability.

The result of these and other climatic influences are major variations in rainfall and temperature, particularly drought cycles. In addition to this natural variability in climate, weather station data from across the region is showing longer term changes (trends) to rainfall, temperature and other variables attributed to climate change.

Over the past ten years both cycles of wet and dry have occurred in the region. Many of the resources used in the farming system, such as ground water and soils, respond in various ways to this change in climate. For example, ground water across the region is dependent on recharging in wet years. As the rain falls across the region it recharges the upper (unconfined) aquifer. Over time water moves through cracks in the rock layers between the upper (unconfined) and lower (confined) aquifer where it is 'stored'.

Climatic cycles also affect the regions soils. In a wet year (above average rainfall) cover crops and pastures respond with longer growth cycles, the presence of these plants provides stability to the soil. This is particularly pertinent in the northern areas of the region where sandy and less stable soils tend to occur. Conversely dry and hot years tend to cause soil to become loose and drift when wind is present causing erosion and loss of top soil.

Climatic patters and variances have a major impact on agriculture and industry in the region. For example more intensive agriculture, such as dairy and horticulture tend to occur in the south where there is higher rainfall and cooler weather (Fig. 5). Whereas broad acre cropping and irrigated horticulture enterprises are more common in the northern parts of the region where it is drier and warmer, such as around Keith (Fig. 6) and Naracoorte (Fig 7).

Climate change effects including drought impact on ground cover and soil stability

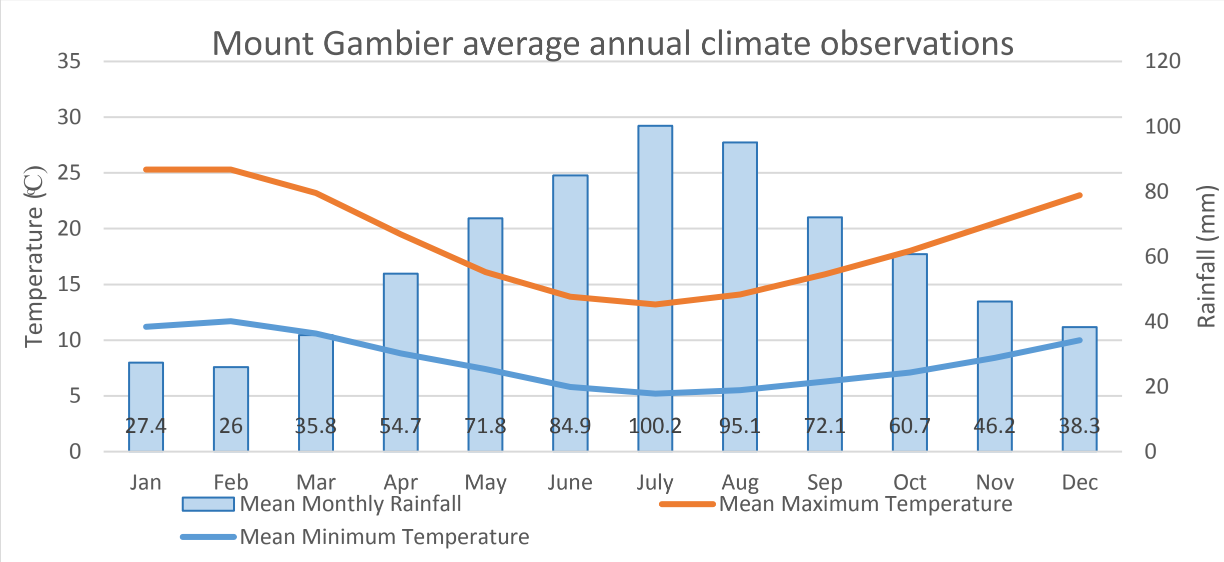


Figure 5. Mount Gambier average annual climate observations.

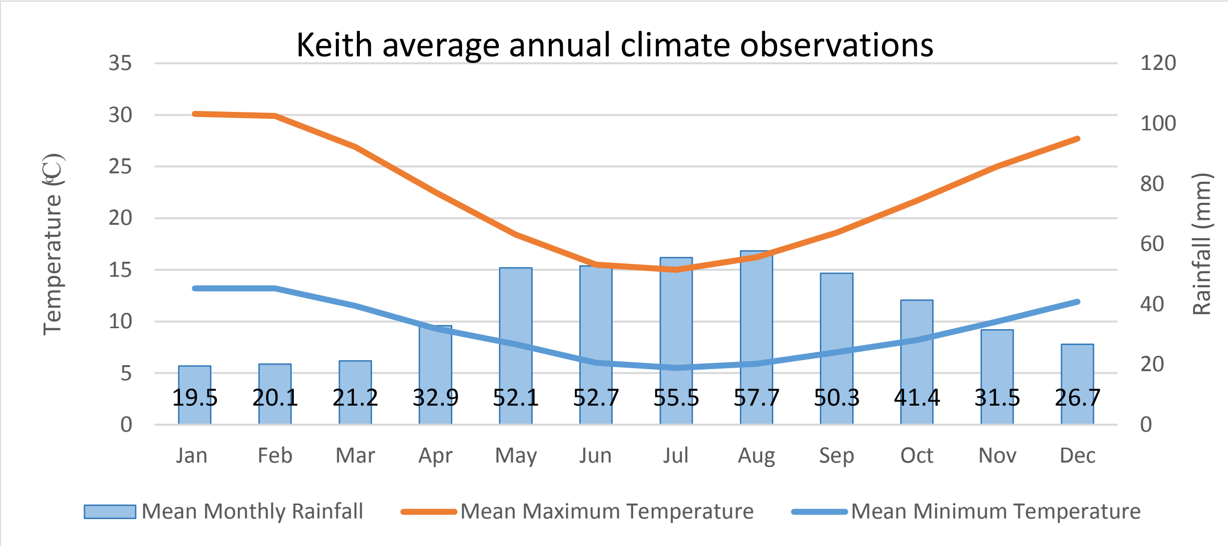


Figure 6. Keith average annual climate observations.

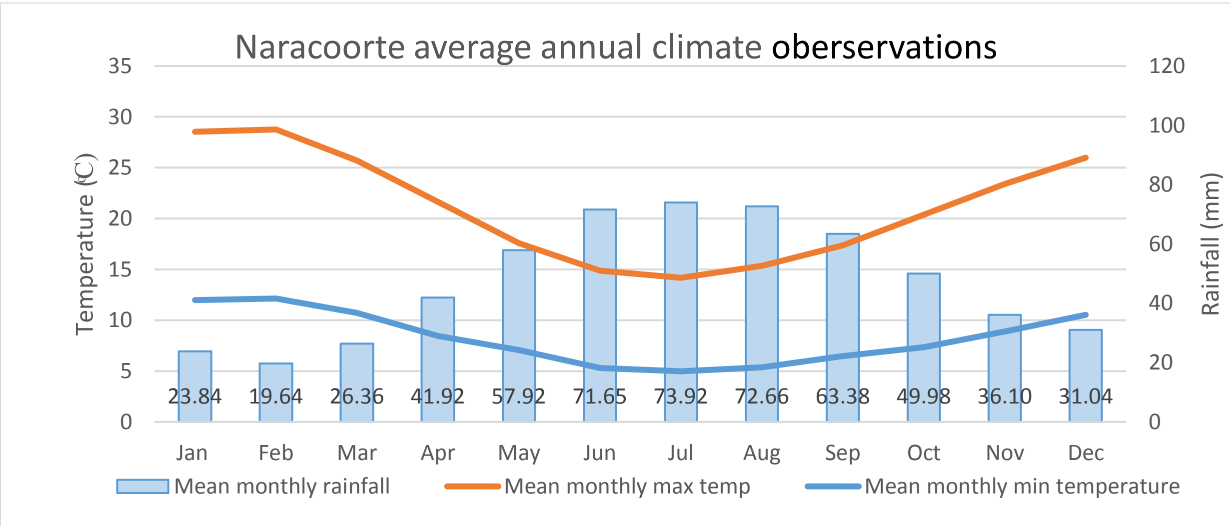


Figure 7. Naracoorte average annual climate observations.

For more information on localised weather visit the SENRM's weather website here
Or visit https://www.awsnetwork.com.au/

What changes in climate are predicted for the region?

Natural variability in climate occurs in all regions of the world, however climate change will create a different future climate. Predictions suggest conditions for the South East will be warmer and drier. Climate projections differ depending on a range of factors including which climate model, concentration pathway (previously referred to as emissions scenario) and timeframe for the concentration pathway are selected. A climate projections report was prepared for the Limestone Coast in 2015, the following sections summarise the findings of the report, for further detail the full report is available here.

For more climate change information
http://www.naturalresources.sa.gov.au/files/sharedassets/south_east/corporate/nrm_plan/climate-projections-report-rep.pdf].

Rainfall

The South Australian Climate Ready data (https://data.environment.sa.gov.au/Climate/SA-Climate-Ready/Pages/default.aspx) suggests that by:

- 2050, annual median rainfall will decline by 4.8% and 7.9% compared with the baseline under the intermediate and high concentration pathways (previously referred to as emissions scenario), respectively (Fig. 8).
- 2070, the rainfall will further decline by 6.8% and 11.1 % under the intermediate and high concentration pathways respectively (Fig 8).

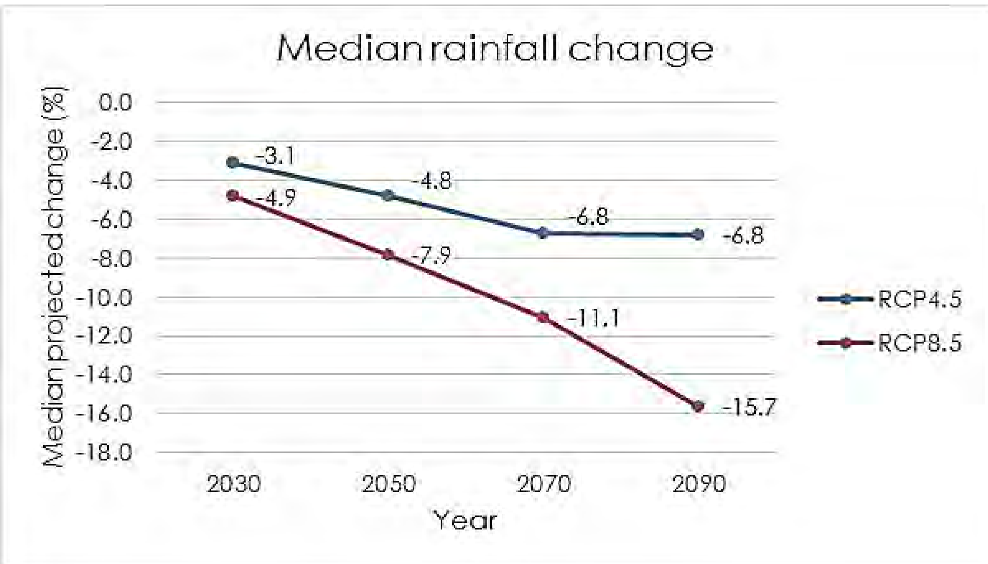
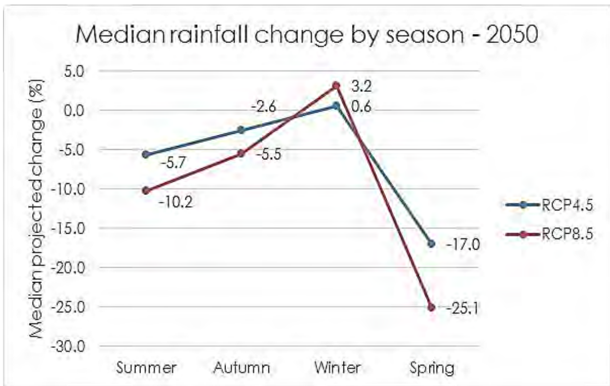


Figure 8. Median rainfall change for the Limestone Coast. RCP4.5 representing the intermediate concentration pathway (emissions scenario) and RCP8.5 representing the high concentration pathway (emissions pathway).



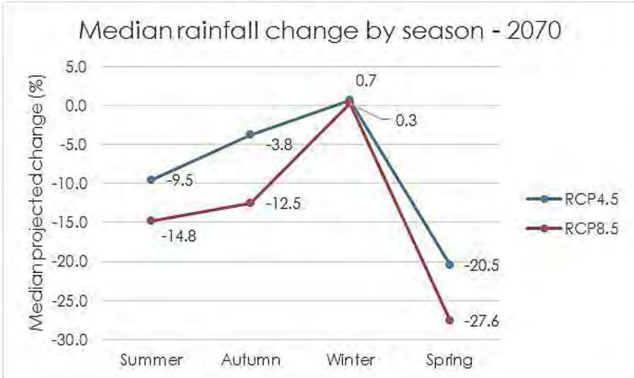


Figure 9. Projected change in median rainfall by season – 2050 and 2070 for the Limestone Coast. RCP4.5 representing the intermediate concentration pathway (emissions scenario) and RCP8.5 representing the high concentration pathway (emissions pathway).

The seasonal differences in rainfall change are also significant (Fig 9). By 2050, spring rainfall declines are at least 17% whereas declines in winter and autumn rainfall are less than 6% for both concentration pathways. This trend continues over the following twenty years, with 2070 figures predicting declines of 20.5% and 27.6% projected under intermediate and high concentration pathways, respectively.

(Source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

Rainfall intensity

The Climate Change Industry Adoption (CCIA) project results suggest that while median annual rainfall is tending to decrease, the extremes in rainfall intensity are projected to increase. There is high confidence that the intensity of daily rainfall events will increase, however, there is low confidence in the magnitude of the change. Therefore there is also low confidence in determining the time when these changes will be observed on the ground, because they may also seem very similar to the natural variations in climate already experienced.

Data for the entire Murray Basin cluster suggests that annual maximum one-day-rainfall compared to baseline conditions (1986-2005) could increase by:

- 7% and 6% by 2050 under an intermediate and high concentration pathway and
- 5% and 15% by 2070 under an intermediate and high concentration pathway.

Other analysis suggests that for each degree of global warming, extreme daily rainfall may increase by 7%. If this was to apply in the Limestone Coast region, increasing temperatures could be expected to increase rainfall intensity by nearly 7% in the region by 2030 and at least 14% by 2070 under a high concentration pathway.

(source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

Temperature

National records for surface air temperatures in the region commenced in 1910. In this time the region has warmed, particularly since 1960 (Fig. 10). From 1910 to 2013 mean temperature across the Murray Basin rose by 0.8 °C (CCIA project data), local data for Robe shows a similar change.

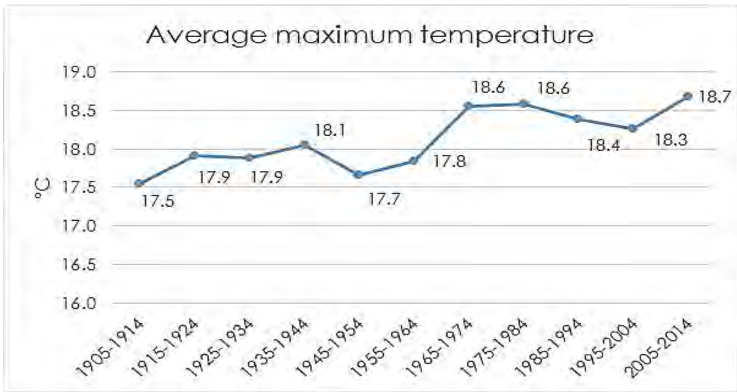


Figure 10. Average maximum temperature changes for the Limestone Coast, 1910-2014

SA Climate Ready data suggests that the annual median maximum temperature (Fig. 11) will increase by:

- 1.1°C and 1.4°C by 2050 under the intermediate (RCP4.5) and high (RCP8.5) concentration pathways, respectively.
- 1.4°C and 2.1°C by 2070 under the intermediate (RCP4.5) and high (RCP8.5) concentration pathways, respectively.

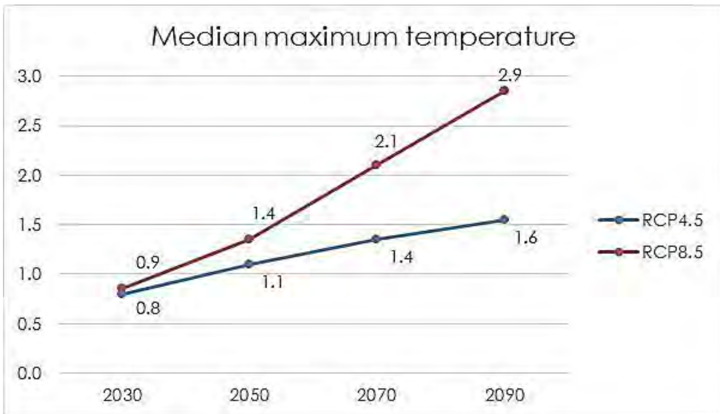


Figure 11. Annual median maximum temperature prediction 2030 – 2090.

The difference between seasons in maximum temperature by 2070 is limited, with summer-autumn-winter projected to increase by 1.2-1.3°C compared to 1.6°C for spring under the intermediate concentration pathway. A similar difference exists under the high concentration pathway with a projected summer-autumn-winter increase of 2.0-2.2°C compared with 2.4°C for spring.

Minimum median temperatures show a similar trend to maximums (Fig. 12), suggesting an increase of:

- 0.9°C and 1.3°C by 2050 under the intermediate (RCP4.5) and high (RCP8.5) concentration pathways, respectively.
- 1.1°C and1.9°C by 2070 under the intermediate (RCP4.5) and high (RCP8.5) concentration pathways, respectively.

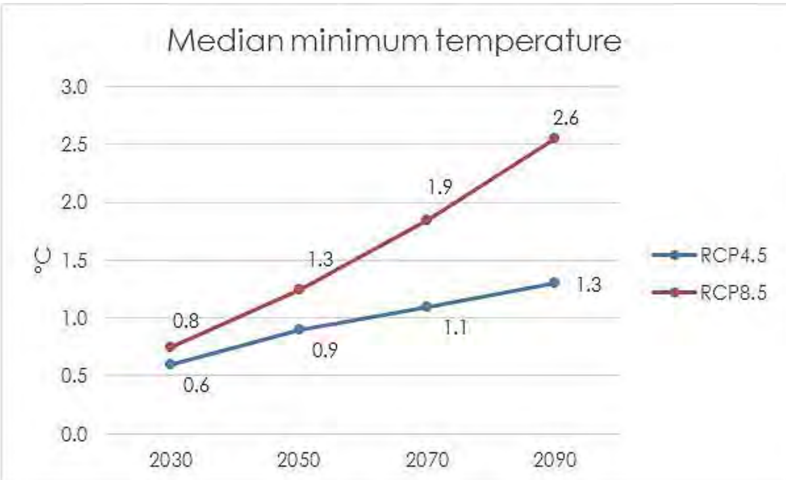


Figure 12. Annual median minimum temperature prediction 2030 – 2090.

The difference between seasonal changes in minimum temperature by 2070 is limited, with all seasons projected to increase by 1.0 to 1.2°C under an intermediate concentration pathway. Under the high concentration pathway the summer, winter and spring increase by 1.8°C and autumn by 2.1°C.

(source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

Heat extremes

The occurrence of heat extremes (days over 35°C) are also expected to change as climate change occurs:

- In Keith by 2050 the number of days over 35°C is projected to increase by 33% under intermediate and 50% under high concentration pathways respectively, and
- In Keith by 2070 number of days over 35°C is projected to increase by 48% under intermediate and 76 under high concentration pathways respectively.
- A greater increase is also predicted in for days over 40°C, with an 88 to 125% increase by 2050 under an intermediate and high concentration pathway and 113 to 163% by 2070.
- In Mount Gambier by 2050 -number of days over 35°C is projected to increase by 50% under intermediate and 75% under high concentration pathways respectively, and
- In Mount Gambier by 2070 number of days over 35°C is projected to increase by 75% under intermediate and 117% under high concentration pathways respectively.

Similar to Keith, an increase in days over 40°C is also predicted. Forecasts suggest these will double by 2050 and increase by 100-200% by 2070, under intermediate and high concentration pathways, respectively.

(source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

Fire risk

The CCIA projections suggest an increased fire weather risk for Mt Gambier. General fire weather danger increases by about 9-11% by 2030 (for both concentration pathways). By 2090 under intermediate concentration pathways a 15 % increase is forecast and under high concentration pathways a 29% increase is predicted.

The number of days per year with a 'severe' fire danger rating is predicted to increases by 19-27% by 2030, and from 36% to 55% by 2090.

(source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

Sea level rise

It is expected that as oceans warm they will thermally expand, and coupled with melting ice entering the world's oceans sea levels will increase. Observations suggest that global sea levels have risen by about 21 centimetres from 1880 to 2009, it is though this is principally due to thermal expansion.

Sea level records have recorded an average rise of 2.1 mm/yr around the Australian coastline over the period 1966–2009. This average increased to 3.1 mm/yr over the period from 1993 to 2009. This rate allows for removal of the influence of:

- El Niño Southern Oscillation
- vertical land movements due to glacial rebound
- natural climate variability
- changes in atmospheric pressure.

Projections of global mean sea level rise at Victor Harbor suggest an increase of 11-13 centimetres by 2030 and 30-40 centimetres by 2070. By the end of the century sea levels are expected to rise by approximately 0.5 metre under an intermediate concentration pathway. Victor Harbor is the closet tide gauge to the Murray Basin cluster coast and the CCIA project plan notes that this prediction is indicative of the coast line through to Portland. Portland in the adjacent climate cluster is included in the CCIA project and shows almost identical projections for sea level rise.

(source: LSC Regional Climate Change Adaption Plan Project – Climate Projections Report 2015)

For more information on climate change and its effects on our region visit CSIRO's climate change for Australia
https://www.csiro.au/en/Research/OandA/Areas/Oceans-and-climate/Climate-change-information

CSIRO's State of the climate 2016
https://www.csiro.au/en/Showcase/state-of-the-climate

CSIRO's Climate change in Australia interactive website
https://www.climatechangeinaustralia.gov.au/en/

Research indicates that under climate change scenarios our region may experience greater coastal inundation in some parts of the region.

As a result greater planning is being conducted around these climate change scenarios for future proofing our region.

Pre settlement landscape

What did our region look like before European settlement?

At the time of European settlement, the South East was a mosaic of vegetation types including forests, woodlands, mallee, shrubland, sedgeland, herblands and grasslands along with extensive areas of wetlands and swamps covering over 40% of the region (Fig. 13).

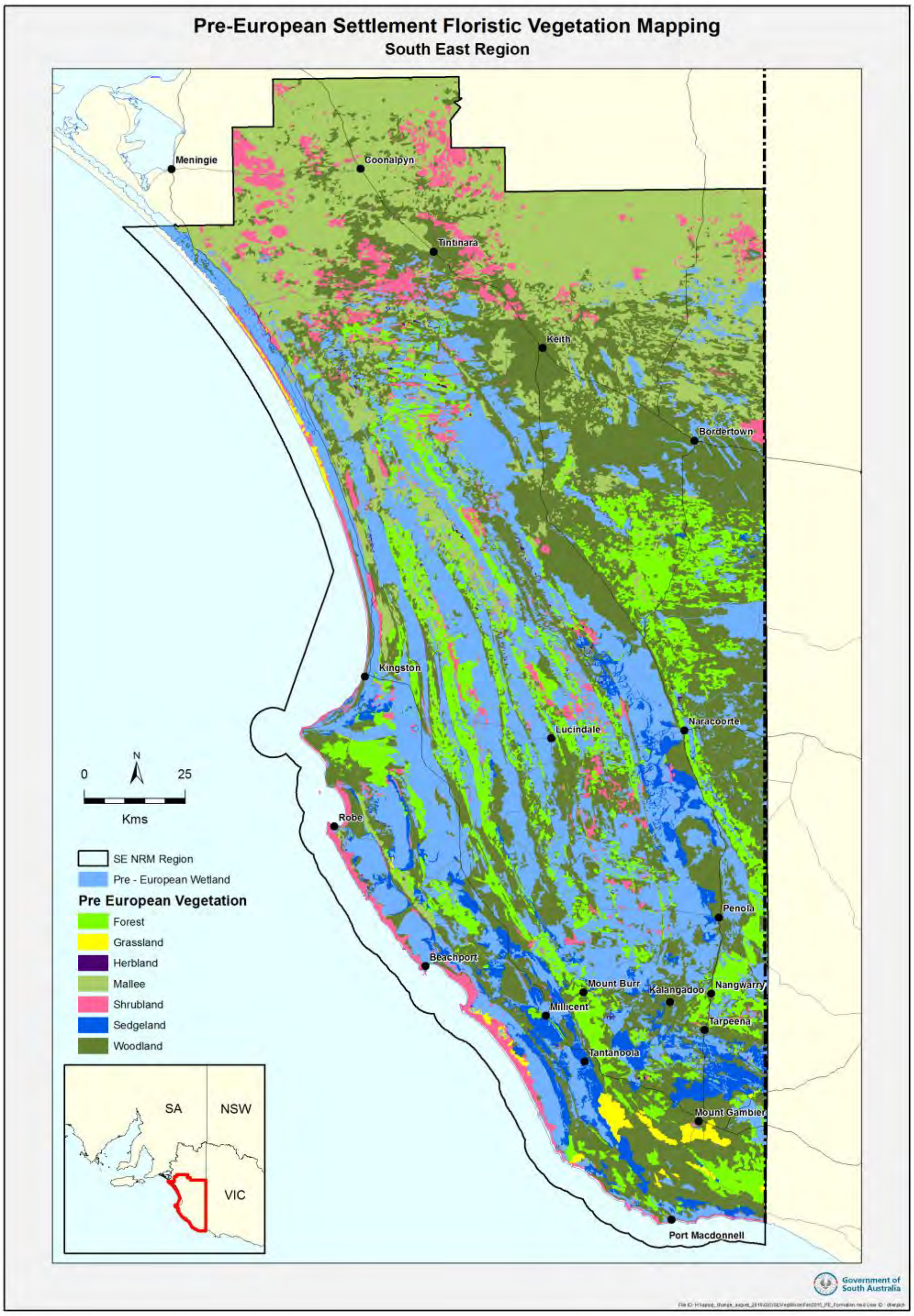


Figure 13. Floristic vegetation mapping for the South East prior to European settlement. Significant differences in vegetation cover and the extent of wetlands can be seen between Figs. 13 and 14.

The range of vegetation types and their location were very much related to the geological landscape and the soil and water present at different times throughout the season.

Wetland areas were prolific on the interdunal flats. As summers progressed they would retreat to the western side of the swales. While on the sand ridges of the old dune there was a mixture of forest and woodland. These forests and woodlands became thicker and more abundant on the higher country to the east, near the border.

To the south on volcanic earth around Mount Gambier supported grasslands while in the north of the region, sandy soils and warmer climates lead to an abundance of Mallee woodlands and shrub lands.

In this pre-European settlement landscape around 40 percent of the region was covered in woodlands and forests. These areas supported high numbers of birds, mammals, plants, frogs and freshwater fish. The vast range of plants and animals was due to the grading of climatic conditions that occur through the region. This grading, from a temperate climate in the south to a more arid landscape in the north, created what was known as a "transition zone". This zone created environmental conditions which led to a variety of habitats, and a great range of biodiversity existing throughout the region.

How has the landscape changed since European settlement?

The current landscape looks very different to that of pre-European settlement (compare Figs. 13 and 14). The extent of biodiversity in the region has been dramatically altered as a result of historical land management practices to become Fragmented and isolated in nature (Croft et al. 1999). These changes include:

- clearance of native vegetation
- drainage of wetlands
- the introduction of plant and animal species, insect pests and diseases

Historically, as agriculture and forestry expanded, drains were constructed throughout the South East. These altered the natural regional flows of water and drained excess water to the ocean. The area of wetlands in the South East region is now significantly different to pre-European settlement (Figure 3 and 4). Wetlands originally comprised around 46 percent of the region's landscape. They now account for less than seven percent and much of this habitat is severely degraded.

Even though major changes have occurred to the landscape, there has been a lot of work undertaken to reduce and remedy the impact to the landscape in the region. Some of the works undertaken in the past by individual landholders, groups and governments have meant that valuable areas of vegetation have been retained. Many nationally threatened species of plants and animals are represented only in the South East region. They survive in isolated pockets of habitat, highlighting the importance of conserving and managing the remaining habitat and linking these areas.

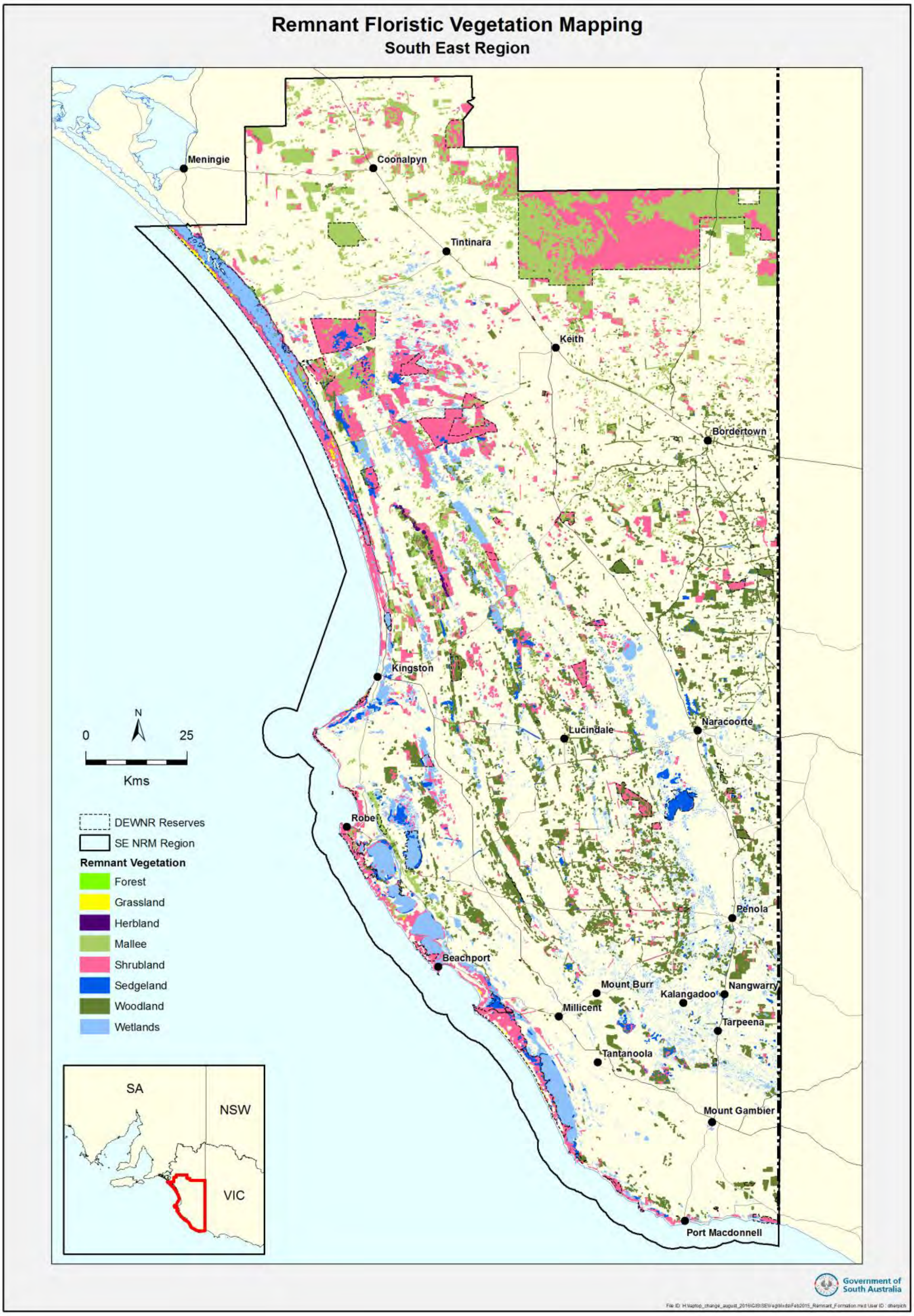


Figure 14. Floristic vegetation mapping for the South East following European settlement. Significant differences in vegetation cover and the extent of wetlands can be seen between Figs. 13 and 14.

Biodiversity of the South East region

What do we mean by biodiversity?

Biodiversity is all living things!

The term biodiversity refers to the variety of life forms on earth:

- Diversity of ecosystems across the landscape
- Many different species of plants, animals, fungi and micro-organisms in those systems
- Genetic diversity within and between individuals.

Healthy functioning ecosystems are necessary for maintaining ecological services that support the natural environment as well as our economic and social activities. Such services include the maintenance of healthy soil and water for the production of food, recycling nutrients, providing shelter for livestock and crops, regulating climate and the air we breathe.

How has biodiversity in the southeast changed over time?

Prior to European settlement, the South East supported an amazing array of biodiversity in part made up by areas of woodlands and forests, heathlands and grasslands interspersed between vast expanses of seasonal and permanent wetlands (Fig. 13). The range and amount of biodiversity in the region is greatly influenced by geological features in the region, along with the occurrence and availability of soil and water resources.

While representing only two percent of the total area of South Australia, the South East region in pre-European times supported a significant proportion of the States plant and animal species (Croft et al. 1999), including:

- birds (77%)
- plants (42%)
- mammals (53%)
- reptiles (21%)
- frogs (42%)
- freshwater fish (24%)

Juvenile Copper head snake at Picannini ponds

However, over time changes to the landscape have had a direct effect on the occurrence of biodiversity in the region. Threatening processes such as native vegetation clearance, wetland drainage, and the introduction of pest plants and animals have significantly reduced the biodiversity of the region. For some species this has meant a reduction in habitat to the point that their existence is threatened as population numbers dwindle. Species that are at risk of extinction may be listed as threatened under the *National Parks and Wildlife Act 1972* (South Australia) and/or the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Even though major changes have occurred to the landscape, there has been a lot of good work undertaken to reduce and remedy the impact to biodiversity in the region. Some of the good work undertaken in the past by individual landholders, groups and governments includes:

- Revegetation
- Fencing of remnant vegetation
- Pest plant and animal control
- Management of water flows
- Threatened species habitat protection.

Whilst there is still much work to be done, works to date have assisted in the protection of valuable biodiversity. Many nationally threatened plant and animal species are represented only in the South East region, highlighting the importance of conserving and managing the remaining habitat and linking these areas.

What threatened species occur in our region?

Many nationally threatened species are represented only in the South East region of South Australia (Fig. 15) and survive in isolated pockets of suitable habitat, highlighting the importance of conserving and managing the remaining habitat and linking remnant areas.

Group	Critically Endangered	Endangered		Vulnerable		Rare
	National	State	National	State	National	State
Birds	1	21	3	16	4	63
Pelagic Birds	0	3	3	7	5	1
Mammals	1	13	3	4	2	9
Marine Mammals	0	2	2	3	2	11
Reptiles	0	4	0	2	1	6
Marine reptiles	0	1	1	2	2	0
Amphibians	0	0	0	2	1	2
Fishes	0	n/a*	0	n/a*	4	n/a
Flora	1	57	10	85	16	166

Note: Figures not additive due to overlap of state and nationally endangered and vulnerable species (e.g. a species may be listed as endangered at a state level but not a national level OR it may be listed at both national and state levels)

*Fish threatened at the state level are currently not included under the *National Parks and Wildlife Act 1972*. Freshwater fishes are, however, recognised and listed within the *Action Plan for South Australian Freshwater Fishes* (Hammer et al. 009). Three (3) critically endangered, six (6) endangered, three (3) vulnerable and two (2) rare species occur within the region.

Figure 15. Summary of threatened flora and fauna in the SE NRM Region (Source: Department for Environment and Heritage 2009)

Although only 13 percent of original native vegetation cover remains in the South East, the region is still home to a very diverse range of native plant and animal species. Many of these are shared with south west Victoria. Just over one quarter of all species are listed as threatened at either a state or national level, and around 76 percent are classified 'at risk'. There are several reasons why there are so many threatened species in the South East, including:

- The region is a 'transition zone' where climate ranges from temperate in the south arid in the north. This means that many species are at the end of their range in the South East and populations are limited.
- There are highly variable landscapes, soil and rainfall across the region. For example rainfall ranges from 850 millimetres in the south to 450 millimetres in the north.
- A unique geological history means the South East is home to species either not seen elsewhere, or only found in small populations in other places such as the Fleurieu Peninsula, Tasmania or alpine areas.

- The occurrence of a wide range of threatening factors that can impact on habitats and/or species.

The South East is made up of three bioregions– areas of common climate, geology, landform and vegetation. 'Corridor' projects aim to reconnect patches of native vegetation and wetlands across the fragmented landscape by revegetating links to these refuges or patches.

A full list of the threatened species of the region can be found here:
SE NRM Board (2010) South East Natural Resources Management Plan, Part One: Regional Description. Mount Gambier. Pp 45-47

Examples of threatened species in the South East

Orange bellied parrot – *Neophema chrysogaster*

EPBC Act listing status: critically endangered

State listing: endangered

The orange bellied parrot is one of the rarest birds in Australia, with only around 50 individuals left in the wild. They feed on, and near, the ground on seeds and fruits and coastal grasses. Adult birds reach about 21 centimetres in length. They migrate from Tasmania in the summer where they breed to the mainland in the winter to feed, staying within 1km of the coast.

Useful Links: http://birdlife.org.au/projects/orange-bellied-parrot-recovery

Photo Credit: Natural Resources South East

Yarra pygmy perch - *Nannoperca obscura*

EPBC Act listing status: vulnerable

State listing: endangered

Usually 3-4 centimetres in length, can grow up to 7.5 centimetres. Males develop jet black fins when spawning.

Prefers larger and more permanent water bodies rather than swamps, requires dense aquatic vegetation and feeds on a variety of invertebrates.

Threats include habitat loss, isolation of water bodies, pollution and the introduction of gambusia a non-native fish.

Useful Links: Yarra pygmy perch SWIFFT profile

Photo Credit: Mike Hammer

Little Dip spider-orchid - *Caladenia richardsiorum*

EPBC Act listing status: endangered

State listing: endangered

A perennial spider-orchid with a leaf 16-22 cm in length. Usually a singular yellowish-green flower, up to 40 mm wide, arises from a stem 20-40 cm in length. Flowering occurs from late September to early November, remaining dormant when conditions are unsuitable. It is very palatable to stock, thus coming under pressure when native areas along the coastal area are grazed. The orchid relies on a little wasp for pollination by deceiving the male wasp into thinking they are a female wasp.

Useful Links: [Little Dip spider-orchid Recovery Plan]

Photo Credit: Natural Resources South East

How might biodiversity look in the future?

The SE NRM Board has a plan for managing the regions natural resources. The plan outlines how the Board works closely with the community, landholders and other government agencies and partners to help conserve habitats and manage threats that impact on native species. It also outlines the number of different approaches to managing biodiversity in the region, including protecting habitats. The Board programs can make a significant impact on protecting the native plants and animals in the region.

Category	Resource Condition Target
Biodiversity	The condition and extent of terrestrial habitats in the South East will be improved
	The condition and extent of wetland habitats in the South East will be improved
	The conservation status of threatened species and ecological communities occurring in the South East will be maintained or improved
Land	The condition of land in the South East will be improved
	The adverse impacts of dryland salinity in the South East are reduced
Coast and Marine	The condition of marine habitats in the South East will be maintained or improved
People	The involvement of all members of the community in positive NRM activities will be increased
Water	The ability of ground water systems in the South East to support beneficial uses and ground water-dependent ecosystems will be maintained or improved
	The ability of surface water systems in the South East to support beneficial uses and surface water dependent ecosystems will be improved

Figure 16. SE NRM Resource Condition Targets for natural resources in the South East

The Plan is a comprehensive document and outlines the key areas of focus for the Board. This includes goals for:

- Landscapes and biodiversity
- Regional community involvement

- Industry and sustainable use of natural resources
- Partnerships for effective natural resources management

The plan also includes details regarding 'resource condition targets' to be achieved for the region by 2030. These are divided into key categories, outlined in the following table:

A copy of the full SE NRM plan can be found on the website here.

Wetlands in our landscape

What is a wetland?

The word 'wetland' is used to describe areas that are either regularly or permanently inundated with water. So what makes a puddle different from a wetland?

Water is the key to wetlands and patterns of wetting and drying determine what a wetland looks like and what species call it home. The significant indicator of a wetland is that it supports animals and plants that need water to complete all or part of their lifecycle. Many wetlands also contain hydric soils, which are soils that have formed in the presence of water.

Australia is a dry continent and most wetlands in Australia experience a dry phase, some of which can last for years. Because of these changing conditions wetlands tend to be very dynamic and flexible environments that support a wide range of specially adapted plants and animals.

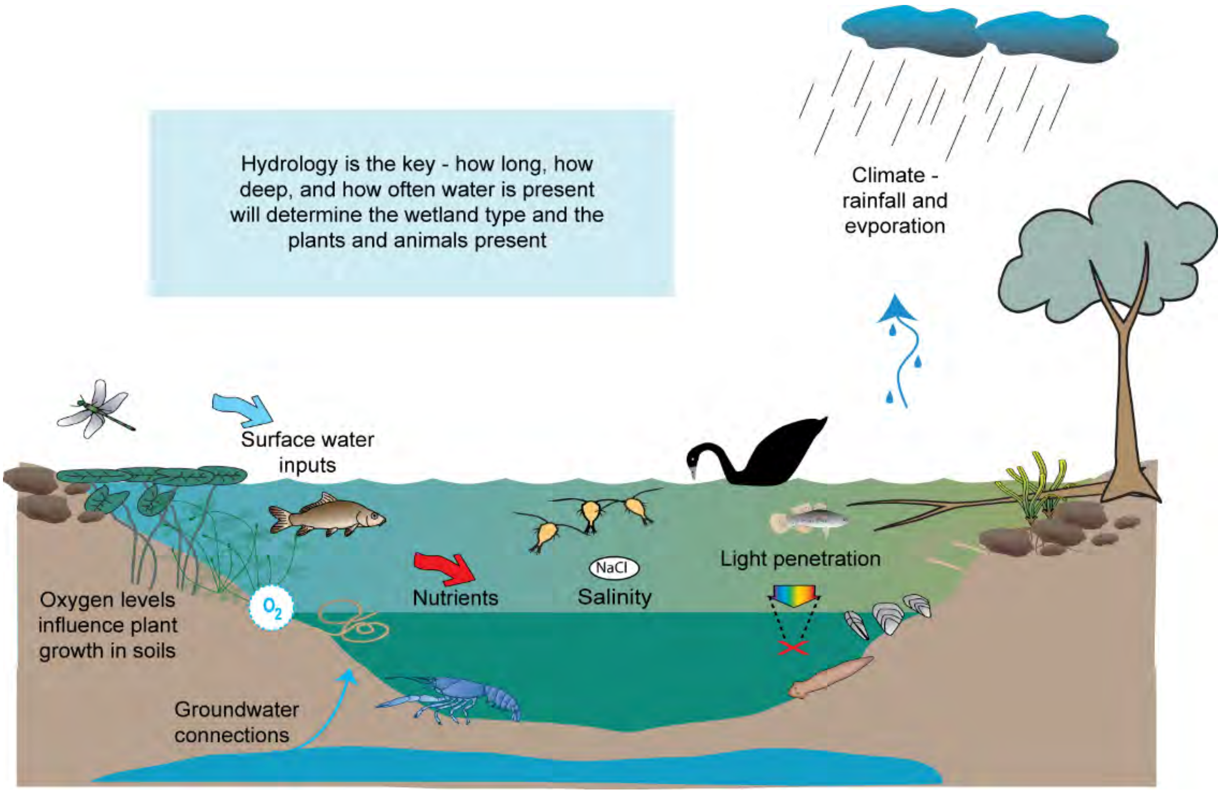


Figure 17. Key elements of wetland ecology include climate, water source and quality, soils and wetland plants and animals.

What types of wetlands are there in the South East?

Wetlands fall into three major categories:

- Permanent wetlands hold water all year round (although the level may drop during dry times).
- Seasonal wetlands hold water regularly at certain times of year.
- Ephemeral wetlands may dry out for years at a time, but reappear when enough rain has fallen.

Wetland types depend on various factors including:

- How long is water present?
- Is the water fresh or brackish or salty?
- Where does the wetland occur?

Currently less than 1 percent of the known wetlands in the South East region are permanent.

Wetlands can fall into several different categories, which can make it tricky to identify what type is actually is! Really it comes down to the water and how long, how much and how often the water is present. Wetlands can be broadly categorised into the following:

Freshwater meadows – very shallow (20-30 centimeters deep), often small, annual wetlands that are common in the inland parts of the region. They are common 'puddles in paddocks' seen throughout the region. For example; Penola and Dismal Swamp area.

Grass sedge wetlands – these can be temporary or permanent. Usually 50-100 centimeters deep, and have a high presence of grasses and sedges, with very little open water. These are the most common of the wetland types in the South East. Some examples are Deadman Swamp and Lake Frome.

Soaks, springs and peat swamps – these occur where groundwater seeps out of the ground under pressure. Not always recognized as wetlands, however they are some of the most unique wetlands in the region! This type of wetland is often found near the coast, but sometimes occur further inland. Examples include parts of Pick Swamp, springs of the Mosquito Creek catchment.

Saline swamps and salt lakes – Due to the salty nature of these wetlands you will find low lying salt tolerant plants growing in these areas, and a lack of trees. These are some of the largest wetlands in the region, and are often thought to have low biodiversity value. Whilst they often have a low variety of different species, they do have large numbers of individuals within each species. Examples in the South East include Butchers Lake, Lake Eliza and Lake George.

Coastal dune lakes – as the name suggests, these wetlands occur within the coastal dunes. They range in size from small to medium and can be freshwater or brackish. These can be permanent or temporary and range in depth greatly. Some examples include Lake Robe, Little Dip and the wetlands around Nora Creina.

Karst wetlands – these are very rare around the world, and therefore very important. They are formed in holes created by the dissolution of limestone that is plentiful throughout the region. They are found only in the Lower South East and includes sink holes such as the Little Blue Lake. They are a permanent wetland and therefore an important source of refuge in the summer months and though drought. Other examples include Piccaninnie Ponds, Ewens Ponds, and Death Hole.

Inland interdunal wetlands – this wetland type forms in basins in the lowest part of the flats between dune systems. They are fed by local water runoff and surface water from the catchment. These wetlands tend to be shallow, and often seasonal filing annually or every few years. Examples include Tilley Swamp wetlands, West Avenue wetlands and Kungari.

Terminal lakes – forming basins at the bottom of creeks and streams, the water naturally sits in the basin until it evaporates. These lakes are usually large and quite shallow, ranging from 0-150 centimeters in depth. Terminal Lakes are usually temporary, but may take a long time to empty following a fill event. They provide excellent habitat for water bird breeding and are also important for fish and frog species. Local Examples include Bool Lagoon and Cockatoo Lake.

Permanent freshwater lakes – as the name suggests, these have water all year round. Most are more than two meters deep and can be quite large. This wetland type is particularly important for animals and plants during periods of dry. Whilst rare across Australia, there are several in the South East, including Blue Lake, Valley lake, Lake Edward and Lake Leake.

Source: Herpich, M. and Butcher, R. 2014 (2nd Edition). All wetlands great and small: A guide to the wetland diversity of the South East. Produced for the Department of Environment, Water and Natural Resources. Mount Gambier South Australia.

Why are wetlands important in our landscape?

Wetlands are important features in the landscape that provide many benefits! Providing habitat for wetland animals, as well as food and water for species that pass through these areas, they also protect and improve water quality, store floodwaters, help recharge groundwater and maintain surface water flow during dry periods. An enormous variety of species of micro-organisms, plants, insects, amphibians, reptiles, birds, fish and mammals make up and depend on wetland ecosystems.


Black Swans Hacks Lagoon

These valuable functions are the result of a combination of shallow water and high nutrient levels provide perfect conditions for a wide variety of micro-organisms to flourish. These little creatures form the base of the food web, feeding many species of fish, amphibians and insects. In turn, many species of birds and mammals rely on wetlands for this source of food and water as well as the habitats they provide. Some wetlands are also important for particular species of birds during migration and breeding.

Wetlands can also store carbon within their plant communities and soil instead of releasing it to the atmosphere as carbon dioxide. Therefore wetlands can play a role in assisting to manage global climate change conditions.

Wetlands function as natural sponges that trap and slowly release surface water, rain, groundwater and flood waters. Trees, shrubs, roots and other wetland vegetation also slow the speed of flood waters over a floodplain or swale area. Wetlands themselves also provide an important role in water storage. All of these factors can reduce the impact of possible flooding, as well as assisting to reduce the impact of erosion across the landscape and provide an important source of water.

What are the threats to wetlands in the South East?

Broadly speaking, the greatest threat to wetlands is human activity and this includes:

- Changes in hydrology (or water flow)
- Water pollution including increased nutrient levels
- Introduction of plants and animals
- Clearance of land, for agriculture and forestry
- Groundwater extraction due to irrigated crops and pastures

Progressive encroachment on, and loss of, wetlands causes serious and sometimes irreparable environmental damage, and greatly reduces the benefits wetlands provide to ecosystems.

Seasonally inundated paddocks near Wrattonbully after summer rainfall 2016

Prior to European settlement wetlands covered around 46 percent of the region's landscape (Fig. 18). Around 95 percent of the wetlands in the South East have been lost due to drainage and vegetation clearance (Fig. 19). They now account for less than seven percent and much of the remaining wetland area is severely degraded. Unfortunately this is not isolated to the South East, across Australia more than half of the wetlands have been exploited for other uses such as agriculture or urban development. Piccaninnie Ponds and Bool and Hacks Lagoons are several of the few remaining wetlands in the South East that maintain a permanent or semi-permanent water supply.

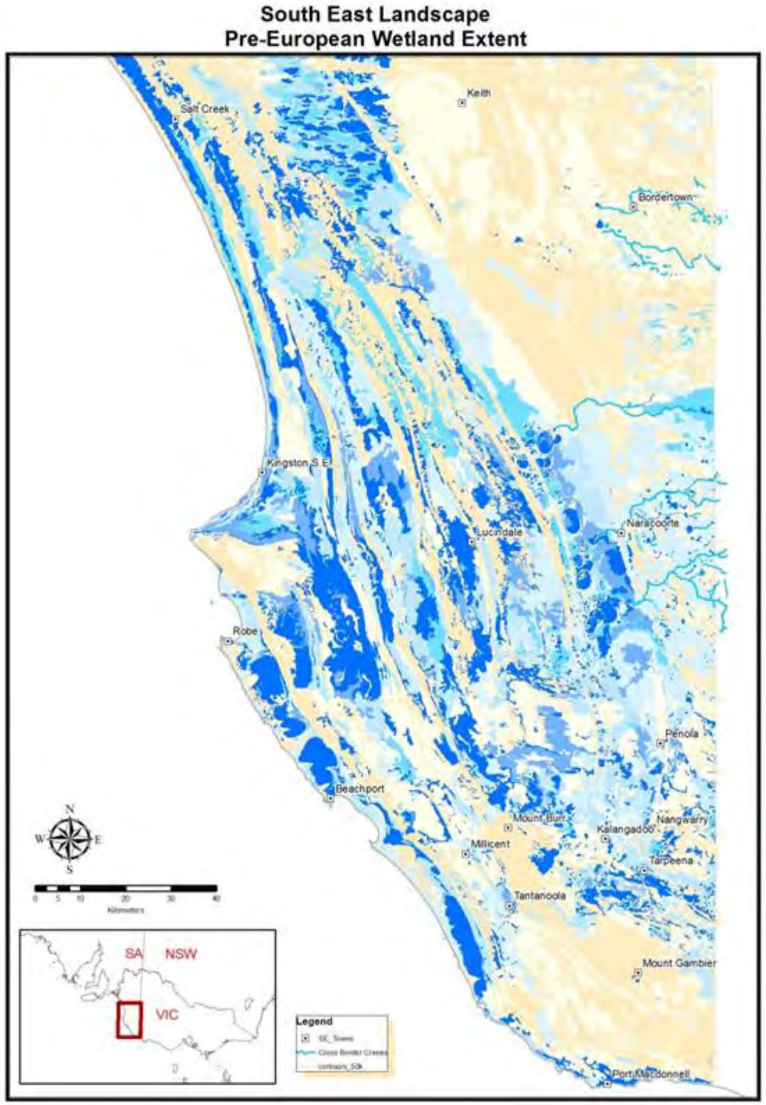


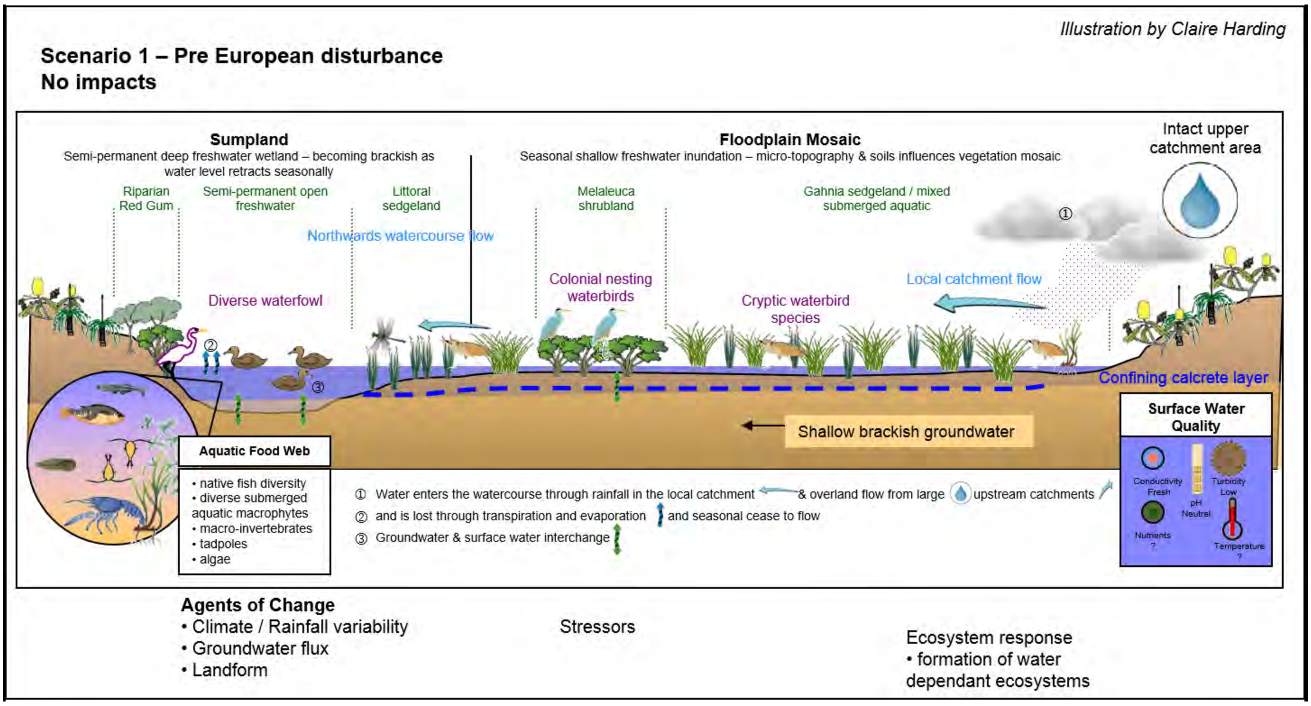
Figure 18. Prior to european settlement wetlands in the South East region covered around 46 percent of the landscape.

Figure 19. Current extent (2014) of wetlands and drainage network in the South East region, wetlands now account for less than seven percent of the landscape.

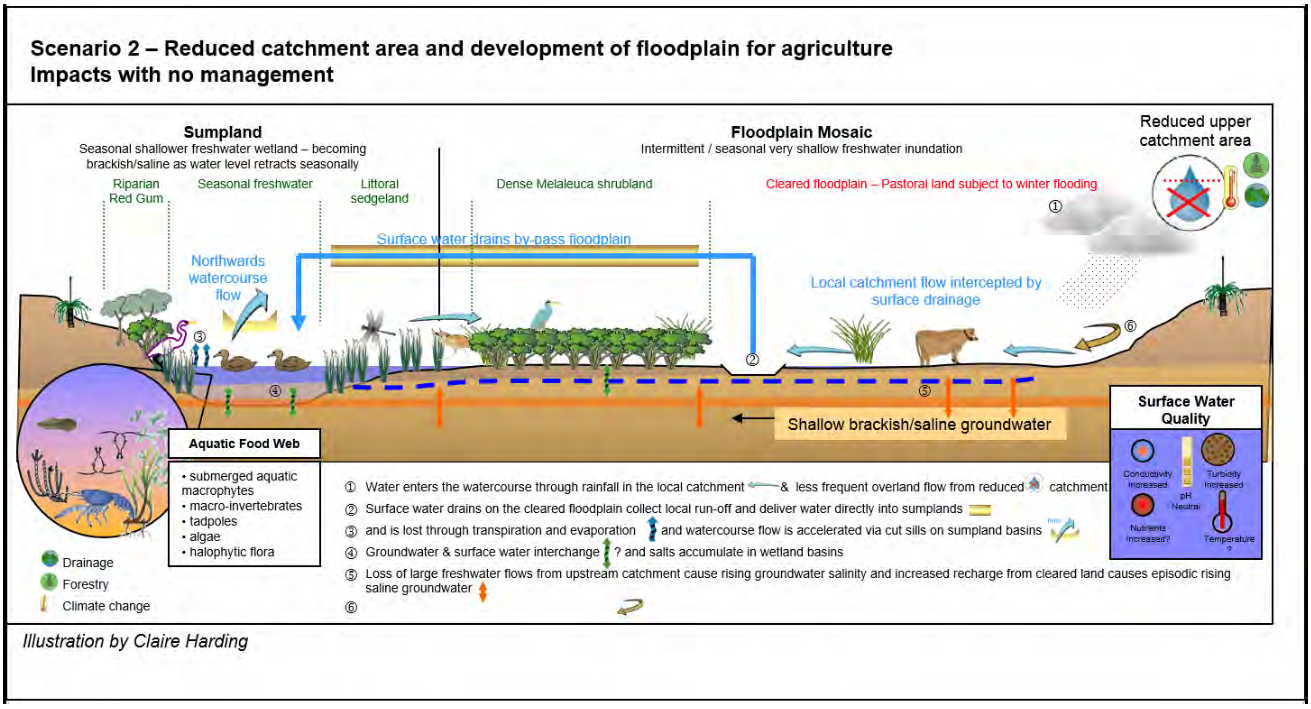
How have wetlands changed over time?

The following sequence of charts depicts how wetlands within the region have undergone transformation from pre European settlement, to post drainage farming of the landscape. They then look at how restoration of some of these regional wetlands is occurring and what the final goal of restoration is.

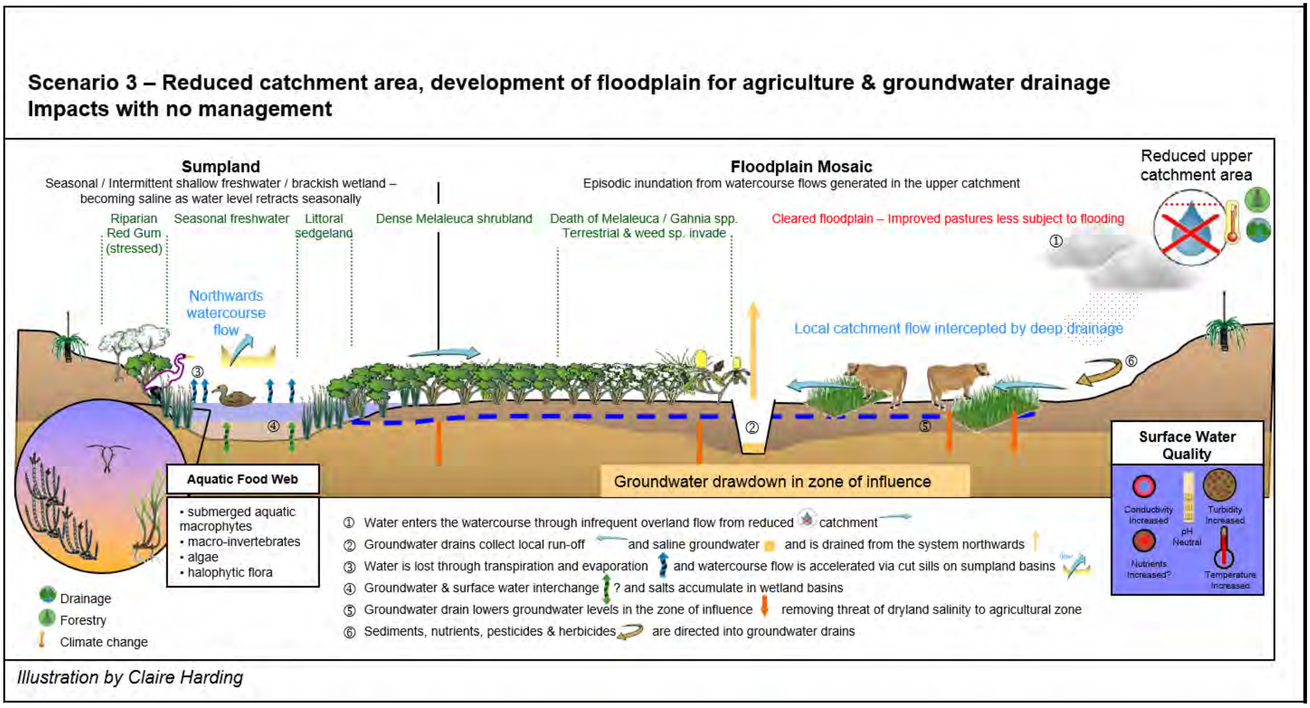
200 years ago



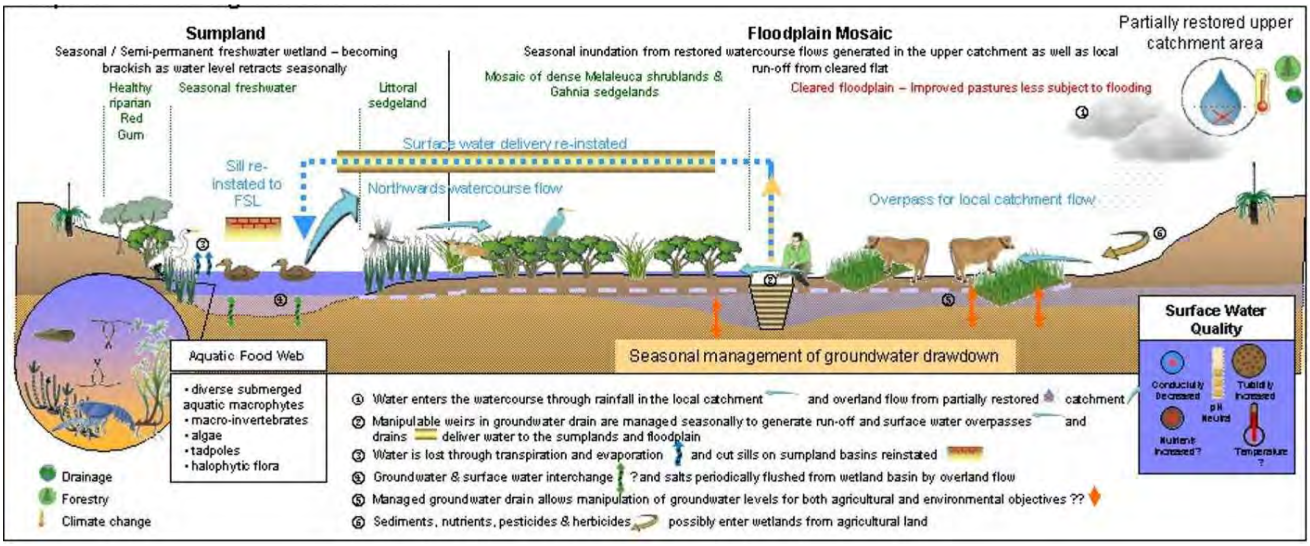
1900-1980's



Early Upper South East drains



The ultimate goal of managing water in our landscape



Soil Types in our Landscape

What types of soil are there in the region?

Within the South East region there are 62 different types of soil (appendix x) of these about 37 make up the main soil types of the region. These soil types are grouped into 14 different soil groups (figure 20. with similar characteristics and management methods as follows:

Soil Group Type	Hectares	% of region
Calcareous soils	49,044	1.8%
Shallow soils on calcrete or limestone	805,062	29.9%
Gradational soils with highly calcareous lower subsoils	29,956	1.1%
Hard red-brown texture contrast soils with neutral to alkaline subsoil	24,766	0.9%
Cracking clay soils	71,263	2.6%
Deep loamy texture contrast soils with brown or dark subsoil	136,947	5.1%
Sand over clay soils	601,914	22.4%
Deep sands	485,259	18.0%
Highly leached sands	117,197	4.4%
Shallow soils on rock	1,085	0.04%
Deep uniform to gradational soils	51,793	1.9%
Wet soils	205,736	7.6%
Volcanic ash soils	15,852	0.6%
Rocks	44,368	1.6%
Water	51,677	1.9%
Total Regional Hectares	***2,691,918***	

Figure 20. Hectares of different soil groups in the South East region.

Each soil grouping is broken down into sub groups, for example the Calcareous Soils sub group has 8 different soil types within it as shown in the chart to the right.

Even though each of these soil types may be grouped as Calcareous soils each will have a different look and chemical composition. Although they share some form of physical attribute that allows them to be grouped together.

These sub groups will be explained more in the second part of this section on soils.

Calcareous soils	**49,044**
Highly calcareous sandy loam	2,044
Calcareous loam on rock	0
Deep moderately calcareous loam	6
Deep (rubbly) calcareous loam	10,546
Rubbly calcareous loam on clay	5,783
Gradational calcareous clay loam	4,446
Calcareous clay loam on marl	25,676
Gypseous calcareous loam	543

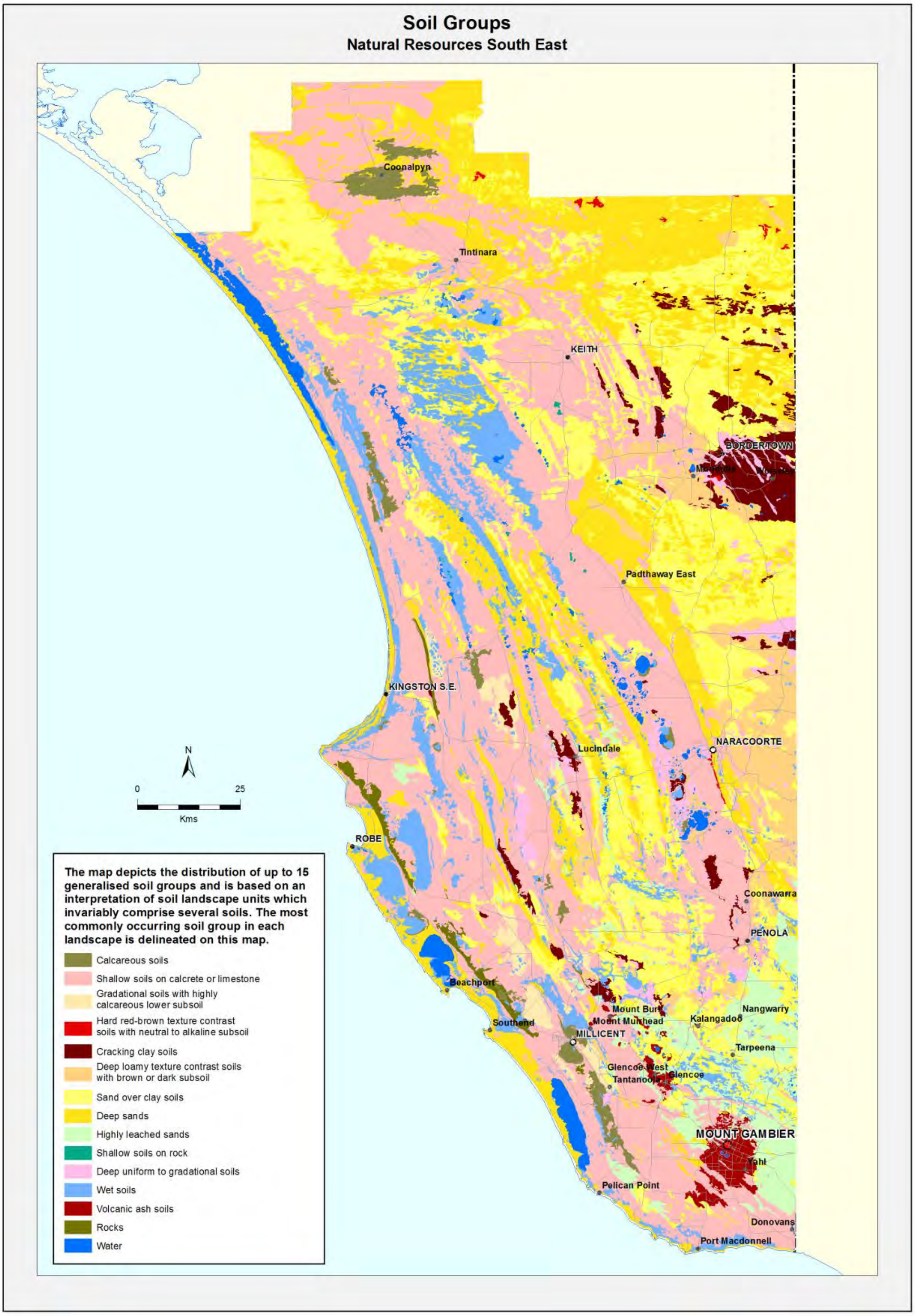


Figure 21. Regional map of the south east region depicting the distribution of soil type groupings across the regional landscape.

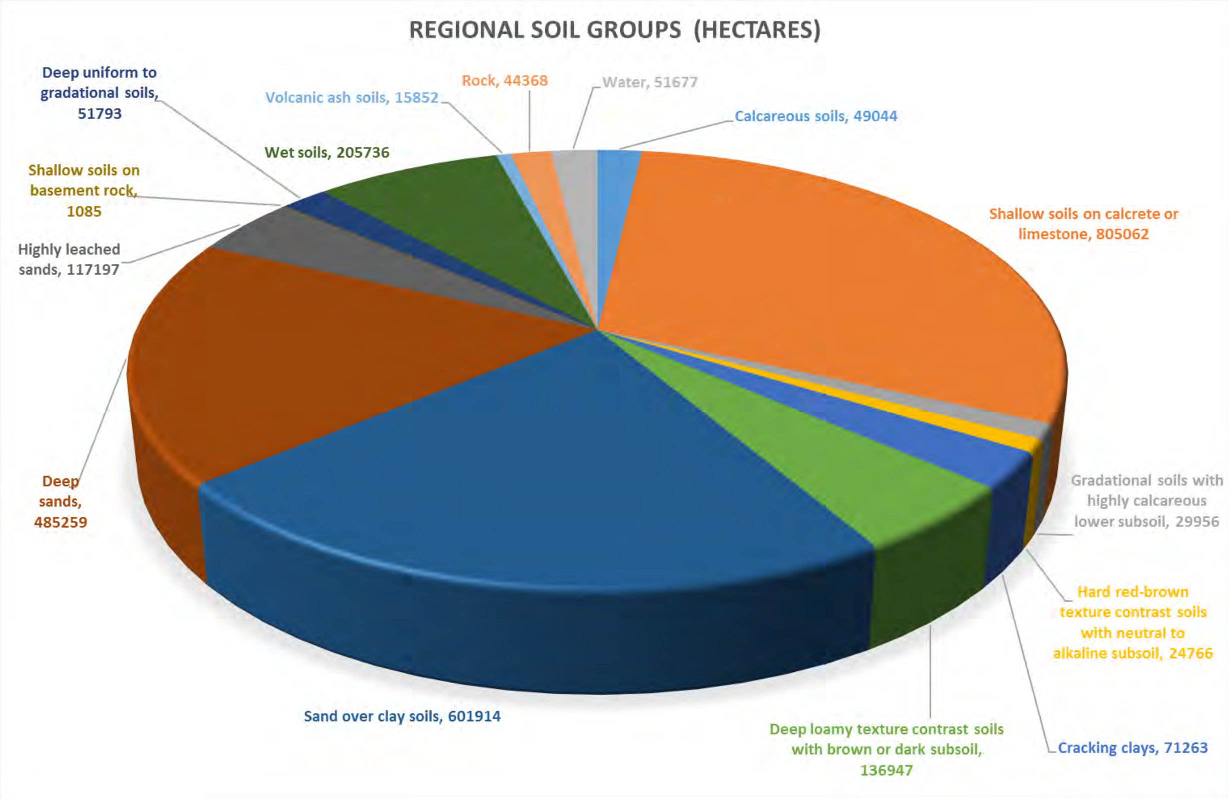


Figure 22. Representation of the percentage of each soil group present in the region

These soil groups occur across the different landscape subregions across the South East. The area of each soil group in relation to each Landscape Subregion is broken down in the following table:

	Soil Group	Landscape Subregions			
		Dunes & Flats	Mallee Woodlands	Ranges & Cross Border Creeks	Volcanic Plains and Southern Dunes
A	Calcareous soils	20,973	15,815	5	12,251
B	Shallow soils on calcrete or limestone	409,610	218,026	33,665	143,744
C	Gradational soils with highly calcareous lower subsoil	13,161	3,363	44	13,387
D	Hard red-brown texture contrast soils with neutral to alkaline subsoil	1,730	14,030	8,574	431
E	Cracking clays	13,566	22,593	25,290	9,814
F	Deep loamy texture contrast soils with brown or dark subsoil	10,585	34,144	77,888	14,330
G	Sand over clay soils	145,251	254,949	101,370	100,344
H	Deep sands	130,833	254,138	62,878	36,848
I	Highly leached sands	28,126	0	5,685	83,386
L	Shallow soils on basement rock	358	318	31	378
M	Deep uniform to gradational soils	22,989	852	16,022	11,930
N	Wet soils	141,719	15,301	4,058	44,657
O	Volcanic ash soils	0	0	0	15,852
R	Rock	29,118	29	592	14,626
W	Water	25,900	15,005	941	9,831
	Total area by hectare	993,919	848,561	337,045	511,808

Calcareous soils

1.9%
of the regions soil

Source: Hall et al 2009

The dominant feature of this soil type is that it is calcareous throughout the soil profile.

The presence of carbonate is generally beneficial but can limit availability of some nutrients required by plants.

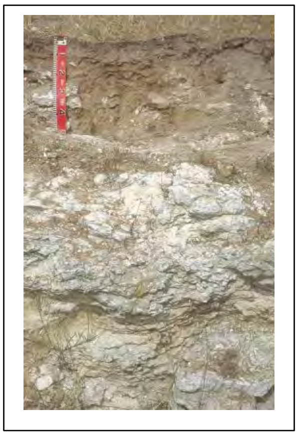
Lighter textured types of this soil are prone to wind erosion.

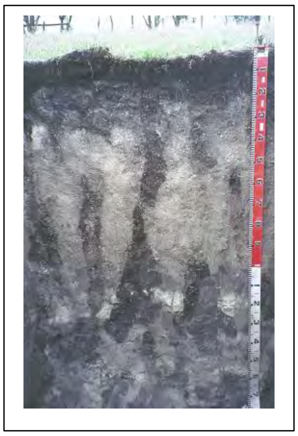
More finely textured types of this soil can be highly productive.

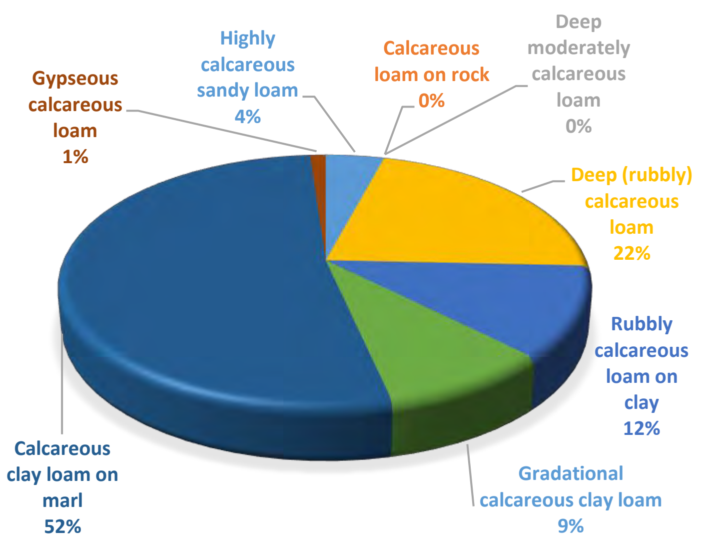
Generally found in the low to moderate rainfall districts.

Largely used for rain fed cropping and some irrigated cropping.

Examples from the South East



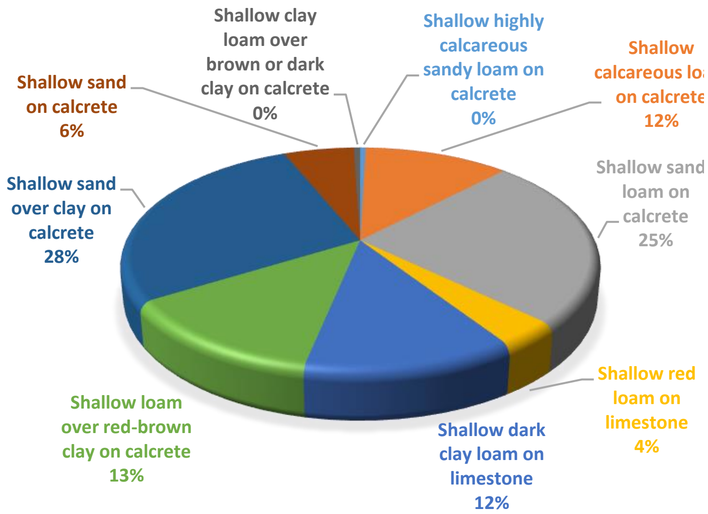


Highly calcareous sandy loam	2,044 ha
Calcareous loam on rock	0 ha
Deep moderately calcareous loam	6 ha
Deep (rubbly) calcareous loam	10,546 ha
Rubbly calcareous loam on clay	5,783 ha
Gradational calcareous clay loam	4,446 ha
Calcareous clay loam on marl	25,676 ha
Gypseous calcareous loam	543 ha

Shallow soils on calcrete or limestone

29.9%
of the regions soil

Source: Hall et al 2009

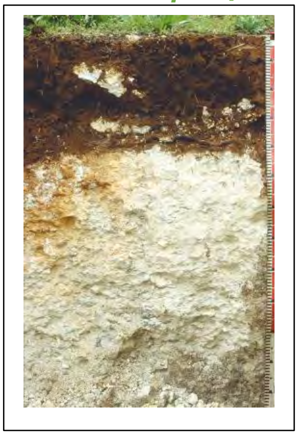


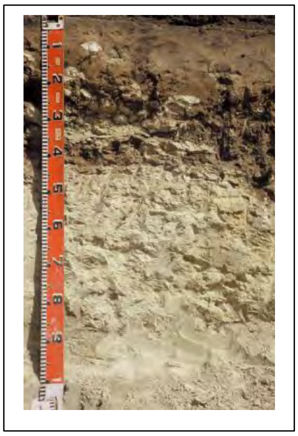
Soil profiles are variable, but all are underlain by a hard carbonate-rich layer of calcrete, calcrete-capped limestone or calcarenite (or occasionally uncapped limestone) — at a depth of 50 centimetres or less.

The calcrete is often fractured, and its thickness can vary from a few centimetres to many metres.

Hard carbonate layers act as an impediment to plant root growth and drainage — the degree depends on the thickness and extent of fracturing.

Examples from the South East



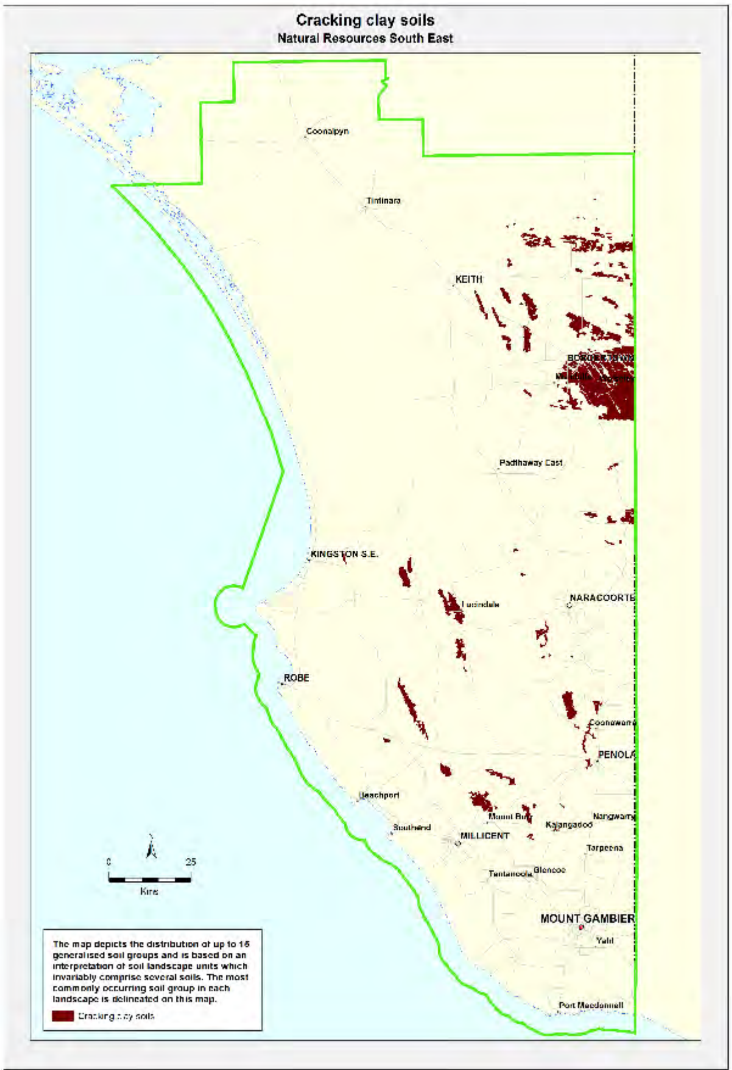


Highly Calcareous sandy loam on cal.	3,606ha
Calcareous loam on calcrete	94,317 ha
Sandy loam on calcrete	201,111 ha
Red loam on limestone	29,019 ha
Dark clay loam on limestone	100,679 ha
Loam over red brown clay on cal.	104,500 ha
Sand over clay on calcrete	222,128 ha
Sand on calcrete	45,585 ha
Clay loam over dark clay on cal.	4,117 ha

Cracking clay soils

2.6%
of the regions soil

Source: Hall et al 2009



Soil profiles are uniformly textured and clayey throughout.

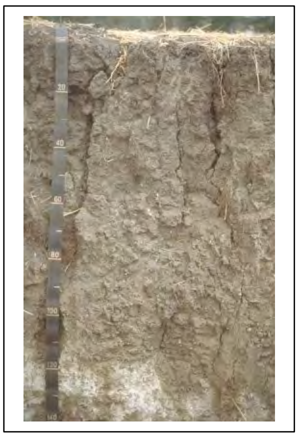
They are usually underlain by unconsolidated clayey materials, often of alluvial origin.

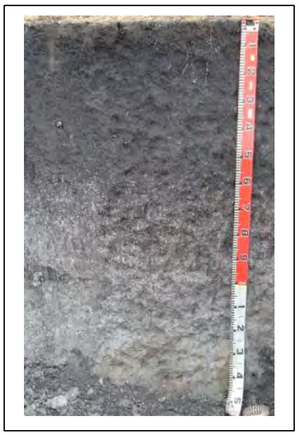
Soil profiles are dominated by smectitic clay minerals (e.g. montmorillonite), which expand when moist and contract when dry.

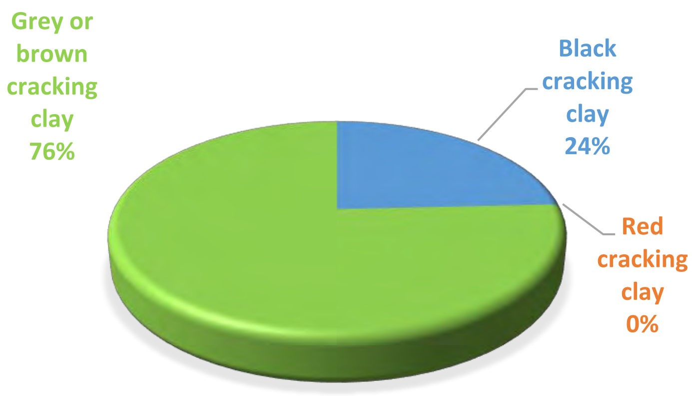
This causes the soil as a whole to swell when wet, but also to shrink and crack upon drying.

Large cracks, which penetrate from the surface to the subsoil, and can be as wide as ten centimetres, develop in dry soils

Examples from the South East





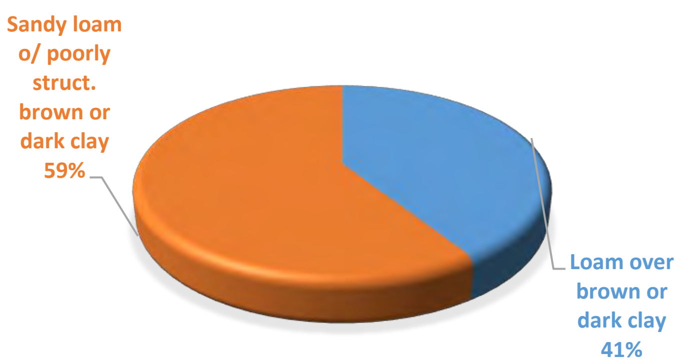



Black Cracking Clays	17,285ha
Red Cracking Clays	5ha
Grey or Brown Cracking Clays	53,973ha

Deep loamy texture contrast soils

5.1%
of the regions soil

Source: Hall et al 2009



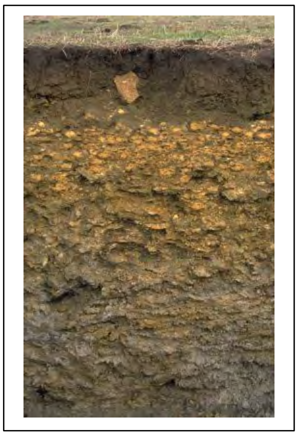
Soil profiles are characterised by a distinct break between the topsoil and a subsoil with significantly higher clay content.

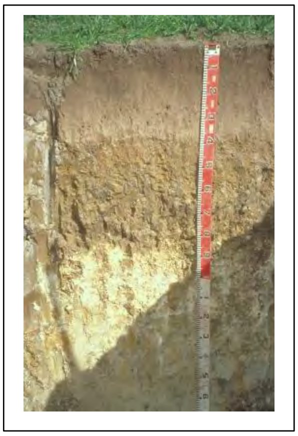
The most common topsoil texture is sandy loam; subsoils are clayey.

Underlying materials are predominantly unconsolidated clays that have been formed or deposited in a variety of ways.

For example: in situ formation from underlying rock (especially in high-elevation situations), or deposition as alluvium or outwash derived from basement rock highs.

Examples from the South East



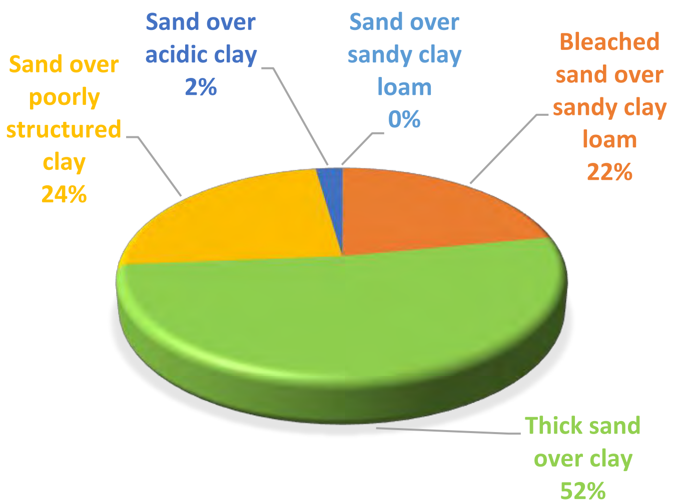


Loam over brown or dark clay	56,100ha
Sandy Loam over poor structured brown or dark clay	80,847ha

Sand over clay soils

22.4%
of the regions soil

Source: Hall et al 2009



Soil profiles are characterised sandy topsoil, which is typically loose to soft (unless compacted), and a distinct colour and texture boundary between topsoil and subsoil.

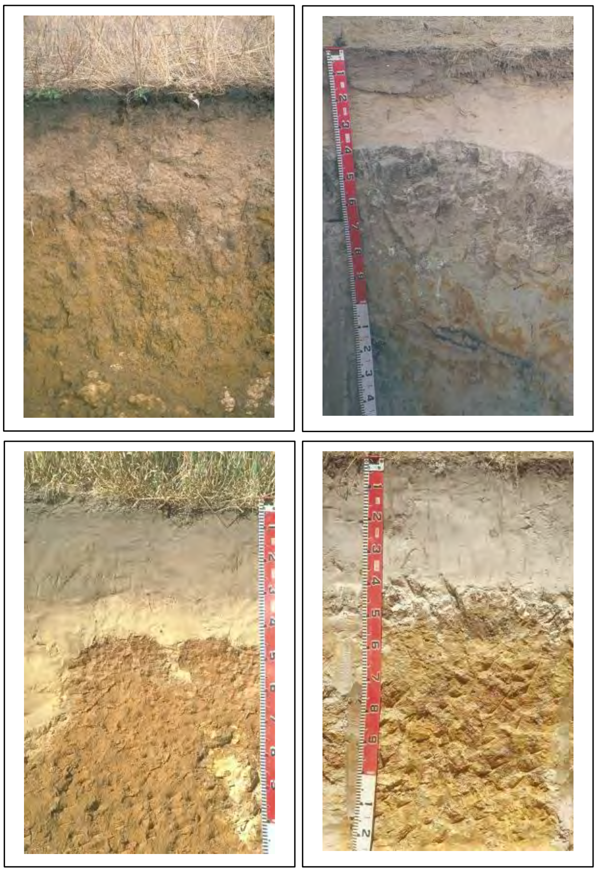
Profiles are predominantly texture-contrast.

Subsoil textures are usually clayey or clay loamy, while subsoil structure ranges from massive to coarse.

Clay translocation has been a dominant soil-forming process in many profiles.

Underlying materials are predominantly unconsolidated, ranging from clays to clayey sands.

Examples from the South East



Sand over sandy clay loam	185ha
Bleached sand over sandy clay loam	131,995ha
Thick sand over clay	311,639ha
Sand over poorly structured clay	144,460ha
Sand over acidic clay	13,634ha

Deep sand soils

18%
of the regions soil

Source: Hall et al 2009

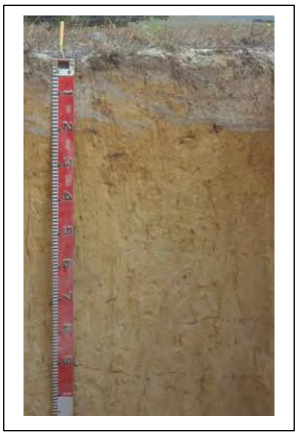
Soil profiles are characterised by sandy textures, apedal structure, and loose to soft surfaces.

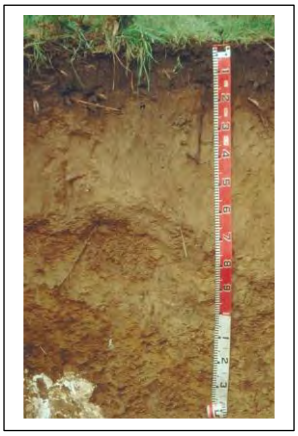
They have formed in sediments deposited and reworked by wind.

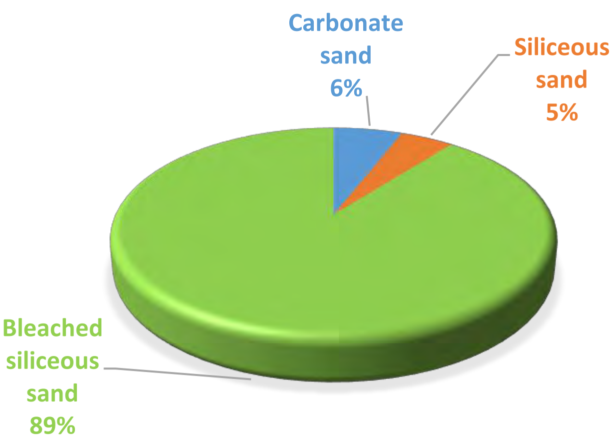
The extent of leaching within profiles varies from slight to high, with rainfall and age of deposition the main determinants.

They mostly occur on linear or jumbled inland dunes, coastal dunes, sand spreads, and old coastal dune ranges.

Examples from the South East



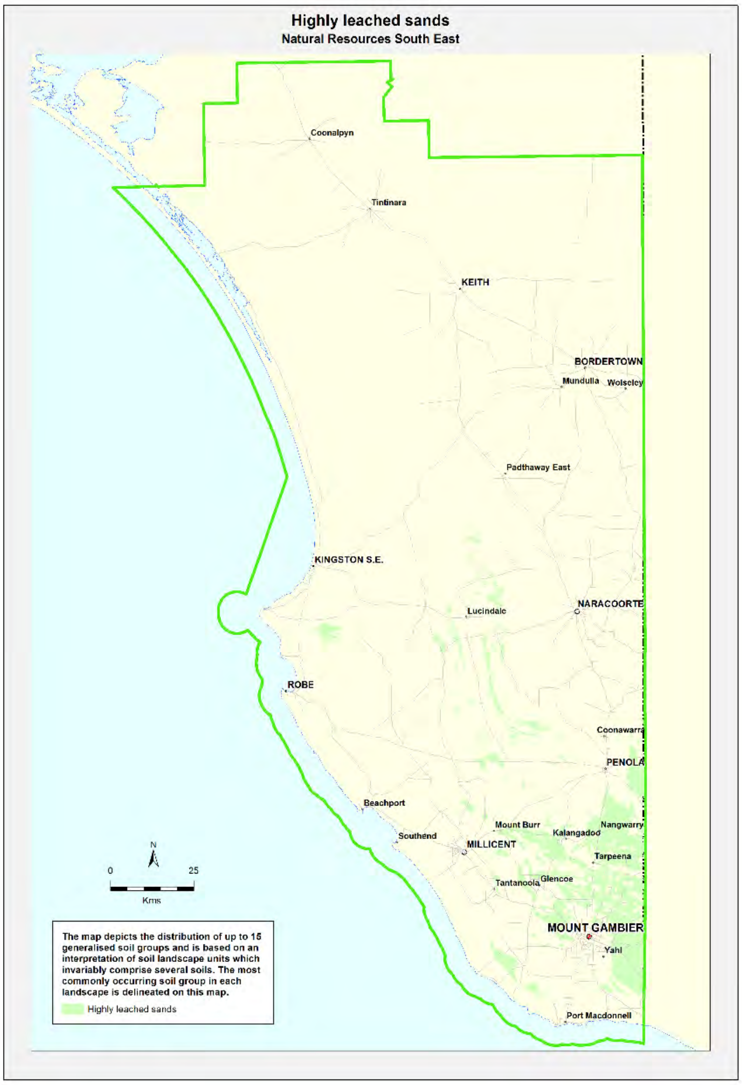


Bleached siliceous sand	28,977ha
Carbonate sand	22,416ha
Siliceous sand	433,867ha

Highly leached sands

4.4%
of the regions soil

Source: Hall et al 2009

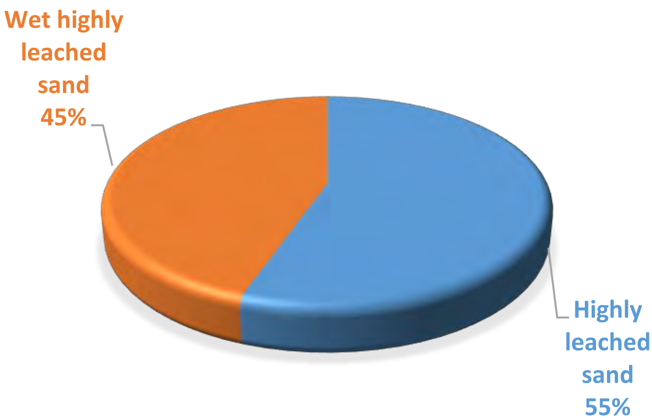


Soils are characterised by sandy textures, apedal structure, strongly bleached subsurface layers, and a subsoil accumulation of amorphous organic-aluminium and aluminium-silica complexes, with or without iron.

These are highly leached, acidic and infertile soils, formed in sandy sediments that were variously deposited by wind, water and, possibly, glaciers.

They occur on dunes, plains, rises, old coastal dune ranges and in valleys and depressions, and are also sometimes associated with hillside soaks.

Examples from the South East

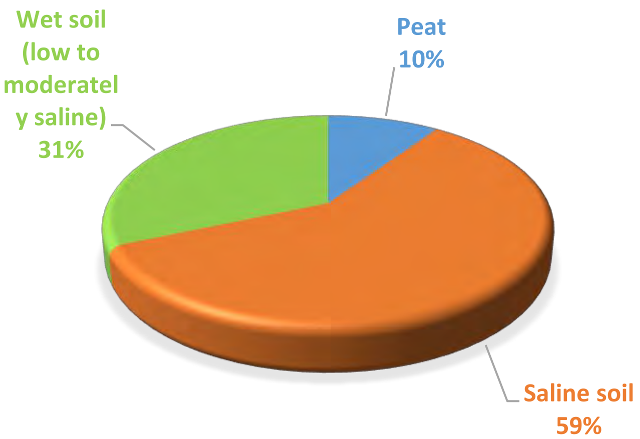


Highly leached sand	64,906ha
Wet highly leached sand	52,291ha

Wet soils

7.6%
of the regions soil

Source: Hall et al 2009

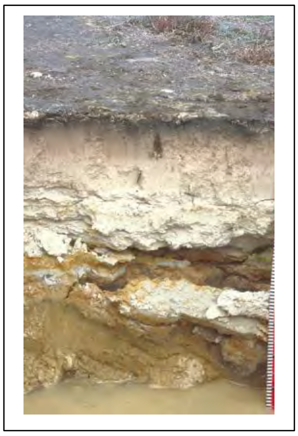


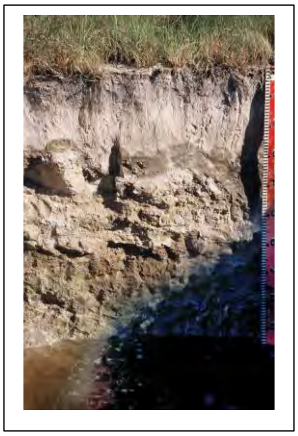
Soil profiles are saturated over the majority of their thickness for at least two to three months a year, and many are subject to seasonal inundation.

Indicative conditions include a seasonal water table within one metre of the surface, poor to very poor drainage, high to extreme water table-induced salinity, or the presence of peat.

The degree to which soils are wet, salty, peaty or flooded influences land use and management.

Examples from the South East



Wet soil – moderate to low saline	64,741ha
Peat	19,638ha
Saline soil	121,357ha

Drainage through the landscape

Why are there drains through our region?

The topography of the region provides little natural relief for surface water runoff. This, in combination with the presence of the shallow unconfined aquifer and relatively high rainfall, has historically resulted in surface water inundation (flooding) on the interdunal plains most years.

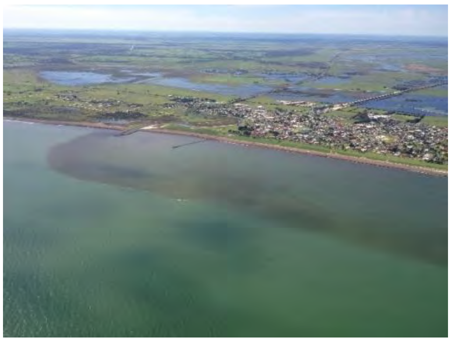
The South East Drainage Network has several purposes, which depend upon the geographical location and requirements of the particular part of the network. They are:

1. To remove floodwaters caused by significant annual rainfall events and mitigate the impact of large-scale, prolonged inundation of production land and groundwater recharge - requiring surface water drainage.
2. To drain saline groundwater from the upper soil profile in 'at risk' parts of the landscape and mitigate the effect of salinity in the root zone of pasture and native plant species – requiring deeper drainage.
3. To provide for appropriate environmental flows to key wetland systems of regional, national and international significance - requiring flood-ways and regulators for manipulation of fresh surface water resources.

Whilst drains themselves are relatively simply formed earthwork structures, it is complex and challenging to develop and operate an extensive network of drains to achieve all three objectives. Particularly in a very large and extremely flat landscape where large volumes of water can accumulate (during wet climatic periods) and through which water naturally moves quite slowly.

How long did it take to build the drains?

Dating back as far as 1864, an extensive artificial drainage network was engineered throughout the Lower South East (LSE), with initial drain construction near Millicent (South East Catchment Water Management Board 2003).



The drainage network in the LSE expanded steadily through the late 1800s up to 1950, primarily channelling surface waters to the north. The construction of the Jackie Whites and Blackford drains from 1950-1972 finally diverted drain water to the coast instead. Each drain is given a name, much like a road, to allow for easy identification.

Since this time, the private network of shallow drains has expanded considerably and from 1997 – 2009 the Upper South East (USE) Dryland Salinity and Flood Management Program was implemented to address the effects of salinity and waterlogging in the USE. This program saw the construction of a number of major channels such as the Fairview and Bald Hill drains, adding an additional 714 kilometres of drains in the USE. This was additional to the 1,875 kilometres of infrastructure that already existed in the LSE (Department for Water 2012).

What happens to all the water?

Historically, quantities of freshwater flowed into the Coorong South Lagoon from the South East. This source of freshwater has been reduced over the past 150 years since the construction of the drainage network.

The drains have significantly changed the natural flow of water in the region. Historically water moved south to north along the flats between the dunes, nowadays it moves east to west across the region through these manmade channels. The outlets for these drains all end at the ocean with some (such as drain L) travelling through wetlands and lake basins along the way.

What happens to eco systems that are dependent on surface water?

Many of the seasonal wetlands in our region are dependent on surface water either flowing to them or being held up in the landscape, unfortunately drains have the opposite effect. The aim of a drain is to remove this water as quickly as possible, however there is an opportunity to find balance through careful management of water flows using tools to 'regulate' the amount of water that moves through the drainage network.

Structures such as weirs and regulators do this job and have been installed at various points throughout the drainage network (Fig. 24). These tools assist in managing the flow path of water throughout the region. In recent years much work has been done to identify wetlands in the region which are surface water dependant. The aim has been to manage flows to ensure these areas are fed water as often as possible and for appropriate periods of time.

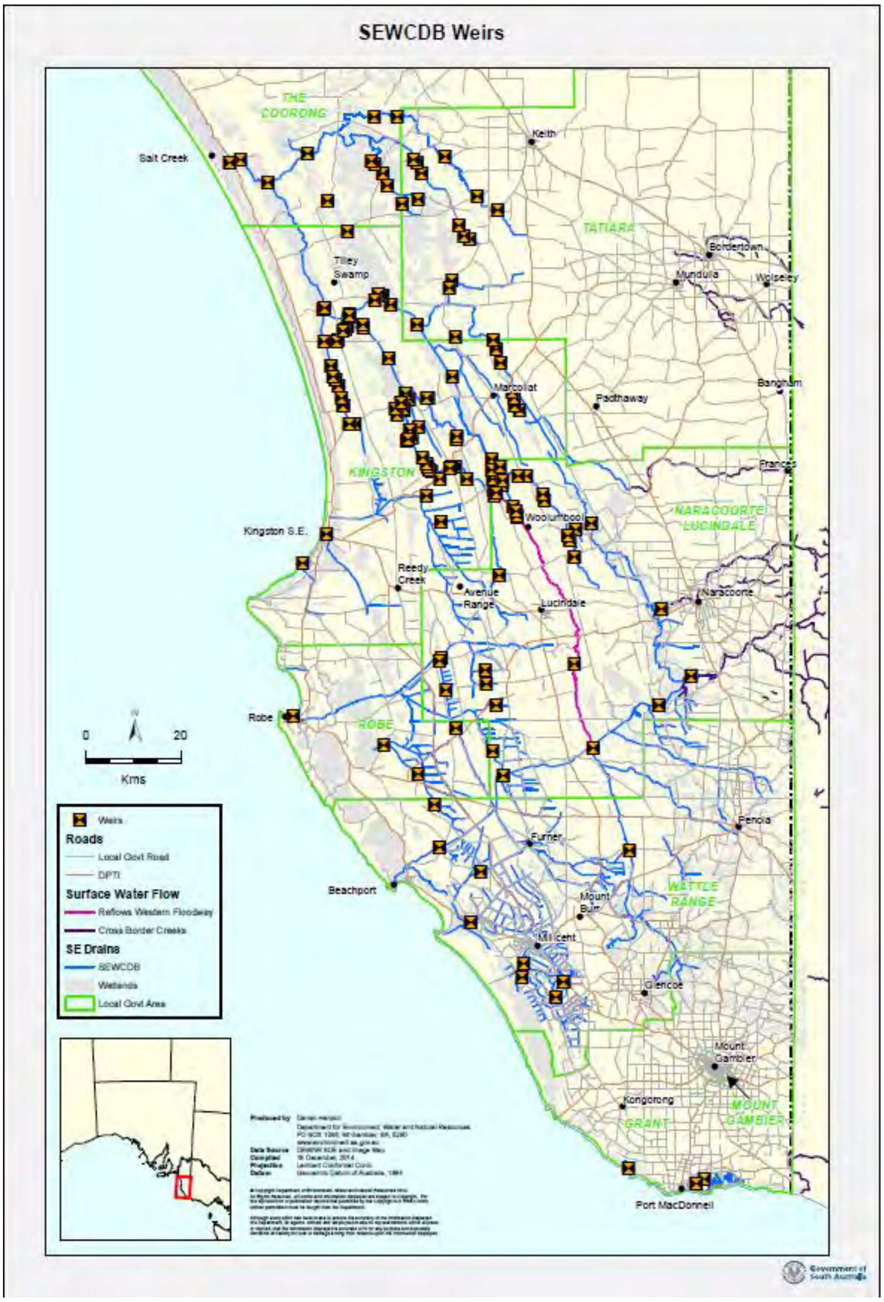


Figure 24. Location of weirs installed throughout the SE Drainage Network

Are drains changing?

The South East Drainage Network is constantly under development! For example, the $60 million South East Flows Restoration Project (SEFRP) has plans to add to the drainage network. This investment made by the State and Federal Governments aims to:

- assist salinity management in the Coorong South Lagoon
- enhance flows to wetlands in the Upper South East
- reduce drainage outflow at Kingston SE beach.

The SEFRP is proposing a new channel to connect existing areas of the network. This would provide capacity to deliver a median volume of up to 26.5 gigalitres (GL) per year directly into the Coorong South Lagoon, with annual volumes between 5-45.3GL per year. It will also allow the delivery of water to local wetlands along the flow path, where landholder approval is granted.


Coorong South Lagoon

The project area extends from the existing Blackford Drain to the Salt Creek outlet and into the Coorong South Lagoon, covering 93.4 kilometers.

The SEFRP will construct a 13 kilometer channel from the Blackford Drain to the southern end of the Taratap Drain (Fig. 24) and widen existing Taratap and Tilley Swamp drains (approximately 81 kilometers) to a capacity of 600ML/day.

As water approaches Tilley Swamp, the Tilley Swamp Watercourse will be used to transport it to the Coorong and Tilley Swamp Drain. This will be particularly useful in years where faster water transfer is required.

The Tilley Swamp Watercourse, a natural wetland system, covers an area of 6,100 hectares and can store up to 42GL of water. This provides the SE Water Conservation and Drainage Board (SE WCDB) - who are responsible for managing the drain network - the flexibility to deliver water to the Coorong when required, assisting in the management of salinity and the ecological health of the Coorong South Lagoon.

Planned water storage in the Tilley Swamp Watercourse will also restore and promote wetland ecology in the region by recreating aquatic habitat for birds, fish, frogs and vegetation.

SEFRP Alignment and Water Flows
Floodway South - Blackford to Henry Creek Road

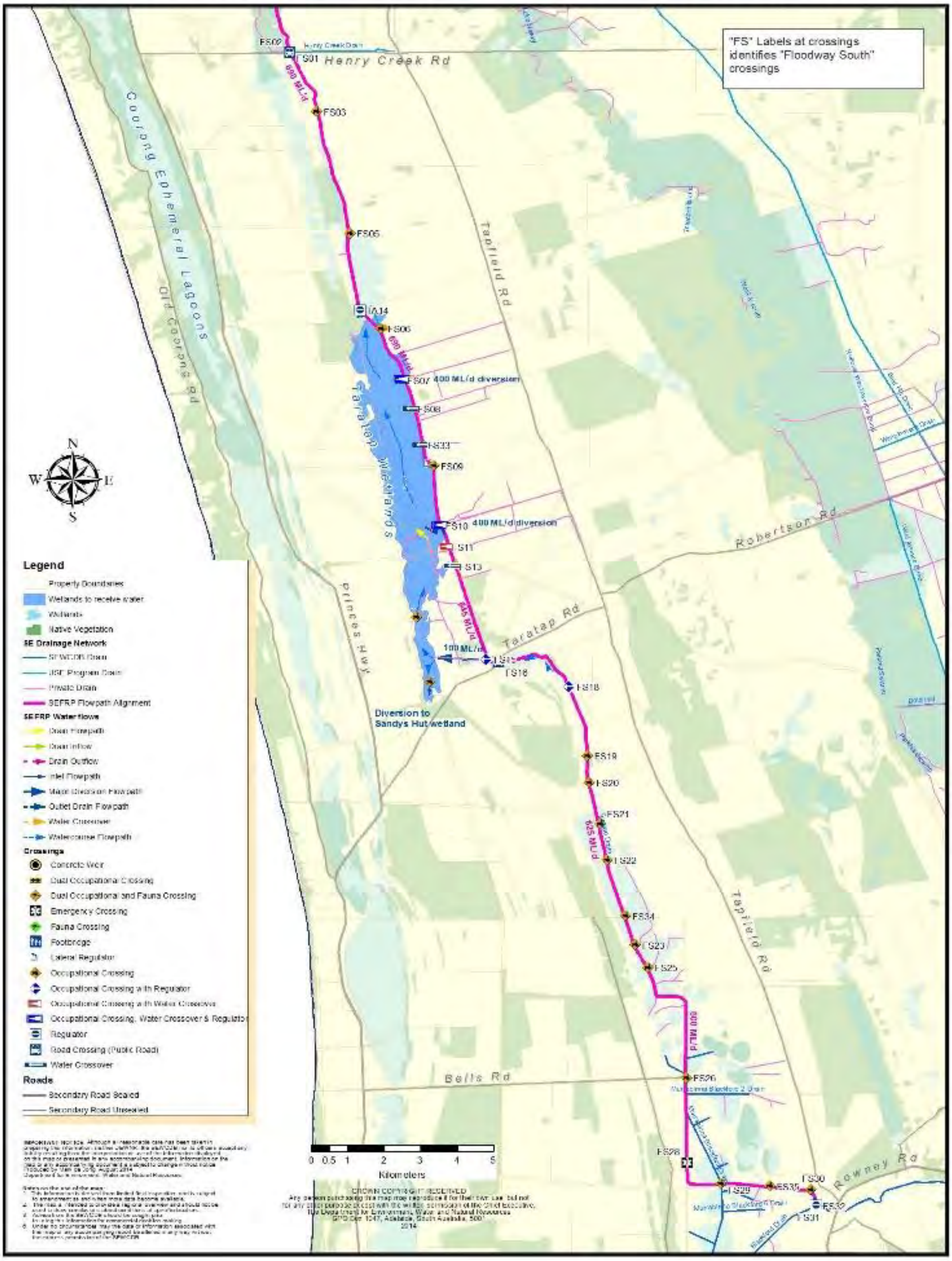


Figure 24. The SE Flows Restoration Project, the flowpath alignment will see an extension of the existing drainage network.

Land use in the landscape

How is our land currently used?

The region has a total land area of 21,376 square kilometres (2.1 million hectares!). Much of it with fertile soils, access to underground water and a Mediterranean-type climate. The combination of these factors has resulted in the establishment of significant primary industry based land use, such as:

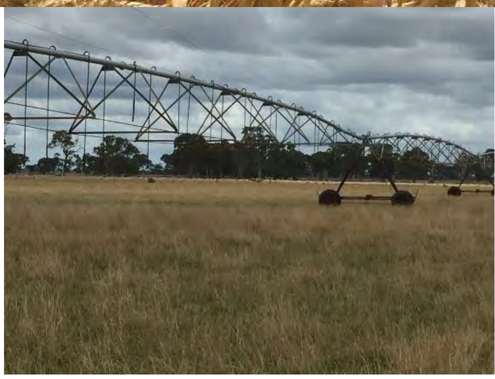
- viticulture
- forestry
- dairy
- livestock (beef, sheep meat and wool)
- aquaculture
- grains and pasture
- fresh and processing potatoes and vegetable seeds.

Fig. 25 shows land use categories mapped for the South East region, giving a visual representation of the approximate area each of these covers. Appendix 6 provides further detail regarding land use types by hectares and as a percentage of landscape coverage.

In 2014 the region contributed $3.6 billion in gross regional product of which $2.2 billion was exported (PIRSA 2015). Agriculture, forestry and fishing provided $521 million of these earnings and employed 21 percent of the workforce. Increasing economies of scale and mechanisation in various sectors has resulted in a decline in workforce requirements over the past decade.

For further information on the regional economy visit
http://pir.sa.gov.au/__data/assets/pdf_file/0007/277549/RIF_Limestone_Coast.pdf





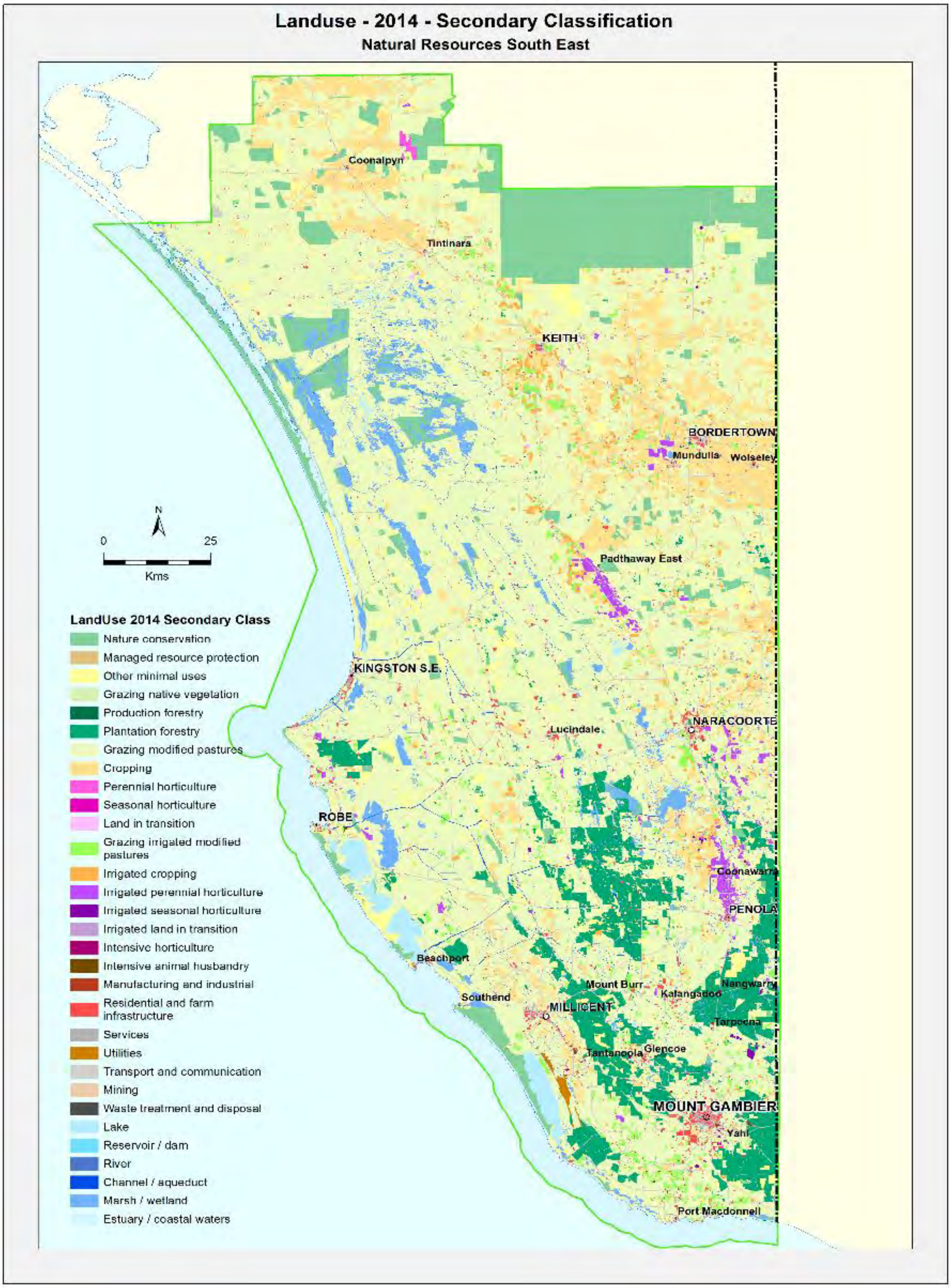



Figure 25. Landuse categories for the South East region (2014).

Currently 67 percent of the land in the South East is used for production from dryland agriculture and plantations, while 14 percent is used for conservation and natural environments and 13 percent is covered by water or wetlands (Fig. 26).

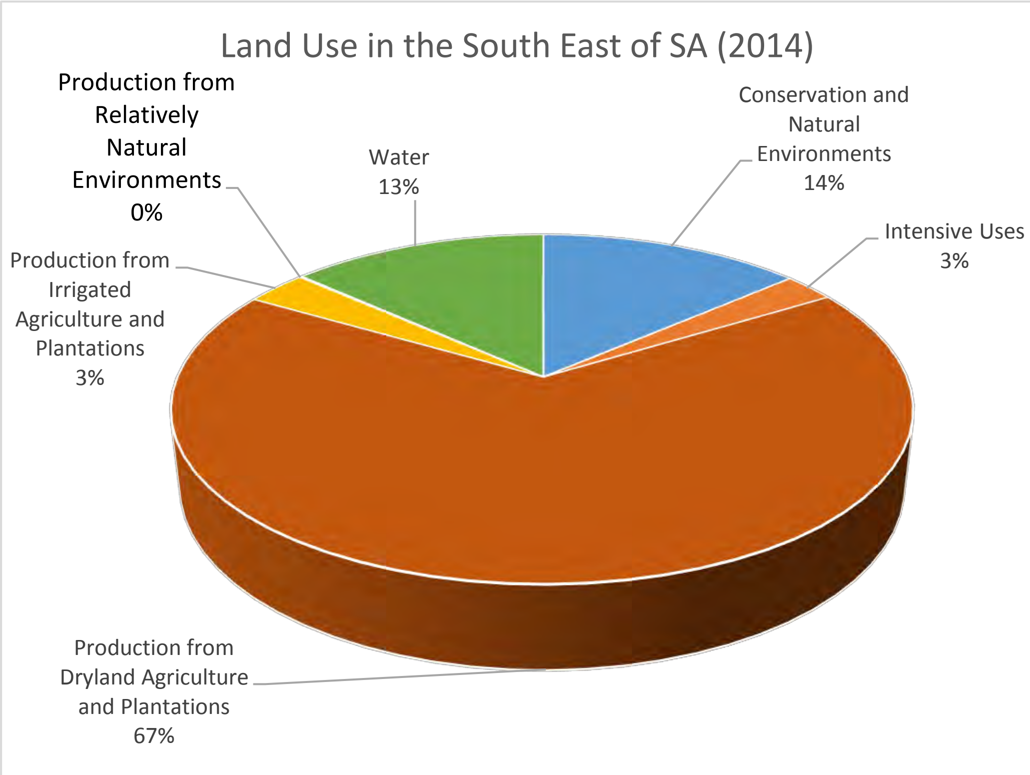


Figure 26. Land use in the South East (2014) broadly categorised into use types.

How has land use changed over time?

Prior to European settlement, the South East of South Australia comprised a mosaic of both freshwater and saline wetlands running from the South Australian-Victorian border through to the Coorong (DEH 2009). These habitats supported a wealth of biological diversity with their extensive wetland plant communities providing important feeding and breeding sites for a range of waterbirds, frogs, native fish, macroinvertebrates and several mammal species.

Land use change following European settlement was very rapid. The first Europeans used the open woodland vegetation for grazing of sheep and cattle. However, with approximately 40 percent of the region regularly flooded it became near impossible to effectively farm these areas. To overcome problems associated with inundation, an extensive drainage network was planned, with the first drains constructed in the Millicent area in the 1880s.

In response to the rapid spread of dryland salinity in the USE, the State and Commonwealth Government and landholders combined to initiate the USE Dryland Salinity and Flood Management Program (Drainage Scheme) to protect agricultural production and environmental assets. Once completed, the scheme aims to control the distribution of freshwater flows to wetlands and dispose of highly saline flows away from high value wetlands, whilst sustaining agricultural productivity.

The second major change to land use in the region occurred as a result of the development of mechanical native vegetation clearance methods following the Second World War (WWII). Large areas of vegetation were cleared in the mid and USE changing the landscape considerably.

Today, around 20 percent of the landscape has remnant native vegetation cover (this figure includes a large part of Ngarkat Conservation Park), six percent of this includes wetlands. Most of these remnant wetland areas are in poor condition (Foulkes & Heard, 2003) largely due to the combination of changes in water flow and clearance. Since the 1980s, land use change can be characterised as:

- intensification of agriculture away from extensive grazing to intensive irrigation (80,000 ha)
- intensified grazing and a movement to cropping
- conversion of agricultural land to plantation forestry.

Future land use changes which may pose a threat to natural resources management include:

- increases in urban and rural living development
- coastal development
- changing agricultural practices.

Soil management in the landscape

Why do different soils require different management?

The South East region is large with various land forms and features which have been shaped over millions of years. The processes that shape this region have produced a wide range of soils from deep sands through to black cracking clays. These soils support a wide variety of agricultural enterprises from intensive horticulture to broad-acre cropping, livestock grazing to dairy, along with providing important ecosystem functions linked to sustainable farming.

All agricultural enterprises are reliant on healthy soils and sustainable management of the soil resource. Employing sound management practices will ensure that farm business is sustainable into the future. A good understanding of soil properties allows landholders to identify soil constraints and develop and instigate methods of overcoming these constraints to improve production.

Throughout the region a range of issues are faced by land managers in the South East region in terms of managing their soil, including:

- acidic soils
- soil fertility
- dryland salinity
- erosion management.

For further information on soil management in the region visit

http://www.naturalresources.sa.gov.au/southeast/land/soil-management

These issues pose a risk to land managers and can vary throughout each of the landscape types. A summary of the major threats to agricultural production for each of the landscape types are summarised in Fig. 27. Different threats need to be managed in different ways which is the reason that differing soil types require differing management techniques – as the threats each of them face differs.

Figure 27: Summary of major landscape issues in the SE NRM Region (Source: SE NRM Board 2010. South East Natural Resources Management Plan *Part One: Regional Description* . Table 23 p100)

Landscape feature	Soil acidity	Dryland salinity	Soil nutritional fertility	Erosion	Water repellent soils	Soil physical condition	Irrigated soils	Waterlogging	Land use planning	Soil modification	Agricultural enterprise change	Soil borne diseases and contaminants	Pest plants and animals
Black flats		H	L			L	L	H	M		M	M	M
Coastal landscapes		M		H				L	H		M	L	M
Deep sands and dune flats	H	L	L	H	H		M	L		M	M	L	M
Mallee soils		M	H	L		M	M				M	L	M
Range country	M		M	H	M	M	L			M	M	L	M
Red gum country	H	M	H	L	L	H	H	H	L	M	M	M	M
Shallow sand over limestone	L	M	M	M	L	L	L				M	L	M
Salty/saline flats		H	L			L		H			M	L	M
Sand over clay	H	M	L	H	H	L	M	H		M	M	L	M
Terra rossa	M	L	M			M	H		M		M	M	M
Volcanics	H		M	M		M			H		M	M	M
Wimmera country	M	L	H	L		H	H	M	L		M	M	M

Relevance: L= low, M= moderate, H= high

What is soil acidification and where is it most likely to occur?

Soil acidity is one of the threats facing land managers and is quantified as any point below neutral on the pH scale. Soil acidity is a severe soil degradation problem which can greatly reduce the production potential of farming systems. Soil acidity literally eats into farm productivity and the long term sustainability of the soil resource by affecting many aspects of soil and plant health. Many soils in the South East are prone to soil acidity (Fig 28). Levels become very serious when pH reaches levels of pH 5.0 and below in calcium chloride.

Soil acidification is often associated with nutrient deficiencies and/or imbalances (e.g. calcium, magnesium and potassium) that adversely affect plant growth. Some compounds become soluble at very low pH (e.g. manganese and aluminium), and can be toxic to plants. Acidity also decreases the activity of many micro-organisms, notably nitrogen fixing rhizobia bacteria associated with legumes.

Approximately 24,000 hectares of cleared land have strongly acidic soil (refer Fig. 28). Approximately 613,000 hectares (28 percent) of cleared land have acid soil requiring management to prevent acidity reaching critical levels. A total of 534,000 hectares (24 percent), of land is moderate to highly susceptible to rapid soil acidification due to low buffering capacity. Fig. 29 details the future acidification potential of soils in the South East.

Source: Soil statistics are from the Department of Water Land and Biodiversity Conservation's Soil and Land Program (November 2009).

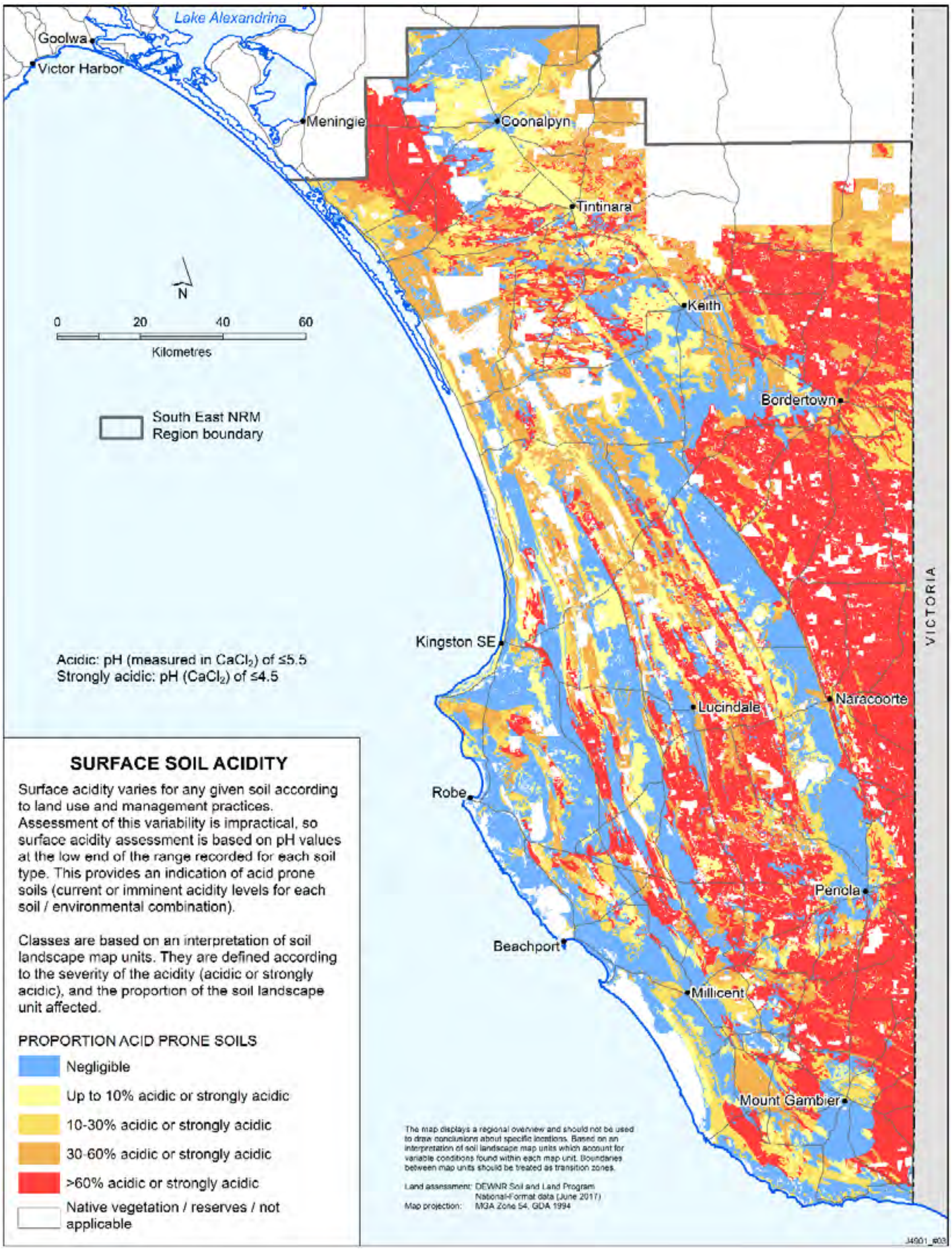


Figure 28. Surface soil acidity in the South East Region, according to land use and management practices.

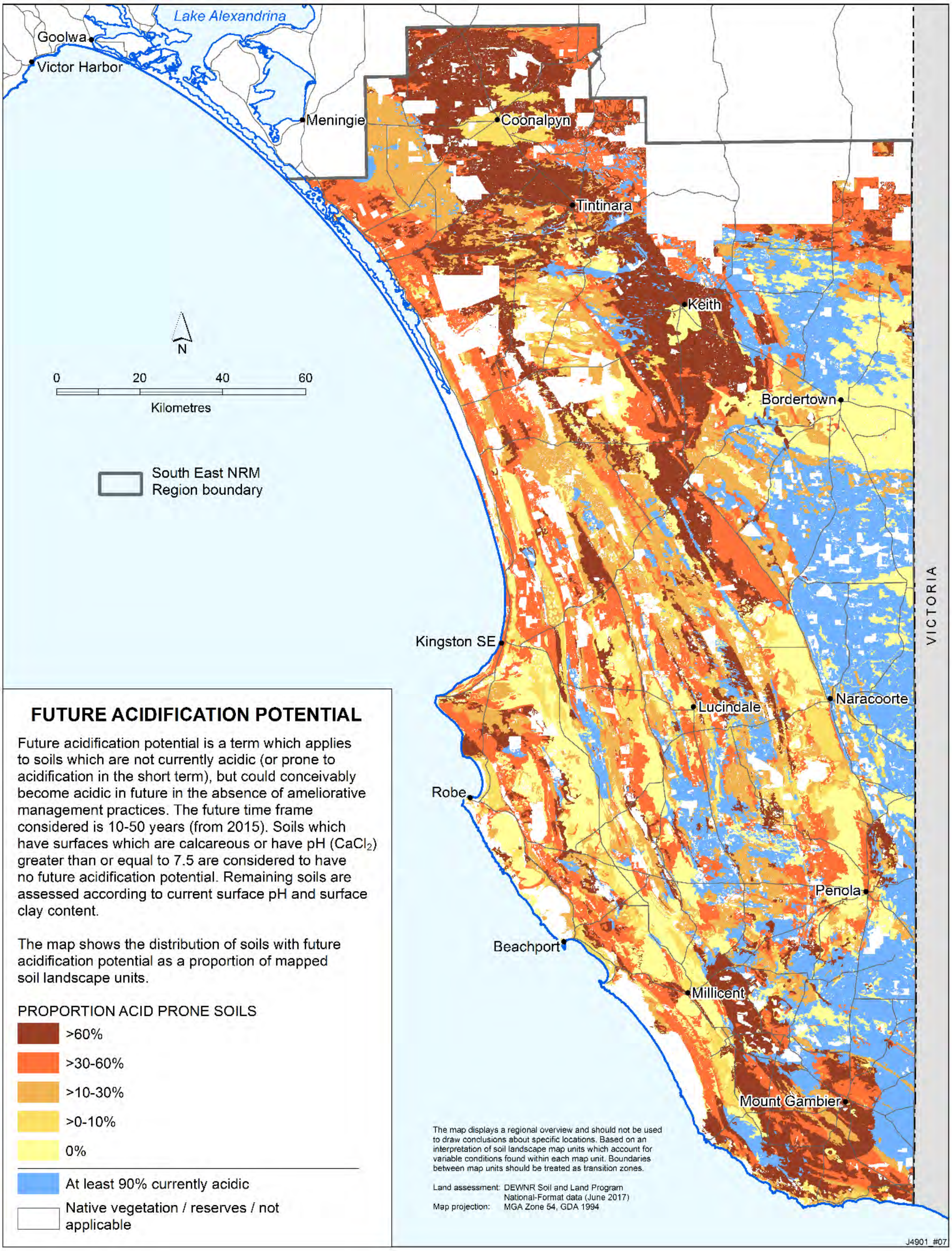


Figure 29. Soils in the south east that are prone to acidity in the short term.

What can be done to minimise soil acidity?

Soil acidity is treated by adding lime to the soil. The main sources of liming material in the South East are:

- agricultural lime
- clays of higher pH
- irrigation water.

There are many methods of applying alkaline materials to soil. An annual surface liming program and good fertiliser management are essential to counteract the ongoing acidification effects of high level production. Even if landholders decide to undertake other management options (e.g. clay spreading) to improve soil pH, a regular follow up liming program is important to ensure that the problem does not return.

For further information on treating acidification in south east soils visit
http://www.naturalresources.sa.gov.au/southeast/land/soil-management/South-East-Soil-Issues

What is soil erosion and where is it most likely to occur?

Soil erosion is a naturally occurring process. In an agricultural context it refers to the wearing away of topsoil by either natural forces (such as wind and water) or through forces associated with farming practices (such as tillage). It involves three processes: soil detachment, soil movement and soil deposition. It generally affects the topsoil layer which is high in nutrients and organic matter and is critical to productive agriculture. Erosion of this top soil layer reduces cropland productivity and can also contribute to pollution of water ways from the deposited soil. Soil erosion can be a slow process or can occur rapidly in a major weather event (such as a wind storm or heavy rainfall). There are also many factors that can increase the likelihood or severity of soil erosion, such as:

- soil compaction
- poor drainage
- loss of soil structure
- salinity
- acidic soils
- low organic matter.

Of the 2.2 million hectares of cleared agricultural land in the South East, around half (1.1 million hectares) is comprised of sandy textured soils. This soil type is particularly susceptible to wind erosion. In addition to this there is approximately thirteen percent (290,000 hectares) on sloping and hilly land which is vulnerable to water erosion (as well as wind erosion in some parts!).

Sandy textured soils tend to occur in the coastal landscapes, dune-flats, range country, shallow sand over limestone and the sand over clays, particularly in the drier USE (Fig. 30), and where cultivation is widespread.

The deep sands are also vulnerable to wind erosion, however, these tend to be under permanent vegetative cover, and so are rarely at risk. The more fertile loamy soils of the mallee soils, range country, red gum country, volcanics, and Wimmera country, while generally a lower risk, can be susceptible if over-cultivated to a very fine till.

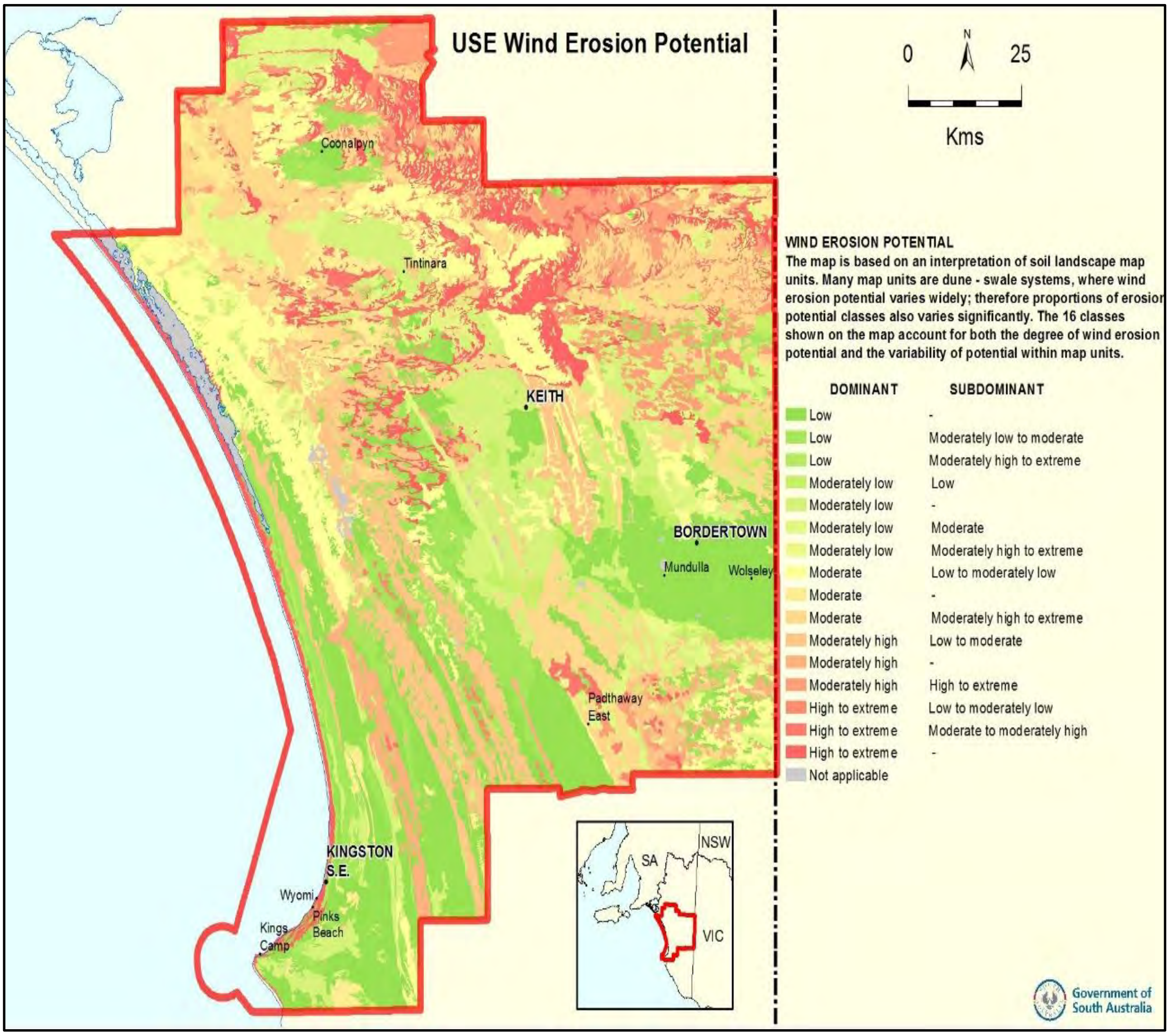


Figure 30. The Upper South East has a higher proportion of soils which are susceptible to erosion due to the sandy nature of the top soil.

What can be done to minimise soil erosion?

The top centimetre of the soil is the most fertile and the most at risk of erosion. The loss of any topsoil is expensive from economic and production perspectives. Sound soil management practices can have great success in reducing the risk of erosion. Practices that maintain groundcover and minimise soil disturbance are critical to minimising this risk.

Soil erosion protection has been one of the highest priorities for soil management in the South East region. Monitoring the condition of soil cover across the landscape (or on a farm scale) is an important indicator for how many days of the year susceptible soils are exposed for.

There are a number of ways to manage the impact of agricultural activities on soil erosion potential, including:

- planning and grazing land to its capacity and capability
- using zero till farming practices
- adopting confinement feeding in dry years
- moving gates and watering points to heavier ground
- controlling pest plants and animals
- fencing susceptible areas to exclude stock
- matching pasture selection to soil type and climate.

Once erosion has occurred it is imperative to stabilise the remaining soil. This process takes planning and careful management to achieve the desired outcome.

Source: Covercrops and Clay: A landholder guide to the management of erosion in the South East. SE Natural Resources Management Board (2017).

For further information on erosion control visit
http://www.naturalresources.sa.gov.au/southeast/land/soil-management/South-East-Soil-Issues

Ripping of Rabbit holes in the winter season allows for replanting and revegetation of the roadside areas to allow the new plantings to establish without the pressure of being destroyed. This action helps to re-establish ground cover and avoid erosion in the sandy roadside soils

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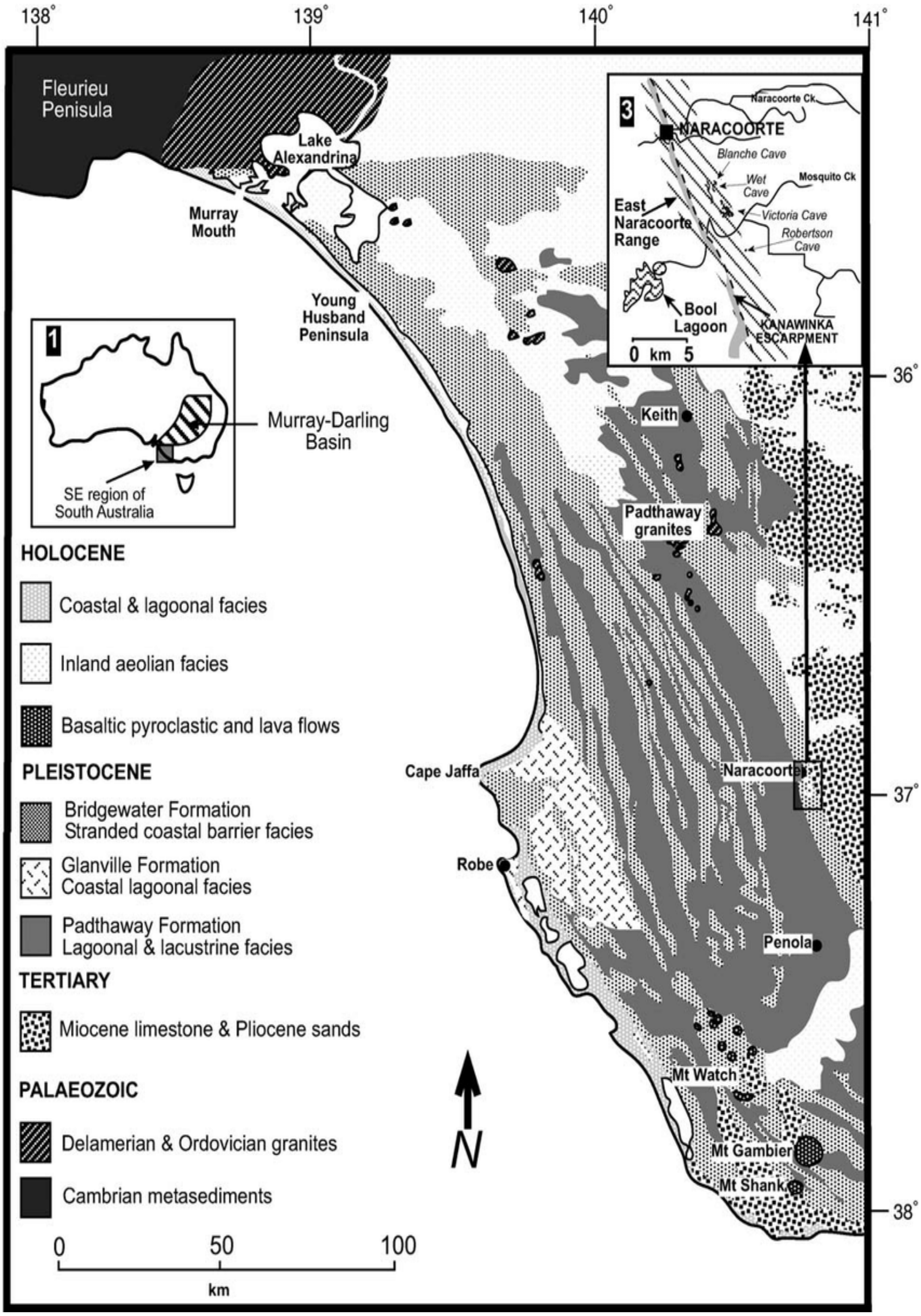
Appendix 1. Table of geological development in the South East

ERA	Period	Epoch	Millions of years ago	Formation	Key Characteristics
Cainozoic	Quaternary	Pleistocene	2.5	Padthaway (Qpcp)	Lacustrine and lagoonal dolomite, limestone clay and sand of the interdunal plains.
				Bridgewater (Qpcb)	Subtidal, beach and aeolian calcarenite[1] of stranded coastal ridges (dunes).
				Coomandook (Qpmc)	Shallow-marine fossiliferous limestone, sandstone and clay (subsurface).
	Tertiary (Paleogene and Neogene)	Pliocene	5.3	Parilla Sand (Tpp)	Ferruginous (containing iron oxides) fine to medium clayey sandstone. East of Kanawinka Fault, extending to Frances.
		Oligocene / Miocene	33.9	Gambier Limestone (Thg)	Bryozoal[2] Limestone deposited in open marine conditions with minor marl, chert and dolomite. Includes Naracoorte limestone found on the eastern edge of the Kanawinka Fault.
		Palaeocene / Eocene	66	Dilwyn (Twd)	Terrestrial[3] fluvial fine to coarse sandstone, carbonaceous mudstone and siltstone.
Mesozoic	Cretaceous	Lower and Upper	145	Otway Supergroup (Ko)	Terrestrial sandstones, siltstones, claystones and mudstones.
Palaeozoic	Cambrian	?	541 to 485.4	Kanmantoo Group (Ck)	Basement rocks of lithic metasandstone, schist, gneiss and minor quartz and marble; found in the east of the Gambier Embayment.

Table 1. Geology of the South East

[1] Calcarenite is a type of limestone that is composed predominantly (more than 50 percent) of detrital (transported) sand-size (0.0625 to 2 mm in diameter), carbonate grains, that have been eroded from elsewhere.
[2] Bryozoal limestone is fossiliferous; it is formed by Lacy Bryozoans, which are lace-like structures made of colonies of small marine animals fused together.
[3] Terrestrial – relating to the earth, of or on dry land, rather than in oceans or water.

Appendix 2. **Key geological formations in the South East and the period of formation .**



(Source: Forbes, Bestland and Wells (2007)

Appendix 3. **Soil types in the South East region by group and sub group**.

Code	Soil type	Subtotals hectares	total by soil group (ha)
A	Calcareous soils		49,044
A1	Highly calcareous sandy loam	2,044	
A2	Calcareous loam on rock	0	
A3	Deep moderately calcareous loam	6	
A4	Deep (rubbly) calcareous loam	10,546	
A5	Rubbly calcareous loam on clay	5,783	
A6	Gradational calcareous clay loam	4,446	
A7	Calcareous clay loam on marl	25,676	
A8	Gypseous calcareous loam	543	
B	Shallow soils on calcrete or limestone		805,062
B1	Shallow highly calcareous sandy loam on calcrete	3,606	
B2	Shallow calcareous loam on calcrete	94,317	
B3	Shallow sandy loam on calcrete	201,111	
B4	Shallow red loam on limestone	29,019	
B5	Shallow dark clay loam on limestone	100,679	
B6	Shallow loam over red-brown clay on calcrete	104,500	
B7	Shallow sand over clay on calcrete	222,128	
B8	Shallow sand on calcrete	45,585	
B9	Shallow clay loam over brown or dark clay on calcrete	4,117	
C	Gradational soils with highly calcareous lower subsoil		29,956
C1	Gradational red-brown sandy loam	0	
C2	Gradational red-brown loam on rock	29	
C3	Friable gradational red-brown clay loam	4,703	
C4	Hard gradational red-brown clay loam	0	
C5	Gradational dark clay loam	25,224	
D	Hard red-brown texture contrast soils with neutral to alkaline subsoil		24,766
D1	Loam over clay on rock	0	
D2	Loam over red clay	5,509	
D3	Loam over poorly structured red clay	19,204	
D4	Loam over pedaric red clay	0	
D5	Hard loamy sand over red clay	53	
D6	Ironstone gravelly sandy loam over red clay	0	
D7	Loam over poorly structured clay on rock	0	
E	Cracking clay soils		71,263
E1	Black cracking clay	17,285	
E2	Red cracking clay	5	
E3	Grey or brown cracking clay	53,973	
F	Deep loamy texture contrast soils with brown or dark subsoil		136,947
F1	Loam over brown or dark clay	56,100	
F2	Sandy loam over poorly structured brown or dark clay	80,847	

G	Sand over clays		601,914
G1	Sand over sandy clay loam	185	
G2	Bleached sand over sandy clay loam	131,995	
G3	Thick sand over clay	311,639	
G4	Sand over poorly structured clay	144,460	
G5	Sand over acidic clay	13,634	
H	Deep sands		485,259
H1	Carbonate sand	28,977	
H2	Siliceous sand	22,416	
H3	Bleached siliceous sand	433,867	
I	Highly leached sands		117,197
I1	Highly leached sand	64,906	
I2	Wet highly leached sand	52,291	
J	Ironstone soils		0
J1	Ironstone soil with calcareous lower subsoil	0	
J2	Ironstone soil	0	
J3	Shallow soil on ferricrete	0	
K	Shallow to moderately deep acidic soils on basement rock or saprolite		0
K1	Acidic gradational loam on rock	0	
K2	Acidic loam over clay on rock	0	
K3	Acidic sandy loam over red clay on rock	0	
K4	Acidic sandy loam over brown or grey clay on rock	0	
K5	Acidic gradational sandy loam on rock	0	
L	Shallow soils on basement rock		1,085
L1	Shallow soil on rock	1,085	
M	Deep uniform to gradational soils		51,793
M1	Deep sandy loam	58	
M2	Deep friable gradational clay loam	37,014	
M3	Deep gravelly soil	0	
M4	Deep hard gradational sandy loam	14,721	
N	Wet soils		205,736
N1	Peat	19,638	
N2	Saline soil	121,357	
N3	Wet soil (low to moderately saline)	64,741	
O	Volcanic ash soils		15,852
O1	Volcanic ash soil	15,852	
RR	Rock	44,368	44,368
WW	Water	51,677	51,677
	Total area of region		2,691,918

Appendix 4. Soils of dunal and interdunal ranges.

Table 1: Predominant soils of the interdunal plains (Padthaway Formation) in South East region.

	Soil Group[1]	Predominant soil type[2]	Key characteristics[1]	LGA - Location[1]
A7	Calcareous clay loam on marl	Calcarosol	Deep, well-structured, dark coloured fertile soils that become more clayey and calcareous with depth. High inherent fertility, although nutrient availability reduced by high pH. Prone to waterlogging due to high clay content and position in landscape.	Kingston, Robe, Wattle Range, Grant.
B5	Shallow dark clay loam over calcrete/limestone	Calcarosol	Black well-structured clay loam to clay soils that commonly overlay shallow calcrete. High inherent fertility, but the rootzone is impeded by calcrete or high calcareous clayey substrate. Drainage is imperfect and inundation is common. Historically the watertable was within 1.5m of the surface. These soils occur almost exclusively in the SE of SA.	Kingston, Robe, Naracoorte Lucindale, Wattle Range.
B7	Shallow sand over clay on calcrete	Chromosol	Shallow sandy topsoils with thin clayey subsoils that overlay calcrete, commonly within 0.5m. Moderately low inherent fertility and limited available water. Can be acidic in the surface and alkaline at depth.	Kingston, Robe, Naracoorte Lucindale, Wattle Range, Grant.
E1	Black cracking clay	Black Vertosol	Self-mulching dark grey medium clay over a coarsely structured heavy clay that becomes calcareous with depth. Often poorly drained and can become very sticky when wet.	Naracoorte Lucindale, Wattle Range.
E3	Brown or grey cracking clay	Grey Vertosol	Moderately deep clay soils that usually are not self-mulching at the surface. High inherent fertility but can often be high in boron and suffer sodicity and high pH throughout. Slow water infiltration and can be difficult to work.	Naracoorte Lucindale, Tatiara.
G4	Sand over poorly structured clay	Sodosol	Up to 0.3m sandy topsoil overlying a hard mottled, dispersive subsoil clay that becomes increasingly calcareous with depth.	Tatiara, Naracoorte Lucindale, Kingston.

Table 2: Soils of the relic coastal dunes (Bridgewater formation) in the South East region.

	Soil Group[1]	Predominant soil type[2]	Key characteristics[1]	LGA - Location[1]
B2	Shallow calcareous loam on calcrete	Calcarosol	Shallow to very shallow, grey to red-brown soils of aeolian origin; typically alkaline throughout. Low inherent fertility with carbonate induced nutrient deficiencies that limits crop options and productive capacity.	Kingston, Naracoorte Lucindale, Robe, Wattle Range.
B3	Shallow sandy loam on calcrete	Tenosol	Shallow to very shallow, brown to red soils of aeolian origin. Can be slightly acidic to slightly alkaline with moderately low inherent fertility and low water holding capacity.	Kingston, Naracoorte Lucindale, Robe, Wattle Range, Grant.
B4	Shallow red loam on limestone	Dermosol	Shallow, well structured, inherently fertile, red to reddish brown soils formed in calcarenite, limestone or carbonate-rich rock. Neutral to alkaline pH with favourable chemical and structural characteristics owing to their high exchangeable calcium. Valuable and highly sought after for viticulture (Terra Rossa).	Naracoorte Lucindale, Wattle Range.
B6	Shallow loam over red clay on calcrete	Chromosol	Shallow, inherently fertile, red soils formed on calcrete. Neutral to alkaline pH with moderate to high fertility owing to the type and content of clay.	Kingston, Naracoorte Lucindale, Robe, Wattle Range, Grant.
B7	Shallow sand over clay on calcrete	Chromosol	Shallow, texture contrast soils formed on calcrete, which have a bleached sub-surface layer. Neutral to acidic topsoil, overlying alkaline clay. Low to moderately low inherent fertility.	Kingston, Naracoorte Lucindale, Robe, Wattle Range, Grant.
B8	Shallow sand on calcrete	Tenosol	Shallow to very shallow, pale brown soils of Recent aeolian origin. Slightly acidic to slightly alkaline pH with low inherent fertility and very low nutrient and water holding capacity.	Kingston, Robe.
B9	Shallow clay loam over brown or dark clay on calcrete	Kandosol	Shallow, dark coloured soils formed on calcrete in old lagoonal environments. Moderate inherent fertility and slightly acidic to alkaline with good nutrient retention. Root growth impeded due to waterlogging.	Robe.
G3	Thick sand over clay	Chromosol	Moderately deep to deep brown soils, mostly of aeolian origin. Generally acidic to neutral in the surface, increasing in the clayey subsoil. Moderately low to low fertility with limited nutrient and water holding capacity in the sandy topsoil and sub-soil layers.	Kingston, Tatiara, Naracoorte Lucindale, Robe, Wattle Range, Grant.
H3	Bleached silicious sand	Tenosol		Kingston, Tatiara, Naracoorte Lucindale, Robe, Wattle Range, Grant.
I1	Highly leached sand	Podosol		Kingston, Robe, Wattle Range, Grant.
I2	Wet highly leached sand	Podosol		Wattle Range, Grant.

Appendix 5. **Subregional breakdown of soil types in the South East**.

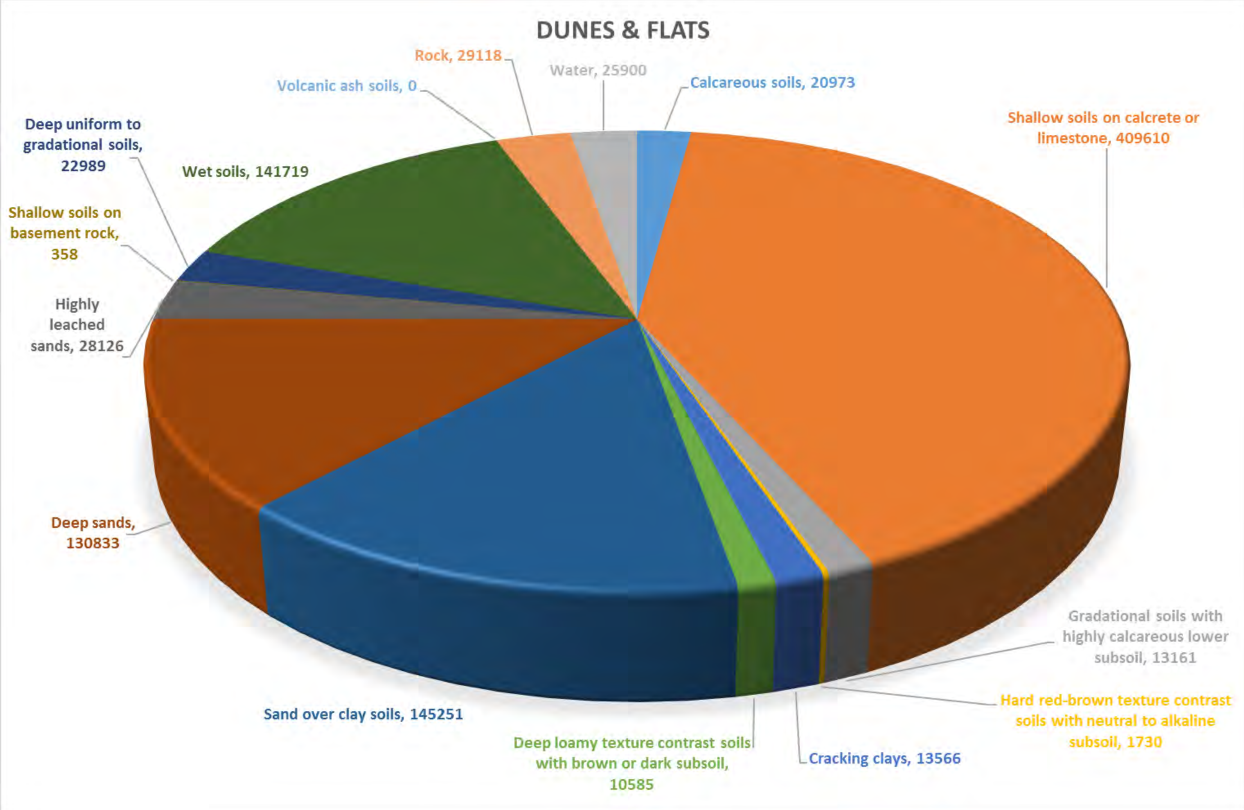


Figure 1. The area (hectares) of each soil group within the Dunes and Flats subregion.

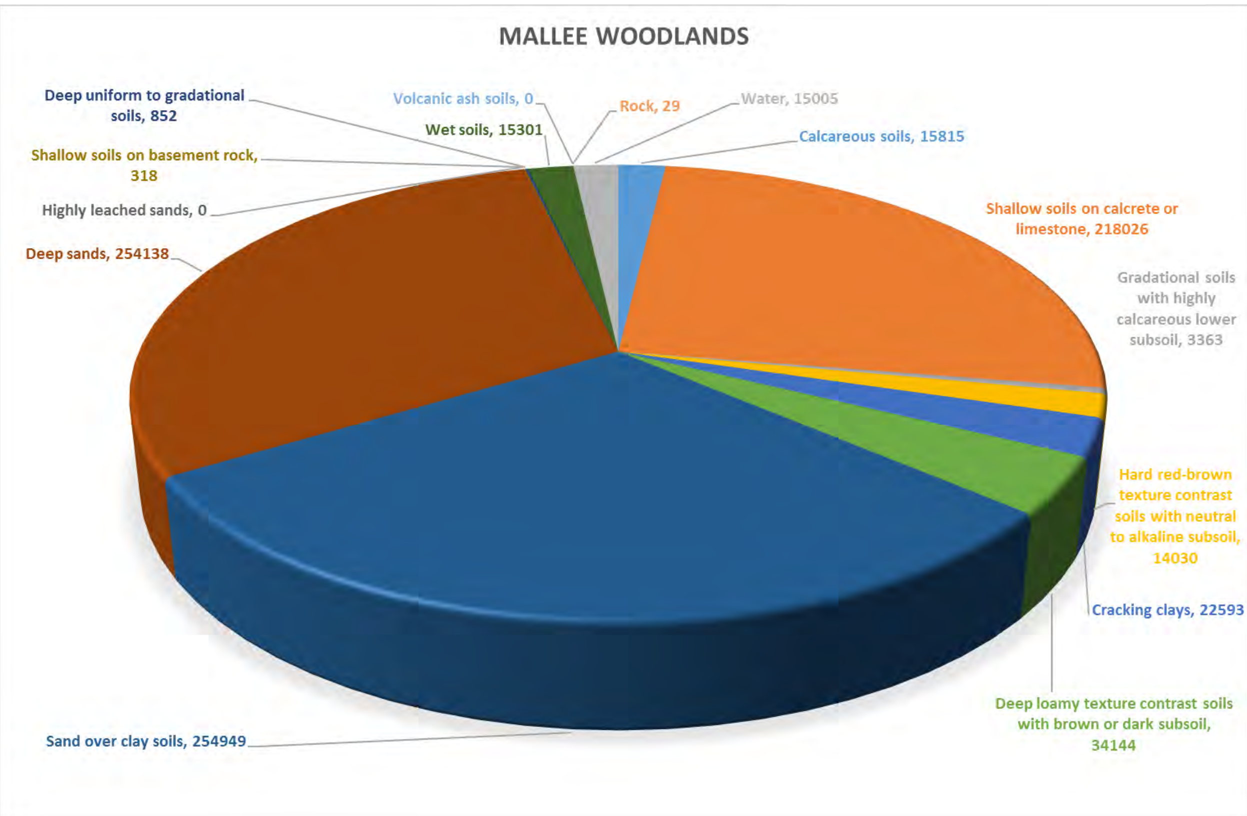


Figure 2. The area (hectares) of each soil group within the Mallee Woodlands subregion.

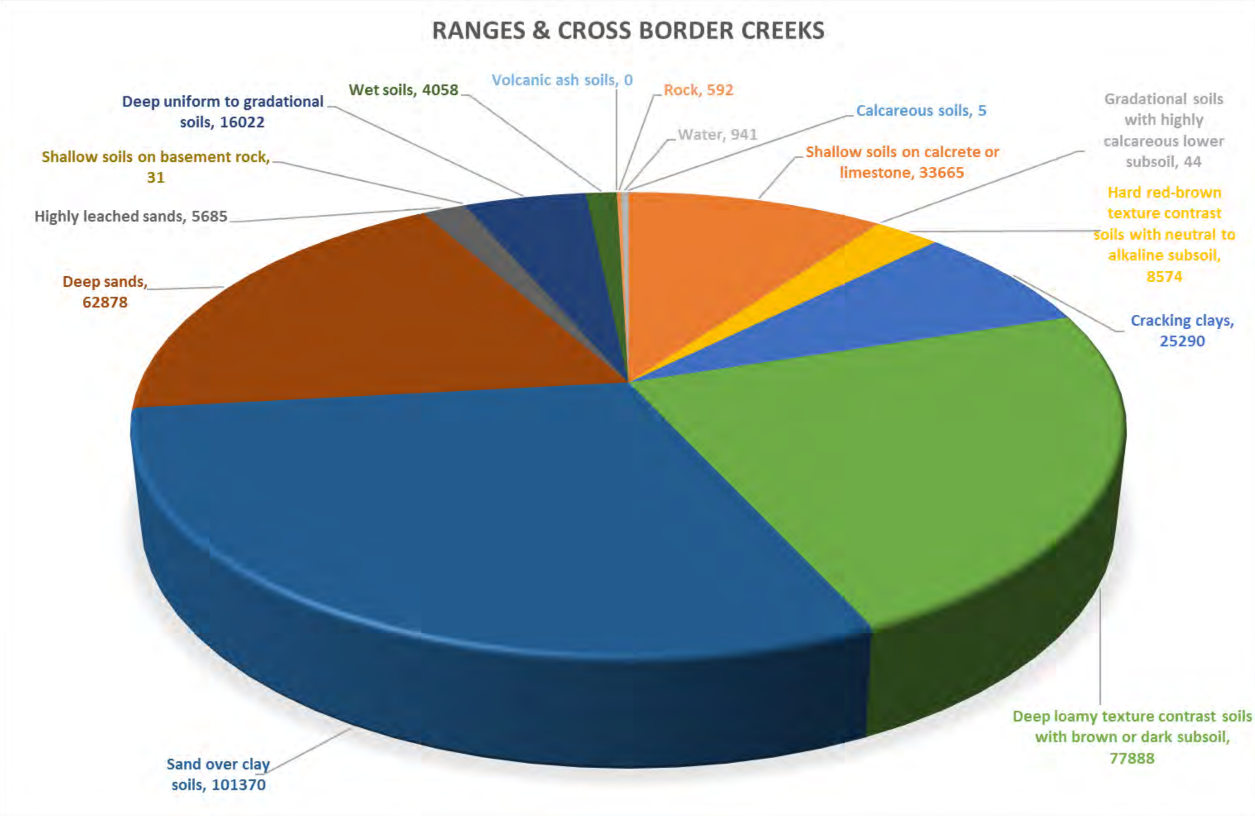


Figure 3. The area (hectares) of each soil group within the Ranges and Cross Border Creeks subregion.

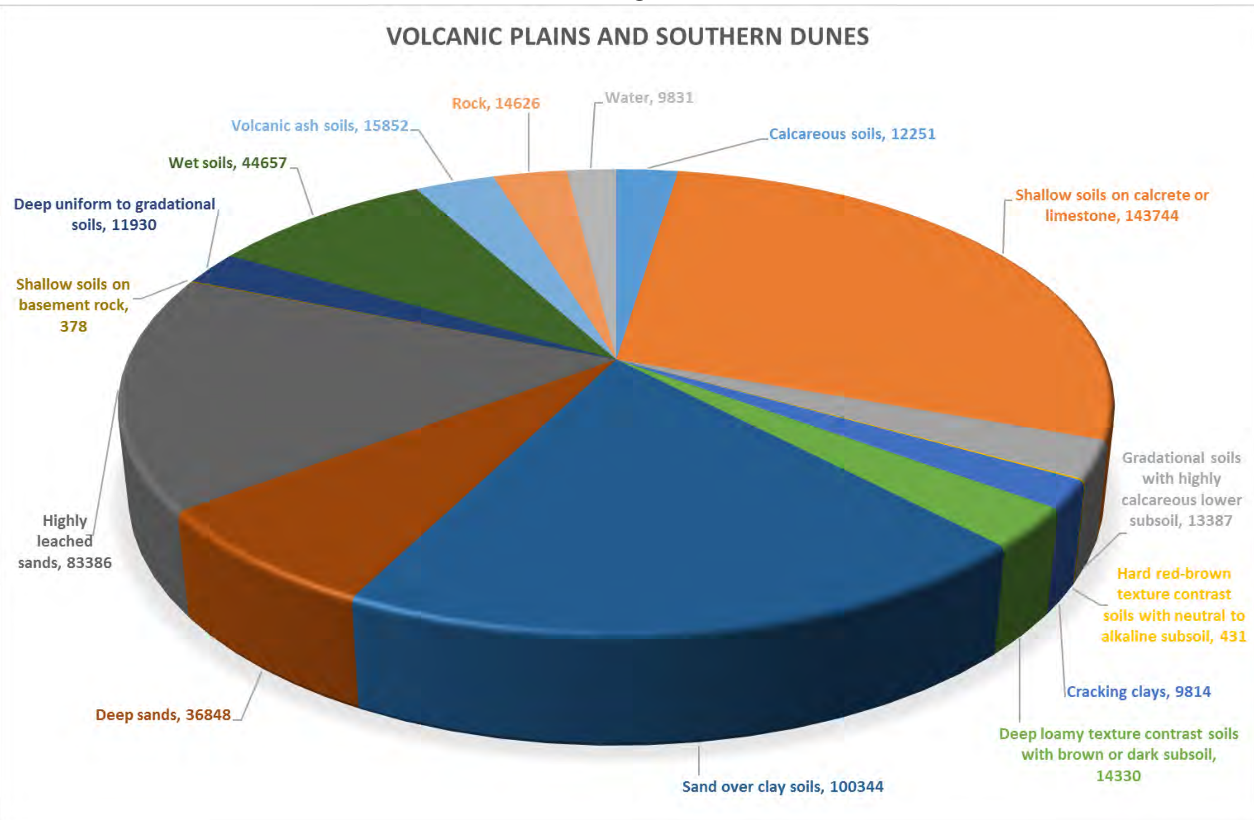


Figure 4. The area (hectares) of each soil group within the Volcanic Plains and Southern Dunes subregion.

Appendix 6. Types of land use in the South East Region (2014).

Type of Land Use	No of enterprises	Hectares	% of region
Channel/aqueduct	365	9,017	0.31%
Cropping	3381	256,418	8.73%
Estuary/coastal waters	30	264,164	9.00%
Grazing irrigated modified pastures	1182	44,488	1.52%
Grazing modified pastures	4521	1,541,014	52.48%
Grazing native vegetation	53	2,901	0.10%
Intensive animal husbandry	114	867	0.03%
Intensive horticulture	4	77	0.00%
Irrigated cropping	712	25,612	0.87%
Irrigated land in transition	130	3,234	0.11%
Irrigated perennial horticulture	401	19,135	0.65%
Irrigated seasonal horticulture	35	1,299	0.04%
Lake	135	26,569	0.90%
Land in transition	97	1,227	0.04%
Managed resource protection	44	412	0.01%
Manufacturing and industrial	156	930	0.03%
Marsh/wetland	5674	91,172	3.11%
Mining	648	1,257	0.04%
Nature conservation	1256	243,610	8.30%
Other minimal use	14908	156,703	5.34%
Perennial horticulture	35	1,617	0.06%
Plantation forestry	1124	168,666	5.74%
Production forestry	1	261	0.01%
Reservoir/dam	156	234	0.01%
Residential and farm infrastructure	6251	27,398	0.93%
River	1	34	0.00%
Seasonal horticulture	4	13	0.00%
Services	874	3,088	0.11%
Transport and communication	223	42,529	1.45%
Utilities	47	2,105	0.07%
Waste treatment and disposal	46	237	0.01%