Government of South Australia
Adelaide and Mount Lofty Ranges
Natural Resources Management Board

Adelaide and Mount Lofty Ranges Natural Resources Management Plan

Volume 1 — Part 2

Strategic Plan

2014-15 to 2023-24

Thriving communities caring for our hills, plains and seas

November 2013

CONTENTS

SUBREGIONS

This section of the Regional Plan describes the subregional social ecological systems identified through community engagement and technical input.

Social ecological systems are areas with generally (although not exclusively) consistent social and ecological characteristics including land form, vegetation types, land uses, and social structures and dynamics. The Adelaide and Mount Lofty Ranges region has been divided into seven subregions.

Subregional boundaries are intended to be fuzzy, and therefore overlap. Each shares a concentration of common characteristics compared with adjacent areas, though there are exceptions to these general classifications.

The subregions for the Adelaide and Mount Lofty Ranges region are (Figure 24):

- Metropolitan Adelaide
- Northern Coast and Plains
- Northern Hills
- Central Hills
- Willunga Basin
- Fleurieu Peninsula
- Marine.

Subregions are described under three key headings:

- Lifestyles – about the people that live in the subregion
- Landscapes – about the landscapes in the subregion, including biodiversity and water resources
- Livelihoods – about the industry and commercial enterprises that rely on the natural resources of the subregion.

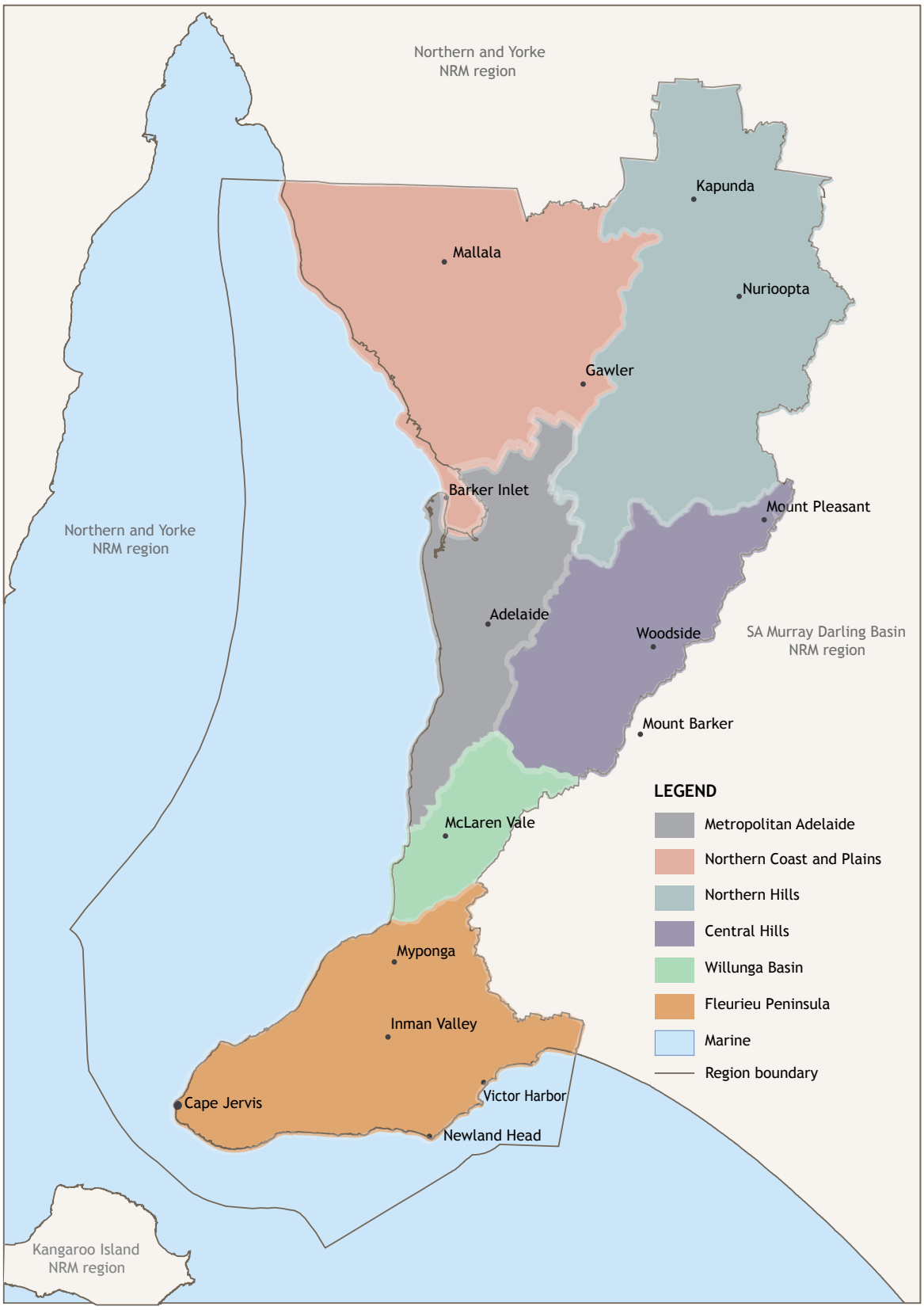


Figure 24: Subregions of the Adelaide and Mount Lofty Ranges NRM region

Metropolitan Adelaide

In summary

The substantial population and urban sprawl of Adelaide (1.1 million people, (Australian Bureau of Statistics 2011)) sets the tone for this subregion. The impacts of the population and reserve of social capacity that can contribute to an ecologically sustainable future are both important factors in this subregion. Mostly sited on coastal and river plains, and urban in nature, the Metropolitan Adelaide subregion (Figure 25) also extends to coastal areas and the Hills Face Zone.

The developed makeup of the subregion encompasses the Port of Adelaide and high intensity industries such as defence construction, power generation, cement production and manufacturing, as well as the activities related to any urban area, such as roads and railways, stormwater and waste disposal, recreation, retail, and education and health institutions. Areas of agriculture and horticulture serve local markets and those further afield.

The space remaining for natural resources is limited and the subregion contains a mere 3% of its pre-European vegetation. Notable extant vegetation groups are Cypress Pine sandy woodland, Grey Box grassy woodland, Chenopod shrubland and coastal vegetation such as mangroves. Some of the remaining land-based vegetation survives along watercourses, most of which are heavily impacted by upstream rural practices, which contribute nutrients and eroded soil, and downstream urban practices, which contribute high volumes of water often contaminated by nutrients and heavy metals. Significant lengths are held 'in place' by concrete and other artificial constraints.

Groundwater resources contribute to the horticultural and industrial practices of this low-rainfall area and water conserving activities, such as wastewater recycling and stormwater retention, are being taken up more and more.

Metropolitan Adelaide - Priorities for the future

A set of priorities for the future for the Metropolitan Adelaide subregion have been developed based on the information contained in this section.

Subregion wide

- Develop corridors to join green spaces and provide links between hills and coast, and along the length of the coast
- Protect and improve the integrity of the shrubby woodland landscapes that dominate the steep and rocky parts of the Hills Face Zone
- Restore and reinstate grassy ecosystems where this will help stem biodiversity declines (along the foothills and less rocky parts of the Hills Face Zone) including the nationally threatened Grey Box grassy woodlands
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Connect communities to their environment (both local and more remote)
- Connect communities to sustainable food production
- Manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)

- Reduce the impact of runoff from stormwater and priority watercourses on aquatic health, the coast and marine environment
- Develop an understanding of the connections between economics and the environment
- Encourage increased demand, and supply of, alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Facilitate integrated climate change adaptation of urban communities
- Protect urban watercourses for aquatic health and urban biodiversity outcomes (quality)
- Monitor for, and control, pests that have not yet become established in the region, or in the Metropolitan Adelaide subregion

Coastal specific

- Protect and rehabilitate priority areas of the metropolitan coast and buffer them from surrounding uses and impacts (including Torrens Island, Section Bank, Mutton Cove Conservation Reserve; the remaining remnant dune systems in metropolitan system, Tennyson and Minda dunes; coastal cliffs of Kingston Park, Marino Conservation Park (CP), Hallett Cove CP, Hallett Headland, Tingira; and coastal dune systems at South Port dunes, and Moana Sands CP)
- Connect communities to their coastal environment
- Monitor and manage for migratory and resident shorebirds at the Onkaparinga estuary and key beach-nesting birds (Hooded Plovers) breeding site including South Port beach

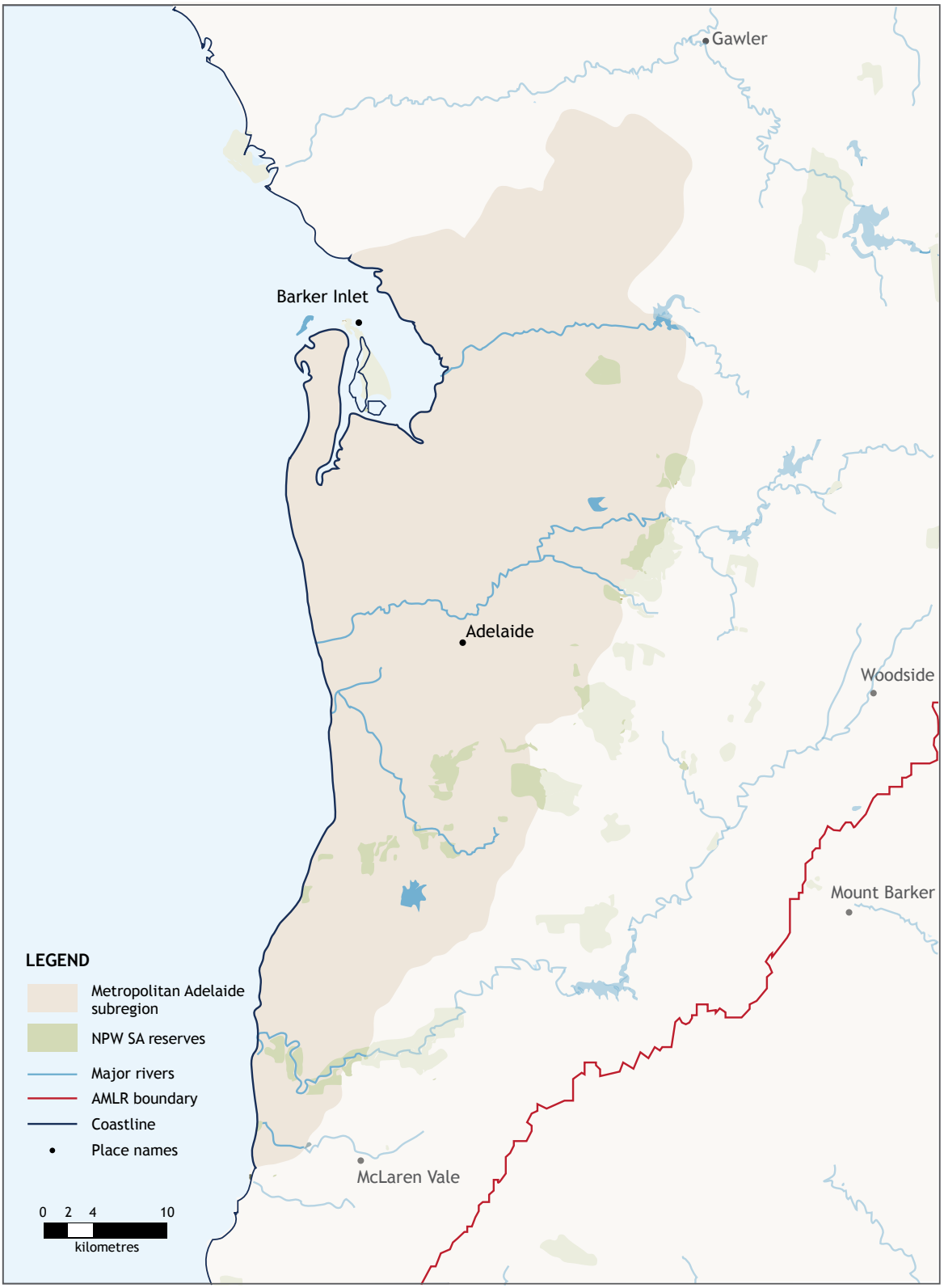


Figure 25: Metropolitan Adelaide subregion

Introduction

Most of South Australia's population resides in the Metropolitan Adelaide subregion. Consequently, it is where the largest and most complex threats to the environment are generated. But it also holds the largest reserve of social capacity for making a more ecologically sustainable future.

Adelaide is defined by its large urban sprawl that extends from Sellicks in the south to Gawler in the north and is bound by the Mount Lofty Ranges to the east and Gulf St Vincent to the west. The impacts of this sprawl are recognised through a goal (we want Adelaide to grow up not out) of *South Australia's Strategic Plan* (Government of South Australia 2011). Situated on a floodplain, Metropolitan Adelaide is dissected by the Torrens River and Patawalonga Creek, and a number of smaller rivers including Little Para River, Christie Creek and Field River. These urban watercourses are often bounded by linear riparian reserve systems that link nature to the community and many species to the Mount Lofty Ranges. The coastline of the area is often highly modified, although some areas of natural biodiversity exist. The Hills Face Zone forms a significant cultural and ecological backdrop to the City of Adelaide and groundwater resources under metropolitan Adelaide support significant industrial activity.

The Lefevre Peninsula, the site of Adelaide's major port, supports a range of port related activities. The area is also becoming a hub for defence industries. While small areas of natural vegetation remain, they are under continued pressure from increased industrial activity.

Urban development and infill generate increased impervious surfaces (paved areas, houses, roofs, bitumen) which results in higher runoff and less infiltration of water into the soil. Increased runoff has the potential to overload stormwater systems resulting in localised flooding and the discharge of polluted stormwater to the marine environment. Managing these issues into the future will require cooperation between stakeholders and the implementation of policies and projects that improve stormwater quality and prevent increased stormwater flows.

The size and extent of Metropolitan Adelaide is regarded as large for its population size, and its ecological footprint suggests that the impact of the metropolitan area on the whole region cannot be disregarded (Adelaide Thinkers in Residence 2011). The growth in population and consequent demands on natural resources are predicted to be enormous drivers of landscape change for the whole region. This will pose planning challenges for agriculture, industry and housing development as well as significant challenges for conservation policies.

The Metropolitan Adelaide subregion intersects the traditional lands of the Kaurna people.

Lifestyles

The metropolitan population is fundamental to the successful management, protection and restoration of the region's natural resources. The health of natural systems is increasingly reliant on social capital and the expertise that underpins sustainable management of natural systems. As the urban area is also a significant generator of the environmental problems, social capital is a key driver of the effort by individuals, communities, governments and business to tackle not only the problems but the behaviours that help create them (The World Bank 2011).

The aim in metropolitan communities is to encourage more sustainable lifestyles and reduce impacts on local and national landscapes. That means most people connected to nature locally and understanding the need to act to protect their wider environment. Examples of what that natural environment looked like, what species it contains and what people need to do to understand how it works and their role in maintaining it, are important. Key environmental messages relating to biodiversity must be associated with more urban concerns such as food security, waste management and energy consumption. A sustainable future needs to include sustainable landscapes that value the original biodiversity and the role it provides in creating a sense of place.

An engaged community is aware of the issues, can identify community concerns and supports actions to tackle these challenges. Good environmental stewardship needs to be supported and developed. A range of strategies can target the general community and key stakeholders to encourage their involvement and build both their knowledge and capacity. These include community consultation processes, developing electronic and hard copy resources, volunteer support initiatives, community resource centres, school and community education programs, and coordination and support for community action and friends groups who drive much of the on-ground work across the region.

Strategies for engagement and collaboration operate in several arenas.

Collaboration with the community

The community needs to understand and support the need for sustainable resource use and allocation as well as the need for sustainable economies to ensure long-term economic prosperity. Community groups that are driving sustainability issues are growing and they can be encouraged to:

- build community capacity to reduce environmental impacts
- develop the resilience of communities to adapt to change
- display the skills and confidence to take action.

Effective and sophisticated engagement strategies, from informing to empowering, can make the most of partnership opportunities.

Collaboration across government

Working in a collaborative way across government agencies and departments is a priority to maximise outcomes and leverage opportunities. Forums and opportunities to facilitate communication between agencies can be developed to support the resilience framework and decode some of the complexities that make problem solving difficult.

Collaboration with local government

With up to 18 local governments operating in the Metropolitan Adelaide subregion, partnerships are an ongoing priority. Local councils are owners and managers of significant areas of open space, remnant vegetation and stormwater management systems. Information sharing and project partnerships need to continue but opportunities to value add to projects should be explored. Communication and engagement strategies need to be developed around all significant investments in natural resources management. For example, the construction of stormwater retention wetlands across Adelaide creates opportunities for community involvement in the growing, planting and maintaining of the associated green belts. Citizen science and community monitoring activities could be used on and around these sites to build community awareness and capacity.

Collaboration with industry

Working with industry bodies and associations will ensure that their needs are incorporated into subregional planning and action. Environmentally sustainable policies and practices can be promoted through a range of mechanisms that can be more effective than one-on-one activities. Opportunities for cross collaboration between industries and land managers or businesses are a significant outcome of working with industry groups.

Landscapes

The development of Adelaide since European settlement has resulted in almost total loss of the original ecology and natural heritage of the subregion. The Adelaide Plains before 1836 would have been a biodiversity hot spot, with 20 vegetation associations across its varied landscapes (Kraehenbuehl 1996).

Today, with over 70% of the state's population (1.1 million people; (Australian Bureau of Statistics 2011)) living in the metropolitan area, the impacts on that original biodiversity have been significant. An estimated 97% of the original vegetation and associated habitat of the plains have been lost; the mangroves at St Kilda account for most of the remaining 3%. Relatively large areas of intact vegetation remain in the Hills Face Zone and can form the basis for increased connectivity across the hills face landscape and through to the riparian zones across Adelaide.

Despite the loss of original biodiversity across what is now the Adelaide metropolitan area, significant opportunities remain to manage natural resources. Remnant vegetation in an urban context can be regarded as a secondary priority from a landscape biodiversity perspective because of its generally less than pristine and degraded nature. However, these areas are an important local focus for metropolitan residents and contribute to the liveability of the city, can assist in reducing the heat island effect of cities, and can contribute to the community's connectedness to natural resources. The most significant change resulting from urban biodiversity may be greater resilience and adaptability of urban communities who support and celebrate environmental works outside the metropolitan area.

The most significant difference between investing in environmental works in the urban environment and a more natural rural one is in the intent. The intent to protect remnant biodiversity across the wider landscape and support more sustainable agriculture is a regional priority. The aim in the urban environment is to communicate, engage, empower and facilitate action by as many stakeholders and partners as possible so that environmental impacts are understood and their causes dealt with through integrated responses.

Knowledge about the natural assets of the region is critical to the community supporting and engaging in natural resources management.

Protected areas*

Angove Conservation Park
Blackwood Forest Recreation Park
Cobbler Creek Conservation Park
Ferguson Conservation Park
Fort Glanville Conservation Park
Hallett Cove Conservation Park
Marino Conservation Park
Moana Sands Conservation Park
O'Halloran Hill Recreation Park
Shepherd's Hill Recreation Park
Sturt Gorge Recreation Park
Torrens Island Conservation Park

*Protected under National Parks and Wildlife and Forestry Acts

Vegetation of Metropolitan Adelaide

Broad vegetation groups found in the Metropolitan Adelaide subregion include:

- Cypress Pine (*Callitris gracilis*) sandy woodland
- Mallee Box (*Eucalyptus porosa*) and Grey Box (*Eucalyptus microcarpa*) grassy woodlands
- Chenopod shrubland
- specific coastal vegetation.

Coastal vegetation

The coastal beaches of the metropolitan area are highly modified, with significant urbanisation and recreational use. Only 2% of remnant vegetation remains between Outer Harbor and Point Malcolm, south of Semaphore, and unmanaged access in Largs Bay and Semaphore dunes is an ongoing problem (Caton et al. 2009). Between Point Malcolm and Holdfast Bay the white sand dunes can extend up

to 200 metres inland and have been extensively mined, bulldozed and urbanised. Tennyson Dunes, Semaphore Park and Minda Dunes are important natural remnants. Additionally a range of large intact coastal habitats can be found at Kingston Park, Marino Conservation Park, Hallett Cove Conservation Park, Hallett Headland, Tingira Reserve, South Port Dunes, and Onkaparinga estuary. A number of important areas of remnant coastal cliff heath occur at Port Stanvac and other metropolitan sites. Intense recreational use of these beaches places high pressure on the remaining natural vegetation (Caton et al. 2009). Further south along the coast the landform changes from dunes to cliffs, starting around Hallett Cove and Port Stanvac to Port Noarlunga. The low undulating coastal plateau has sandy beaches at the base of cliffs and shore platforms.

Coastal vegetation in the subregion includes the broad vegetation types of samphire, coastal cliffs and dunes, and coastal fringing communities. A number of specific vegetation communities in these broad vegetation types are discussed below (Croft et al. 2006).

The condition information comes from baseline vegetation condition monitored in coastal worksites. It is not representative of the vegetation communities as a whole as the sites monitored are all actively managed in some way. Each site has been monitored once over the last three years to provide the condition information. Each site will be revisited over the next three years in the same chronological order to determine trends in condition. The information is an amalgamation of the data for all the sites of that particular vegetation community (Adelaide and Mount Lofty Ranges NRM Board 2012).

Coastal shrubland and tall shrubland

This vegetation community features shrubs 1–3 metres high and often densely spaced. It generally occurs on secondary dunes (often 2nd and 3rd dunes back from the coast) and has a relatively high area of bare ground, usually up to 20%. Dominant overstorey species include Coast Daisy-bush (*Olearia axillaris*), Coastal Wattle (*Acacia sophorae*), Coast Beard-heath (*Leucopogon parviflorus*), Coast Sword-sedge (*Lepidosperma gladiatum*) and Sea-berry Saltbush (*Rhagodia candolleana*). Examples of this vegetation community are found at Minda Dunes and Grange Dunes. Vegetation condition monitoring at these two sites shows variable results. Some vegetation is in quite good condition across the sites, and some is in moderate and poor condition. This is probably a reflection of the level of recreational use and modification at each site.

Metro Coast

Condition: Variable

Source: Mahoney 2011; Adelaide and Mount Lofty Ranges NRM Board 2012

Non-eucalypt coastal low woodland

These communities are dominated by non-eucalypt trees and a diverse number of life forms unless Dryland Teatree is the sole dominant forming low open forest or low closed forest. This community has relatively little bare ground (<10%) and generally occurs on the relatively stable hind dunes. Dominant overstorey species include Drooping Sheoak (*Allocasuarina verticillata*), Southern Cypress Pine (*Callitris gracilis*), Coastal Wattle and Dryland Teatree (*Melaleuca lanceolata*). Examples of this vegetation community can be found at Hallett Cove. Weeds are an issue at both sites and will require ongoing control and monitoring.

Hallet Cove Conservation Park

Condition: Good

Source: Mahoney 2011; Adelaide and Mount Lofty Ranges NRM Board 2012

Coastal cliff low shrubland, hummock grassland and very low open woodland

This vegetation community most often occurs on coastal cliffs and rocky headlands and includes a wide variety of vegetation associations. It is dominated by low growing vegetation <2 metres tall and often <1 metre tall that are usually shrubs but also include hummock grasses and stunted trees. The dominant canopy cover is principally mid-dense (30–70% foliage cover) with moderately high species diversity (20+) and life forms diversity. Exposed or surface rock is often a significant component of groundcover. Dominant species in this community include Pale Turpentine Bush (*Beyeria lechenaultii*), Prickly Ground-berry (*Acrotriche patula*) and Mallee Pomaderris (*Pomaderris paniculosa*). Examples of this vegetation community can be found at Kingston Park, Marino Conservation Park and Tingira Reserve. All sites have high pressure from weed impacts with the potential to reduce the future condition of the vegetation at the sites.

Marino Conservation Park

Condition: Good

Source: Mahoney 2011; Adelaide and Mount Lofty Ranges NRM Board 2012

Tingira Reserve

Condition: Good

Source: Mahoney 2011; Adelaide and Mount Lofty Ranges NRM Board 2012

Threatened species and communities in Metropolitan Adelaide

Action to address threatened species and communities is required at a number of scales. Within the Metropolitan Adelaide subregion, landscape scale restoration is not a priority, but specific action is still required for certain species and communities to prevent further decline and potential extinction. The geographic scope of species status does not directly equate to priority for action. The recovery of some nationally threatened species of very high national significance, will not be strongly influenced by action in the region; the management requirements of state or regional listed species (for which meaningful action can be undertaken) may be more appropriate as a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

Much of the remaining areas of vegetation in this subregion are along the Hills Face Zone, and the coastal mangroves and samphire swamps. Information about the mangroves and coastal areas along the Barker Inlet is contained in the Northern Coasts description. Despite significant clearing of native vegetation in the Metropolitan Adelaide subregion, there are still some threatened ecological communities and species that require protection, for example:

- Grey Box (*Eucalyptus microcarpa*) grassy woodland (listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*)
- Cypress Pine (*Callitris gracilis*) sandy woodland.

Examples of fauna under threat that require particular attention are the Chequered Copper Butterfly (*Lucia limbaria*) that lives in the Adelaide Park Lands, Black-chinned Honeyeater (*Melithreptus gularis*), Australasian Bittern (*Botaurus poiciloptilus*), Tree Martin (*Petrochelidon nigricans*), Hooded Plover and five freshwater fish species:

- Congolli (*Pseudophritis urvilii*) (listed as vulnerable in Hammer et al.2009)
- Pouched Lamprey (*Geotria australis*) (listed as endangered in Hammer et al.2009)
- Short-headed Lamprey *(Mordacia mordax*)(listed as endangered in Hammer et al.2009)
- Mountain galaxias (*Galaxias olidus*) (listed as vulnerable in Hammer et al.2009)
- Short finned eel (*Anguilla australis*) (listed as rare in Hammer et al.2009).

Examples of threatened flora are:

- Sandhills Greenhood (*Pterostylis arenicola*) which grows in Cypress Pine sandy woodland – the one remaining population in the subregion is at Grange Golf course
- Small Scurf-pea (*Cullen parvum*) which grows in Cypress Pine-Blue Gum woodland – the one remaining population is at Hope Valley Reservoir
- Variable Glycine (*Glycine tabacina*) which grows in Grey Box grassy woodland can be found in several small populations in the Southern Hills Face Zone from Brown Hill Creek to Coromandel Valley
- Black Cotton-bush (*Maireana decalvans*) which grows in chenopod shrubland.

Grey Box Grassy Woodland

Grey Box grassy woodland is a nationally threatened vegetation community found in the AMLR region. The Hills Face Zone is one area of the region that contains the largest patches and contiguous remnants of this community. This vegetation is found on public or local council owned land (Mitcham, Belair, Marion) and on private land in the hills face ranging from residential properties to larger 'lifestyle' blocks. Historically this land was used for grazing, but in many instances land use has changed to reserves and open space as urbanisation of the area has increased. Grey Box grassy woodland is under increasing pressure from pest and weed invasion and increased recreational use of parks. However ,there is significant opportunity to protect and restore areas of remnant vegetation in the Hills Face Zone through engaging the community and land managers to improve their knowledge and understanding of this vegetation community.

Water resources of Metropolitan Adelaide

Urban watercourses are generally and variably degraded and highly modified. Water quality is influenced by land management and urban development. Increased impermeable cover associated with urbanisation increases rainfall runoff producing high watercourse flow conditions that transport contaminants, such as nutrients, heavy metals, salt and pathogens, and erode watercourse beds and banks. The quality of stormwater runoff is generally worse during the first flush, after which it can improve. Some watercourses have been remediated to a more natural creek design than those that remain as concrete channels. Urban development and activities and pest animals and plants are ongoing threats to watercourses.

Little Para River

The river's name derives from the Kaurna word Pari, which roughly translates as a stream of flowing water. The Little Para River is a prescribed watercourse that runs from its source near Lower Hermitage in the Mount Lofty Ranges, flows northwesterly to Little Para reservoir and then westerly to Barker Inlet of Gulf St Vincent at Globe Derby Park. The Barker Inlet is described in more detail in the Northern Coast subregion.

Modified natural landscapes remain along the water's edge, with varieties of eucalyptus woodland and native Golden Wattle (*Acacia pycnantha*). Remnants of the earliest almond trees and orange groves are still present. Active management of gullies and hill slopes includes the control of pest plants, removal of rubbish and replanting of local native vegetation.

The estimated 425 dams (1999 data) on the Little Para and the Little Para reservoir significantly reduce stream flow and consequently groundwater recharge below the stream bed. Water quality of the lower reaches of Little Para River has been extensively affected by urban stormwater runoff, as well as runoff from grazing land, with fertilisers and animal waste washing into the river.

Torrens River

The River Torrens catchment extends from Mount Pleasant in the Mount Lofty Ranges to West Beach on the Adelaide Plains. The Lower Torrens catchment includes First to Fifth Creek subcatchments, and has two distinct zones: hills zone and plains zone. The watercourses of this catchment are highly modified on the plains and used as stormwater drains; some sections are inadequate for flood mitigation.

The River Torrens, as it flows across the plains through mostly residential areas, is part of the Western Mount Lofty Prescribed Water Resources Area (PWRA). The water regime of this river has been highly modified, with significant extractions upstream, including water supply reservoirs. This has changed the original values and physical characteristics of the watercourse. Stormwater inflow significantly increases the volume of water downstream, reaching the coast. The water allocation plan for the Western Mount Lofty Ranges (including the Torrens River) proposes to manage the impacts of water extractions through the use of threshold flow rates, below which water cannot be taken. This will help ensure that essential flows support the retention of aquatic refuge habitats. Further studies on the River Torrens to maintain fish migration indicates a seasonal flow variation, and the importance of flows during autumn and spring (Adelaide and Mount Lofty Ranges NRM Board 2013).

Torrens River (Bonython Park)

Condition: Poor

Source: www.epa.sa.gov.au/reports_water/c0278-ecosystem-2011

The River Torrens and its riparian zone serve a number of important purposes including flood and stormwater management, and recreation, particularly along Linear Park. This highly modified river system has extensive areas of formal public open space, particularly in the Adelaide CBD, which are often used for public events. The river banks range from steep embankments and dense vegetation to wetlands and revegetated areas and open unstructured recreation areas such as parks and sporting facilities.

Relatively little remnant vegetation remains along the Linear Park. Most existing vegetation is dominated by exotic planted species and weeds, many of which regenerated from amenity plantings, garden escapees and external soil dumping. The scattered River Red Gums along the entire Linear Park are mainly large and mature, providing habitat for a range of native wildlife. Management of Linear Park is not conducive to the survival (and seed set) of native grasses, particularly because of mowing regimes. Overall, the remnant vegetation component of biodiversity along Linear Park is considered to be in poor condition.

Erosion is a problem along part of the river corridor, exacerbated by a lack of vegetation on the river banks. Excessive reed growth in the channel appears to be causing sedimentation of the existing channel, and is redirecting water flows and resulting in erosion as water is forced to find a new flow path.

A number of stormwater outlets along the River Torrens discharge runoff from buildings, footpaths and streets into the river channel, which can bring higher inputs of pathogens, nutrients, heavy metals and litter. These pollutants and alterations to water flow impact on water quality and lead to algal blooms, erosion and sedimentation, and a continued decline in the abundance and diversity of native flora and fauna (both aquatic and riparian).

River systems also provide natural filtering and decomposition processes that maintain water quality. In urban catchments, impervious surfaces generate more water at higher velocities flowing along the river, and this limits the natural filtering and decomposition. Lowering the peaks and extending the duration of flow in the river is a significant challenge in an urban environment

Torrens River has an artificial extension to Gulf St Vincent known as Breakout Creek. The artificial Torrens River 'estuary' was created by diverting Torrens River away from the Port River system through Breakout Creek flood channel, constructed in 1934, to the dunes at Henley Beach South. Previously, there had been no direct outlet to the sea and water collected in the extensive reedbeds which have since been removed. Large flows would eventually find their way south to the Patawalonga and north to Port Adelaide River.

Breakout Creek has high fish species diversity and abundance (McNeil et al. 2010) and the estuary is used by commercially and recreationally important species, and some recreational fishing (line fishing, hoop netting) takes place. A large weir wall prevents seawater incursion. A small estuarine pool at the base of the weir has a shallow channel through the beach to the sea. Small numbers of Silver Gull, Australian Pelican and Black-faced Cormorant use the estuarine pool, with a range of waterfowl recorded in the freshwater reaches of Breakout Creek.

Algal blooms in Torrens Lake

Torrens Lake is an important community asset and tourism icon for Adelaide, but for much of its recent history it has suffered from frequent and repeated blue-green algal blooms. Microscopic blue-green algae are naturally occurring, but can reach high concentrations (or 'bloom') in situations where warm temperatures, stagnant water and high nutrient levels combine. In high concentrations, blue-green algae can discolour water, form scums, produce unpleasant odours, and release toxins that can be harmful to both humans and wildlife. As a result, once blue-green algae concentrations reach a particular level, Torrens Lake is temporarily closed to the public for health reasons. Lake closure can extend over weeks or even months, and the social, economic and environmental impact is significant.

Photo: Government of SA

Patawalonga Creek

Four major streams of the Patawalonga catchment contribute flow to the Patawalonga Lake at Glenelg. From the lake, water passes through a lock before discharging to Gulf St Vincent.

The four main waterways are:

- Sturt River (largest catchment area)
- Brown Hill Creek
- Keswick Creek (including Glen Osmond and Park Land creeks which flow over both rural and urban areas separated by the Hills Face Zone)
- Mile End Cowandilla drain and the remnant Patawalonga Creek.

The upper catchment is hilly and until recently was mainly rural; the lower part of the catchment is a largely urbanised, coastal plain of low relief. Artificial drains constructed in the urbanised lower subcatchment generally follow along the east-west road patterns; most are concrete-lined and many

are now underground. Some Brown Hill Creek and lower Park Lands Creek/Keswick Creek systems remain unlined. Current modelling indicates that current farm development (including building dams) has an insignificant impact on the quantity of catchment yield in the Patawalonga Creek catchment.

Major land uses in the catchment are residential, industrial and commercial. The major impacts on water quality and quantity occur in the developed part of the catchment. The catchment is home to approximately 310,000 people, has some 114,000 dwellings, and its 9,600 commercial and industrial premises represent a significant portion of Adelaide's business activity. Settlement and development, both in urban and rural catchments, has impacted on the catchment water environment as well as the receiving waters of Patawalonga Basin and Gulf St Vincent.

Watercourses in the urban reaches of the Patawalonga catchment generally have levels of heavy metals in excess of national guidelines, although these levels appear to have been in decline over the last few years. Total phosphorus in the urban reaches does not appear to be of concern, but exceeds guideline levels more than 75% of the time in the upper rural reaches. Phosphorus levels also appear to be declining over time.

The clearing of native vegetation for urban or agricultural use has left very little of the catchment in its original state. On the plains native vegetation and fauna has been almost completely lost and low lying swamp areas behind coastal dunes have disappeared. Remnant vegetation is concentrated in the eastern sections of the catchment area. Of the 14 vegetation associations, the most notable is the band of *Eucalyptus microcarpa* woodland starting from Shepherds Hill Recreation Park. This woodland is distributed across the suburban foothills of Panorama and Torrens Park which links with Brown Hill Recreation Park and Belair National Park. The woodland terminates near the South Eastern Freeway north of the suburb of Waite.

Sturt River

Sturt River is the largest waterway draining to the Patawalonga Lake. The upper part of the 120 km^2 catchment comprises the western slopes of the Adelaide Hills to the southeast of the city. It is steep and includes significant areas of native vegetation, as well as large and expanding areas of urban development in Belair, Blackwood, Coromandel Valley and Flagstaff Hill. The lower portion of the catchment is completely urban. Downstream of Sturt Road the river channel is a concrete lined channel, and runoff from the urban catchment discharges directly into this channel through council drainage systems.

Sturt River (Bedford Park)

Condition: Good

Source:www.epa.sa.gov.au/reports_water/c0249-ecosystem-2011

Sturt flood control dam, located at Craigburn Farm, holds a volume of water upstream at an approximate depth (at the dam wall) of 10 metres. Above this, water spills and is released downstream. This structure changes the timing and rate of flow to downstream environment.

Brown Hill Creek

Brown Hill Creek drains an area of approximately 36 km^2. Most of the catchment is in its upper reaches, which consist primarily of rural land in the Hills Face Zone. Soil is mainly pervious and a significant portion of the rain falling on the catchment is expected to infiltrate into the soil. The upper reaches of the catchment are relatively steep with defined riverine channels that limit the spread of floodwaters. The middle and lower reaches also have defined channels that pass through urban areas but they are of flatter grade. Floodwater can thus overtop the channel and spread across the urban environment. The

storms that cause major flooding along Brown Hill Creek have long periods of rainfall with relatively low intensity. In urban areas the catchment is defined by council drainage systems. The creek is heavily modified and for significant lengths is in private property.

The overall environmental health of the urban section of Brown Hill Creek is very poor. Extensive sections have been concrete lined and the remainder are partially lined or have bare earth with exotic vegetation dominant on all reaches. Sections in private ownership are treated largely as domestic gardens established with a wide range of exotic plant species.

Brownhill Creek (Mitcham)

Condition: Good

Source: www.epa.sa.gov.au/reports_water/c0005-ecosystem-2008

The main features of Brown Hill Creek in the urban section are:

- a channel 16.7 km long – 2.5 km fully concrete lined, 1.3 km concrete lined, 4.2 km earth lined, and 8.7 km through urban gardens
- bank erosion is not widespread, it is confined to localised problem spots and there is no significant channel bed erosion
- no indigenous aquatic or semi-aquatic vegetation is left in the channel with the exception of the creek below the junction with Keswick Creek in Adelaide Airport; the only indigenous trees left are scattered remnant River Red Gums (*Eucalyptus camaldulensis*); exotic trees, mainly ash (*Fraxinus rotundifolia*) are the dominant vegetation type.

Private ownership of urban watercourses

Private ownership of watercourses is a feature of the urban catchment and responsibility for maintenance of the watercourse, even parts damaged by major upstream flows, rests with private landowners. Most are unable to spend thousands of dollars on remediating erosion problems caused by flows originating upstream. In several places along urban watercourses, bank erosion or stability problems require works on a significant scale. Ongoing community engagement in managing urban watercourses is a priority and ensuring development planning actions support sustainable urban watercourse management is critical to reducing continuing impacts both locally and downstream (including the marine environment).

The physical form of watercourses in the rural catchment is more natural than in the urban catchment. Some channelisation has occurred on properties on valley floors where market gardening was once a major land use. Overall, rural watercourses are relatively stable with very little bed or bank erosion observed. The only significant erosion issues are related to road runoff being discharged to private properties and some erosion of hill slopes associated with bicycle and walking paths.

The main features of watercourses in the rural section are:

- 58.5 km of watercourses
- 37 farm dams with an estimated total water storage capacity of 72 ML
- very few erosion problems along watercourses
- exotic trees, which are a problem in most catchments
- much of the original native vegetation along the watercourses lost or replaced by weeds but some good sections, mostly in the upper reaches do remain.

Keswick Creek

Keswick Creek drains approximately 31 km^2 and has two major tributaries, Glen Osmond and Park Lands creeks, both of which have some rural catchment. The catchment of Glen Osmond Creek includes a significant part of the South Eastern Freeway. Park Lands Creek drains part of the southern section of the City of Adelaide. The urban catchment of Keswick Creek is defined by the council drainage schemes which discharge into it.

Park Lands Creek catchment has a high proportion of urban area. Development of land for residential housing and commercial development has increased the impervious area, which contributes to increased runoff. These urban areas include a network of stormwater pits and pipes that collect runoff from roads, and feed the water into the creek system.

Glen Osmond Creek has a mixture of rural and urban areas and therefore, storms of both short and long duration can cause significant flooding. As most of the lower catchment is urbanised, the lower reaches of the creek typically experience flooding during shorter duration storms.

Patawolonga Lake

The Patawalonga Lake system at Glenelg extends from Tapleys Hill Road bridge to the ends of the breakwaters at the entrance to Holdfast Shores marina. Water is regulated by a lock and a pipeline (Barcoo Outlet) that drains into the sea at West Beach. The estuary is fed by the Patawalonga Creek, Brown Hill Creek, Sturt River and other urban drains. Commercially and recreationally important fish use Patawalonga Basin and Black Bream spawn and continue all stages of their life cycle there. It was originally constructed as an artificial stormwater sedimentation basin and received storm and surface waters from council drains and many creeks whose lower sections were highly modified. It now has a seawater circulation system. The Barcoo Outlet now diverts stormwater from Sturt River and Brown Hill, Keswick and Patawalonga creeks away from the Patawalonga Lake and directly out to sea. Water quality is dependent on the operation of the Barcoo Outlet as both a diversion for stormwater and as part of a seawater circulation system. Some major flood flows still pass through the basin and enter Gulf St Vincent by means of the floodgates near the marina. Human uses in the area include recreational line fishing, boating and mooring. Adjacent land use includes residential, industrial, Glenelg Wastewater Treatment Plant, marina facilities at Glenelg, Patawalonga golf course and Adelaide Airport.

Increased nutrients, turbidity and sedimentation from stormwater flows are threats to water quality. Perceived threats include increased turbidity and increased sedimentation caused by dredging operations at Holdfast Shores marina, as well as altered patterns of water and sediment movement from the location of breakwaters at Holdfast Shores marina. Freshwater flows to the system have been reduced with patterns of water and sediment movement already altered by construction of the lock near the estuary mouth.

Field River

The Field River catchment, south of Adelaide, extends over an area of approximately 60 km^2. This predominantly urban catchment is characterised by residential development around the Happy Valley reservoir over the past 20 years. Approximately 50% of the land is used primarily for residential and recreation activities. The remaining land is taken up by the reservoir and surrounding tracts of pine plantation forest, native vegetation and golf course, and the steeply sloped uninhabitable area surrounding Field River. The Lonsdale Industrial Estate sprawls across the coastal region between O'Sullivan Beach and the mouth of Field River.

Field River catchment has undergone significant urbanisation with the expansion of the southern suburbs of Adelaide. Urbanisation of the catchment is estimated to have increased annual average runoff by more than 300% since 1945, and reduced the quality of water entering lower Field River. The additional, poorer quality runoff generated in the catchment is believed to have a detrimental effect on in-stream freshwater ecology and the downstream marine system.

A memory of Field River

Bernard Doube remembers the Field River in the 1950s.

The Field River rose in coastal farmland and joined the sea at Hallett Cove. It never ran dry, not even during the hot, dry Adelaide summer and so we boys could always swim and paddle our rafts in the small brackish lagoon that separated the Field River from the sea.

Only during winter, after rain, did the water flow directly into the sea. At other times a wide sand bar separated the fresh from the salty, with the river water flowing underground to the sea through the sand. We knew this because when we dug a well in the sand bar the water was fresh, not salty. At its broadest, the lagoon was about 5 metres wide, with a mud bank on the uphill side and sand on the sea side. Upstream, both banks of the lagoon were covered with bull rushes in which families of water rats and moorhens lived out their precarious lives, hunted by foxes, dogs and small boys. That was forty years ago. Now the bulldozers have been and gone, and Hallett Cove is a coastal residential suburb called Sheidow Park.

Writen by Bernard Doube South Australia, 20 April 2004

The lower Field River valley, which is relatively undeveloped for a catchment area in metropolitan Adelaide, could provide a significant biodiversity corridor linking the Hills Face Zone to the coast. However, it has been largely cleared for agriculture or grazing and today only small, fragmented patches of indigenous vegetation remain, largely confined to the riparian zone and on steep, rocky hillsides which are not easily accessible to stock. The native vegetation remaining is largely grassy or grassy woodland ecosystems that are often not recognised as native habitats and so can be inappropriately managed for both production and conservation purposes. The ungrazed slopes on steep, rocky hillsides have potentially high conservation value and further information about their condition and extent is required.

Christie Creek

Christie Creek catchment includes Stanvac Creek subcatchment and has five major tributaries that converge near the mid-point of the catchment. A main single channel then meanders its way through coastal hills before reaching the sea at Christies Beach. Much of the catchment has been urbanised with around 50% residential development.

Hydrological records indicate that lower Christie Creek flows at all times of the year, while Field River at Main South Road is known to dry out during the summer months. Evidence shows that groundwater contributes to a small proportion of Christie Creek's annual flow and it is suspected that flow in Field River is also extended due to groundwater discharge through the creek bed and banks.

Urban stormwater

Water for Good is the major water policy statement for the state. It identifies the requirement to reduce reliance on rain-dependent sources (including the River Murray and Mount Lofty Ranges reservoirs) by increasing stormwater harvesting to 20 GL/annum by 2013 and up to 35 GL/annum by 2025. This requires increased demand for stormwater reuse across the community.

The management of stormwater for the future is articulated in the *Stormwater Strategy* (Department for Water 2011a) which supports an integrated approach to stormwater management. It identifies key issues for its management in the future such as impacts of a changing climate on rainfall patterns and

water availability, increased population and increased urban development which can generate larger volumes of runoff. The stormwater strategy aims for water from rainfall events to move through the landscape in a controlled way to:

- minimise the threat of flooding
- ensure water is captured and used for productive purposes
- optimise the environmental outcomes for urban waterways and coastal environments.

The stormwater strategy links its actions with other policy documents, including the *Adelaide Coastal Waters Water Quality Improvement Plan* (McDowell and Pfennig 2013), ensuring management is integrated from the top of the catchment to the marine receiving waters.

Water-proofing the city has created new wetlands and habitats as well as public open spaces that can raise the awareness of the general public. Water management and its value to amenity and biodiversity are important connections in any South Australian landscape.

Groundwater

The groundwater resources of the Metropolitan Adelaide subregion predominantly lie in the sedimentary aquifers of the Adelaide Basin (Figure 26). The Central Adelaide Prescribed Wells Area (PWA), established in 2007, includes the south portion of the Adelaide Plains Sub-basin, the Golden Grove and Noarlunga embayments, and the underlying and adjacent fractured rock aquifers of the Adelaidean System. The boundary of the Central Adelaide PWA abuts the Northern Adelaide Plains (NAP) PWA, which encompasses the remainder of the Adelaide Plains Sub-basin, and extends west and south to the boundary of the Western Mount Lofty Ranges PWRA. A water allocation plan is being developed for the Adelaide Plains, which encompasses the Central Adelaide PWA, the NAP PWA and the Dry Creek Prescribed Area.

The T1 and T2 aquifers are present in the west metropolitan area from the CBD to Glenelg and Outer Harbor with average thicknesses of 70 metres. The underlying sedimentary sequence contains the T3 and T4 aquifers, which are not used due to both poor water quality and depth. The T4 aquifer directly overlies the Adelaidean basement rocks. Groundwater in the Central Adelaide PWA is primarily extracted from the first and second tertiary aquifers (T1 and T2) for irrigation and industrial use with quaternary and fractured rock aquifers providing smaller supplies (Department of Environment, Water and Natural Resources 2012a). The source aquifer for use is dependent on location in the area. The T1 aquifer is the main supply aquifer west of the CBD with the T2 aquifer used at Regency Park and Osborne and fractured rock aquifers providing most supplies east of the central business district.

The Golden Grove Embayment, located between the Para and Eden-Burnside Faults to the east and south of the CBD, comprises a complex sedimentary sequence (Figure 26). The Tertiary sequence is often undifferentiated and thickens from about 20 metres in the Tea Tree Gully area to over 300 metres in the southwest near the coast at Brighton. The underlying fractured rock aquifer is usually accessed for irrigation and MAR. The Noarlunga Embayment is located in the south of the Central Adelaide PWA between Marino and Noarlunga extending east to the foothills. The Tertiary sequence is often undifferentiated in this area and groundwater is generally saline and not widely used (Figure 26).

The fractured rock aquifers are contained in the Adelaidean System of consolidated sediments that form the foothills and Mount Lofty Ranges, and the basement rocks underlying the sediments of the Adelaide Plains. These aquifers are highly variable and occur as multiple local aquifer systems and can provide significant supplies. Lateral groundwater flow from these aquifers recharges the sedimentary aquifers beneath the Adelaide plains.

Managed aquifer recharge (MAR) in various locations of the PWA is undertaken mainly in the T1 and fractured rock aquifers. The quaternary sediments comprise predominantly the Hindmarsh Clay. They are present across the metropolitan area and accessed for domestic irrigation. A perched sand aquifer on the Le Fevre Peninsula contains very good quality water and is heavily accessed by backyard bores in this location.

Groundwater resources of the NAP and Central Adelaide PWAs will be covered by one Adelaide Plains Water Allocation Plan currently in development.

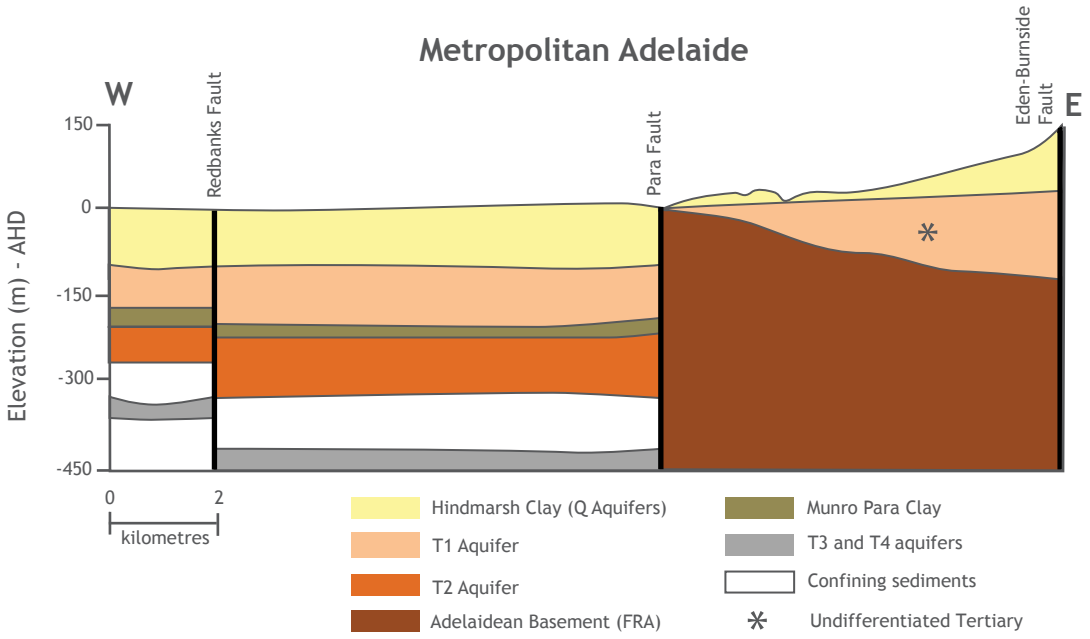


Figure 26: Adelaide Plains Sub-basin and Golden Grove Embayment

Groundwater quality and spatial distribution of extractions in the Central Adelaide area reflects the flowpaths across the Eden-Burnside and Para Faults from recharge areas. Salinity in the T1 aquifer is generally less than 2,000 mg/L in the area extending west of the CBD from West Lakes to Brighton and around Osborne. In these areas significant extractions occur from the T1 aquifer for industrial use and recreational irrigation. Permanent cones of depression are centred on Thebarton and Osborne where continuous industrial extraction has historically occurred and a more seasonal cone of depression occurs around West Lakes with the concentration of recreational irrigation.

The T2 aquifer is generally more saline (> 3,000 mg/L) than T1 and is heavily used by industry at Osborne and Regency Park. In these locations continuous pumping has led to the development of permanent regional cones of depression (Department of Environment, Water and Natural Resources 2012a).

Metering of groundwater extractions is not currently in place and total extraction is estimated at about 10,000 to 12,000 ML/year, predominantly from the T1 aquifer. Water levels in the T1 aquifer are generally stable and the cones of depression in T2 are considered to be stabilising (Department of Environment, Water and Natural Resources 2012a).

Extractions from the fractured rock aquifers throughout the eastern part of the area in the Hills Face Zone, provide for agricultural irrigation. Long-term trends are reasonably stable showing a small decline in the eastern suburbs where tertiary sediments overlie the fractured rock aquifers (Department of Environment, Water and Natural Resources 2012a).

The trend for groundwater quality and salinity in the Central Adelaide PWA is negative but gradual enough to not change the current beneficial uses of the groundwater resource for at least 15 years. It is thus classified as a low risk to the resource in the medium term (Department of Environment, Water and Natural Resources 2012a).

The flattening out of seasonal rainfall patterns induced by climate change may impact water levels and salinity in the long term as the tertiary aquifers are recharged through groundwater flow from the fractured rock aquifers in the Mount Lofty Ranges which receive direct rainfall recharge (Barron et al. 2011).

Land use change may also create more concentrated areas of extraction as urban development occurs and industrial use intensifies in localised areas.

Groundwater dependent ecosystems

The types of groundwater dependent ecosystems (GDEs) found in the Central Adelaide area are generally:

- spring discharge from the fractured rock aquifers
- stream baseflow provided by the fractured rock aquifers
- terrestrial vegetation at the base of the Adelaide Hills (Cooling and Currie 2012).

Fractured rock spring discharge and baseflow occur throughout the Mount Lofty Ranges where fractures outcrop or changes in permeability promote the discharge of groundwater. Discharge may occur as springs at isolated locations on hillsides or near watercourses and as baseflow over extended reaches of watercourses that intersect the aquifer.

Groundwater discharge maintains aquatic habitats in persistent pools and wetlands and supports riparian vegetation (Department of Environment, Water and Natural Resources 2012a). Shallow groundwater systems in the Quaternary aquifer west of the Eden-Burnside Fault also support terrestrial vegetation such as River Red Gums (Cooling and Currie 2012).

A second class of GDEs rely on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include, as an example, riparian forests that require a supply of groundwater in the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases, and new species invade the system leading to a new structure and function to the ecosystem that does not necessarily provide the services required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

These GDEs could be impacted by climate change with reduction in the recharge of the fractured rock and shallow aquifers as a result of hotter, drier conditions and changing rainfall patterns (Barron et al. 2011).

Livelihoods

The economy is of fundamental importance and represents one of the most complex and interconnected systems that affect our region. Unfortunately conventional economics has been poor at addressing environmental or ecological problems that are the result of negative outcomes from market forces. The economy has often failed to address issues such as overuse of resources, habitat loss, air and noise pollution, excessive waste, or overcrowding and stress in communities.

The economy is also considered as the most important driver of the community's wellbeing and this is particularly relevant to the urban region. It is the economy that generates employment and the incomes that enable people to participate in the various markets that supply their needs. In the metropolitan areas the economic system can develop complex supply chains that break down basic connections: for some children food comes from a supermarket, timber from hardware store and water from taps. There can be lack of understanding of the economy's reliance on natural resources, those raw commodities that fuel most industries.

With such a high proportion of the state's population living in our region, connections must be drawn between a strong economy and sustainable environments. People also need to be aware that community wellbeing is dependent on their local environment for access to open space, contact with nature, healthy waterways, clean beaches, clean air, healthy populations of local wildlife and a sense of place. These environmental services are often taken for granted but are important contributors to happy communities.

The key long term outcome for the Metropolitan Adelaide subregion is to ensure that the environment is valued and factored into people's decision making around natural resources. Economic sustainability means ensuring a market for production, distribution and consumption of goods for the long term, which ultimately requires the proper management of scarce and limited natural resources.

The metropolitan area cannot then be understood or effectively managed by focusing only on a subset of system components. The future requires that we focus on the connections and relationships, more than the components themselves.

Adelaide central business district

The more densely built Adelaide central business district (CBD) is an example of the economic contribution made to metropolitan Adelaide. The CBD is a centre for retail, tourism, business, and education and research. It has over 23 million visitors a year (Adelaide City Council 2013). The Park Lands and River Torrens surrounding the CBD highlight connections between a liveable and pleasant city and natural resources. The CBD is also a valuable community resource and source of volunteers and contributors to natural resources management and sustainable living.

Agriculture and food production

Some areas of agriculture still remain in the Metropolitan Adelaide subregion particularly around the Hills Face Zone and foothills. They grow mushrooms, horticulture, small amounts of livestock, turf and cut flowers, and have a value of approximately $20 million (Australian Bureau of Statistics 2012c)

Food production and food security are important issues in light of changing climates and rising energy costs. Food grown in the region requires adequate and suitable land, and access to sufficient water and to markets. Retaining productive agricultural regions, planning for water consumption and connecting the urban community to growers through farmer markets and backyard vegetable gardens are examples of how the general public can be made aware of the fundamental systems involved.

Building and infrastructure

Port Adelaide is the main service point for shipping in South Australia. During 2011–12, 15.67 million tonnes of cargo was moved through the port and 2.4 million tonnes of petroleum was imported (Flinders Ports South Australia 2013). Other industrial activities include Osborne Maritime Precinct (defence industry), a soda ash plant, cement production and a fuel depot.

As a significant contributor to the economy of our state, the port is important infrastructure. These activities, however, pose threats to the natural resources of this subregion, in particular pollution from oil spills, discharge of waste material from soda ash and cement production, and land for samphire retreat restricted by industrial development.

Northern Coast and Plains

In summary

This most northwestern part of the region, with topography of low relief in its gently undulating plains and floodplains, is particularly vulnerable to the impacts of climate change. Its major towns, Gawler, Roseworthy, Mallala, Two Wells and Virginia are the focus of urban and industrial development, which could place further stress on its environmental assets. Gawler has significant riparian assets; Roseworthy is a major grain-holding centre and has a campus of the University of Adelaide. Other centres support surrounding farming and horticultural pursuits, including significant glasshouse tomato production. The northern coastal areas are sparsely populated (Figure 27).

Industry plays a significant role in parts of the region. For example, the salt fields at Dry Creek, along with constructed wetlands, support impressive visitation by migratory bird species, some of which are of international significance, and consequent tourism by bird watchers.

Significant vegetation types include coastal and samphire shrubland, mangrove forest, and diverse mallee and shrubland on the plains. Coastal vegetation, especially in small areas, is a refuge for site specific flora and fauna but is threatened by human development and recreation. A number of plant communities, such as Peppermint Box grassy woodland, Iron-grass natural temperate grassland and Southern Cypress Pine woodland, are threatened, as are certain species of plants and animals.

The surface water resources of the subregion lie in the Lower Light and Gawler rivers. The Light is an unregulated ephemeral river; the much more substantial Gawler River still has variable flows and terminates at Buckland Park lake and on extensive tidal flats. Water quality in the Barker Inlet-Port River estuary complex has improved since 2000 with the decommissioning of the Port Adelaide Wastewater Treatment Plant and other initiatives including the construction of extensive wetlands to treat stormwater.

Groundwater supports industries in the subregion, most notably horticulture, and managed aquifer recharge is practised. Longstanding cones of depression have stabilised in recent years with improved water extraction practices.

Northern Coast and Plains – Priorities for the future

These priorities for the future of the Northern Coast and Plains subregion have been developed from the information in this section. They may be whole of subregion priorities or specific for the coasts or plains.

Subregion wide

- Build community knowledge and support for the value of the biodiversity of the area, especially northern coast, particularly with respect to recreational use
- Encourage increased demand, and supply of, alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Support land use planning to minimise the impact of current and future urban growth to the natural environment

- Protect priority primary production areas from inappropriate development to maintain industry and business viability
- Facilitate integrated climate change adaptation of people and the landscape
- Protect and expand remnant vegetation (which is often retained on roadsides) and buffer it from surrounding impacts
- Promote sustainable land management practices to reduce the risk of erosion in broadacre agriculture
- Promote sustainable horticulture management to reduce impacts on the environment
- Support agriculture and horticulture to adapt to climate change or transition to alternative business models
- Protect water resources for aquatic health and agricultural use (quality)
- Protect and restore the Light and Gawler rivers' riparian zones for improved biodiversity and water quality outcomes
- Manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)
- Monitor for, and control, pests that have not yet become established in the region or in the Northern Coast and Plains subregion

Coastal specific

- Restore and rehabilitate the northern coast saltmarsh and shrubland system (with the highest priority around Port Prime) including planning for climate change impacts on species distribution
- Minimise the impacts of new development (particularly agricultural, industrial and urban) in the northern coast and adjacent subregions through appropriate land use planning controls
- Ensure that land use planning decisions allow for the retreat from sea level rise (as a result of climate change) of northern coastal landscapes (samphire, mangroves and shrubland)
- Improve the condition of the Barker Inlet and Gawler River estuaries through reducing land based impacts
- Protect migratory shorebirds habitat and increase the knowledge of the value of this habitat within the community

Figure 27: Northern Coast and Plains subregion

Introduction

This subregion covers the northwestern most part of our region and is boarded by the Marine, Adelaide Metropolitan, Central Hills and Northern Hills subregions, as well as the Northern and Yorke Natural Resources Management region.

Topographically, in the east, surrounding the towns of Roseworthy and Gawler, it is predominately gently undulating plains. It then flattens out to become plains in the west, which includes the towns of Mallala, Two Wells and Virginia. The plains are dissected by the Light and Gawler rivers which occasionally flood adjacent plains. This subregion intersects the traditional lands of the Kaurna people.

The Northern Coast contains important landscapes and supports a range of industries. Of particular importance are the coastal ecosystems that support internationally listed migratory bird species.

Increases in industrial and urban activity could further degrade natural habitats along the coast. Proposed urban expansion around Two Wells and Roseworthy may also see increased recreational use of the coastal area, which has potential negative impacts on the environment, particularly from off-road vehicles driving through vulnerable samphire habitats that can take a long time to recover.

Increased populations in the subregion also bring opportunities. More volunteers may want to support good natural resources management. Future urban development could include water sensitive urban design principles and promote the use of native vegetation for landscaping, both of which can reduce impacts and improve condition of the natural landscape.

Lifestyles

The Northern Coasts and Plains subregion is a complex mix of industrial, urban, rural and environmental land use. Its towns, of varying sizes, include Gawler as the major service centre, and Roseworthy, Mallala, Two Wells and Virginia.

The 30-year plan for greater Adelaide (Department of Planning and Local Government 2010) forecasts significant changes for the area, particularly in increasing population and urban areas. The local community is apprehensive about rapid residential development at the expense of agricultural land, heritage, natural amenity and rural atmosphere.

There is a strong belief that the urban population has lost the connection to natural resources that is more easily found in a rural setting. The resulting land use conflicts, particularly at the peri-urban fringe, can be exacerbated by planning policy that is not clear and integrated.

Gawler is a major service centre to the surrounding agricultural district. Its proximity to Adelaide has also made it a commuter town, which has contributed to an approximately 12% increase in population in the council area since 2001. This urbanisation puts pressures on the natural resources of the region, in particular remnant native vegetation and stormwater management as land use changes from productive agriculture to urban and industrial development. Gawler has significant riparian landscapes and is noted as the site where the South and North Para rivers join to form the Gawler River.

Population

Gawler	23,957
Roseworthy	1,216
Mallala	1,047
Two Wells	2,293
Virginia	1,748
Angle Vale	2,363

Source: Australian Bureau of Statistics 2011 Census Data

The township of Roseworthy is a major grain-holding centre and site of the Roseworthy Campus of the University of Adelaide. The 30-year plan identifies it as a significant regional city with a population of 60,000 by 2040. This considerable impact on the

landscape will affect areas surrounding Roseworthy, Gawler and the Barossa Valley where housing demand is likely to increase. It is also likely to impact on surrounding natural resources that have a high recreation value, for example the Northern Coast.

To the west, the town of Mallala supports the surrounding farming community. Its population decreased by 2.5% between 2001 and 2011, which is typical of many rural towns that support farming communities.

Further south, around Two Wells, agricultural production moves from broadacre to perennial and annual horticulture, including intensive horticultural (glasshouse) production. Two Wells is home to a significant tomato glasshouse industry and has been identified in the 30-year plan as a site for significant urban expansion, by 10,000 people over 30 years.

The townships of Virginia and Angle Vale support a significant horticulture industry, which is under pressure from increased urbanisation. Horticultural businesses in the area are characterised by a large number of small producers where English is a second language. Horticultural development includes both in-ground and glasshouse production. Irrigated horticulture is highly dependent on water resources. Good quality groundwater resources and recycled water from Bolivar Wastewater Treatment Plant both support horticultural development in the subregion. A range of natural resources management issues are important for sustainable horticultural development, including pest and weed control, and soil degradation.

The southern part of the subregion is an urban framework linked by major green corridors (including rivers and major roads, interspersed with regional parks). The predominantly industrial Dry Creek area contains salt fields and several constructed wetlands. The area has been identified for investigation for future urban growth in the 30-year plan. The proposed urban expansion in this area could significantly impact on both the constructed and natural wetlands and their significant bird habitat. Increased urban expansion will also reduce the ability for samphire and mangrove retreat from predicted sea level rise (as a result of climate change).

North of the salt fields, the coast is sparsely populated with a number of small coastal communities that can only be accessed by smaller arterial roads from the main highway. The population along the coast from St Kilda to the northern border of our region is approximately 900 (Australian Bureau of Statistics 2012d).

The six local councils in this subregion – City of Port Adelaide Enfield, City of Salisbury, City of Playford, Town of Gawler, Light Regional Council and District Council of Mallala – are all important contributors to natural resources management in this subregion. They are owners of open space and natural areas that contribute to habitat. Each council has a strategic plan for their area, which includes protection of natural resources as a key strategic goal in some form.

Even the low population of this subregion has potential to form community groups focused on protecting the small remnants remaining. Private land managers with large areas of biodiversity assets or land adjacent to roadside or remnant vegetation are ideal to promote the benefits of protecting and enhancing the remaining vegetation.

The capacity of this subregion's communities to adapt to climate change will vary with individual and community situations. Higher temperatures and subsequent heat related impacts on the community may increase. There may be increased localised dust pollution if dryer conditions reduce groundcover (Cole 2008). Increased dust could boost pollution related health conditions. Adaptation by these communities will require significant cooperation between community members and governments.

Coastal systems are highly vulnerable to sea level rise and the changing storm and wave energy regimes predicted as a result of climate change (Department of Climate Change 2009). Low lying areas could flood significantly with an increase in the height of storm surges, more intensive storm events and increase in stormwater runoff linked to rainfall events. There is a high risk of damage to building and infrastructure assets in the area as a consequence of climate change.

Landscapes

The Northern Coast and Plains subregion supports a diversity of vegetation including:

- coastal and samphire shrubland
- mangrove forest
- diverse mallee and shrubland vegetation groups on the plains
- River Red Gum woodland along the river systems
- Box woodland on the heavier soils to the southeast and along the floodplains of the lower reaches of the Gawler River.

Protected areas*

Port Gawler Conservation Park

Torrens Island Coservation Park

*Protected under National Parks and Wildlife and Forestry Acts

There is one registered protected area and three major rivers enter the marine environment through estuaries. It is typically an area of low rainfall, which is unique to this subregion in the Adelaide and Mount Lofty Ranges.

Landscape priorities for restoration in the Northern Coast and Plains

An assessment of the health of the landscape, based on bird indicator species, has identified that the low energy coastline systems (samphire, mangroves and mudflats) are a priority to maintain functioning ecosystems and biodiversity in this subregion (D Rogers pers. comm. 2013).

Most of the original vegetation in the Northern Coast and Plains has been lost. The subregion contains less than 10% remnant vegetation, which is considered relictual, and therefore has a low priority for landscape scale reconstruction (D Rogers pers. comm. 2013). The vegetation loss is a result of long-term, broadscale vegetation clearance and the change of land use to agriculture. Rather than landscape scale reconstruction, the focus for the Northern Coast and Plains is on protecting and buffering the remaining remnant vegetation, and ensuring that the threatened vegetation communities, flora and fauna remain and contribute to the system as a whole.

Vegetation of the coast

Coastal vegetation associations are often small in size relative to the scale of inland vegetation; however, they are critical as refuges for site specific flora and fauna. The degree to which the coastal vegetation of the subregion has been impacted by human activity is site dependent although the northern parts of the coast are relatively intact, as a result of low industrial and agricultural impacts and the relative difficulty to access some areas.

The vegetation of the coast is under threat from:

- increased recreational use
- urban expansion

- agricultural and industrial land use
- increased weed and pest impacts
- climate change.

The future of the mining tenements and licences in the saltmarsh area are of concern for this subregion. Mining activity could have significant impacts on the coastal environment. The salt evaporation pans are a valuable habitat for a large number of migratory shorebird species (protected under national and international agreements) and any change to their management or use has the potential to have a negative impact on this habitat.

This coast is vulnerable to the impacts of climate change, particularly sea level rise and changes in storm magnitude. Many areas of the Northern Coast are subject to storm surge inundation which is predicted to become more frequent under a warming climate. For example, samphire communities are sensitive to changes in salt water flood frequency; a sea level rise of 10 cm by 2030 would see some supra-tidal communities displaced by inter-tidal communities. If the supra-tidal communities are unable to migrate upslope they will be lost. Further inland, migration of these supra-tidal communities can be blocked by levees, urban and rural development and the speed at which species can adapt or migrate. The same inundation scenario would be likely to lead urban and farming communities to seek flood protection, further inhibiting the ability of significant supra-tidal habitats to migrate.

A description of coastal vegetation (Croft et al. 2006) and its condition at specific sites comes from baseline vegetation condition monitored in coastal worksites (Mahoney 2011). They are not representative of the vegetation communities as a whole as all the sites are actively managed in some way. Each site has been monitored once over the last three years to provide the condition information, and will be revisited over the next three years in the same chronological order to determine trends in condition. The information presented here is an amalgamation of the data for all the sites of that particular vegetation community (Adelaide and Mount Lofty Ranges NRM Board 2012).

Coastal shrubland and tall shrubland

Features of this vegetation community include shrubs 1–3 metres high and often densely spaced. These vegetation types generally occur on secondary dunes (often two or three dunes back from the coast) and have a relatively high area (up to 20%) of bare ground.

Dominant overstorey species include Coast Daisy-bush (*Olearia axillaris*), Coastal Wattle (*Acacia sophorae*), Coast Beard-heath (*Leucopogon parviflorus*), Coast Sword-sedge (*Lepidosperma gladiatum*) and Sea-berry Saltbush (*Rhagodia candolleana*). Examples can be found at Port Parham and Buckland Park.

Buckland Park

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Port Parham

Condition: Variable

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

The condition of the vegetation at Port Parham is variable. Vegetation has been assessed as in good condition at the southern end; at the northern end, where recruitment and structural diversity of native plants is lower than expected for this type of vegetation community, condition is moderate to fair.

The Buckland Park site indicates good vegetation condition, but this assessment needs to be carefully interpreted as the results may be skewed by the methodology used. Further information is available in the bushland condition monitoring report (Mahoney 2011). Buckland Park shows moderate species and structural diversity with excellent recruitment (regeneration). The condition of Buckland Park is influenced by the balance of fresh and salt

water in the system, this influences the species mix. Historically the system appeared to be more heavily influenced by saltwater intrusion; however, current management practices appear to have increased the influence of freshwater on the system. Freshwater plant species are now more abundant where saltwater species formerly existed. Key threats to vegetation condition are all rated as high, indicating significant pressure on the site. Re-assessment of this site, as part of the monitoring program, to determine trend information, is critical (Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011).

Non-eucalypt coastal low woodland

These vegetation communities are dominated by non-eucalypt trees and typically have little bare ground (<10%). They generally occur on the relatively stable hind dunes.

Dominant overstorey species include Drooping Sheoak (*Allocasuarina verticillata*), Southern Cypress Pine (*Callitris gracilis*), Coastal Wattle and Dryland Teatree (*Melaleuca lanceolata*). Examples of this vegetation community can be found at Middle Beach, Port Prime and Torrens Island.

Middle Beach in particular is under pressure from feral animal impacts. Port Prime is also impacted by feral animals as well as total grazing pressure. Overall the condition of both sites is deemed to be excellent. However, the structural diversity of groundcovers at Port Prime is poor, and may pose a threat to maintaining the condition of the vegetation at this site in the future.

Middle Beach

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Port Prime

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Coastal samphire shrubland

Coastal samphire shrubland vegetation communities are characterised by their samphire vegetation. They contain relatively high amounts of bare ground and are low in elevation. Areas are highly saline and may be inundated with sea water up to twice a day.

The dominant overstorey includes the Bearded Samphire (*Sarcocornia quinqueflora*) and less frequently, *Tecticornia pergranulata, Tecticornia halocnemoides, Tecticornia arbuscula* and other samphire species.

Coastal samphire +/- saltbush, bluebush shrubland

This vegetation community occurs at higher elevations than the coastal samphire shrubland, in moderate salinity and is irregularly and infrequently inundated with water.

It contains salt tolerant plants. Samphires and other chenopods dominate with overstorey species such as samphire species, Heathy Bluebush (*Maireana oppositifolia*) and Marsh Saltbush (*Atriplex paludosa*). Examples of this vegetation community are found in Little Para River Estuary and at Thompsons Beach.

The condition of vegetation at Little Para River estuary is classed as variable. It has good species and structural diversity but very poor recruitment and poorer groundcover structural diversity than expected for this type of community. The vegetation is also under pressure from weeds and feral animal impacts.

Thompsons Beach

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Little Para River Estuary

Condition: Variable

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

The condition of vegetation at Thompson's Beach is good, though threats from weeds and feral animals are high. Ongoing monitoring of this site is important to ensure that any changes in vegetation condition are identified early.

Importance of samphire shrubland

The coastal samphire shrublands of the Northern Coast were once visited by the critically endangered species the Orange-bellied Parrot (*Neophema chrysogaster*). This species winters along the South Australian coastline and such habitats are critical for the species long-term survival. The parrots are known for their habit of returning to the same specific site year after year and for being difficult to locate on the mainland. For this reason it is possible they still visit the area, even though they have not been recently observed on the Northern Coast.

The community is concerned about the lack of knowledge about and the value placed on samphire vegetation, and about increasing threats to samphire ecosystems. Raising awareness about the value of the area with the people who frequent and use the area recreationally is a priority for this subregion.

Mangroves and mudflats

Mangrove vegetation communities naturally have extremely low plant diversity with mangrove commonly the only vascular plant species adapted to such environments. Mangroves most often occur in inter-tidal sheltered areas and can be associated with mudflats. Brown films of diatoms and mats of blue-green algae are common on the exposed mud between trees.

Grey mangroves (*Avicennia marina*) form low woodland along the upper intertidal sandy mud flats in Port River/Barker Inlet and Gawler River estuaries (Department for Environment and Heritage 2007; Edyvane 1999a).

Despite historical loss of mangroves in the northern Adelaide area, in some parts of the Gulf, Grey Mangrove *Avicennia marina* are expanding at an unprecedented rate (Purnell et al. 2012). Mangrove and saltmarsh habitats boundaries do not stay the same over time, but change to reflect factors such as changes in sea level and supply of sediment. The expansion of mangroves may impact on saltmarsh habitats and areas that shorebirds use for roosting and feeding (Purnell et al. 2012). The expansion of mangroves has resulted in the loss of over half the samphire areas and approximately 90% loss of *Melaleuca* swamps.

Historically the increase in the green algae *Ulva* in the coastal waters, as a result of increased nutrients has been regarded as a cause of loss of mangroves (Edyvane 1991; Connolly 1986; Scientific Working Group 2011). The accumulation of large drifts of *Ulva* (together with dead seagrass), may prevent or retard the establishment and growth of young mangrove seedlings. *Ulva* blooms impact on seedlings, and may cause stress to mature mangroves, but some dieback may be attributed to the 'drowning' of mangroves by the accumulation of seagrass and *Ulva* in tidal creeks. The accumulation changes the regular tidal movement and drowns the pneumatophores as well as creating anaerobia and acid conditions near mangrove roots. Such drowning impacts may occur quite rapidly (P Coleman pers. comm. 2013).

Mud flats provide habitat for a range of annelid worms (or polychaetes) and many species of bivalve mollusc (including razor 'fish' (*Pinna bicolor*) and gastropod snails, such as *Bembicium)*. Larger organisms of muddy tidal flats include polychaetes (bristle worms, e.g. *Neanthes vaalii, Arenicola* sp., *Scoloplos simplex*), molluscs (e.g. the mud cockle *Katelysia* spp. and pulmonate snail, *Salinator fragilis*), crustaceans (e.g. the mud crab, *Helograpsus haswellianus*) (Benkendorff et al. 2007).

Tidal mudflats (in addition to other habitats) in Gulf St Vincent are important, both nationally and internationally, for wading or shorebirds. Within our region the Port River Mouth and Penrice Saltfields are of importance, particularly for Red-necked Stint and Sharptailed Sandpiper.

Tidal flats provide a range of ecosystem services, for example improving water quality. Plants and invertebrate fauna are important food sources for prawns, fish and birds. They also are vital settlement areas and habitat for a range of marine larvae, many of which are essential to recreational and commercial fisheries (Edyvane 1999a).

Vegetation of the plains

The plains support high levels of agricultural production (broadacre agriculture and horticulture), made possible by extensive clearing of the historical vegetation. Despite the high levels of modification for agriculture some remnant vegetation remains that holds significant conservation value, particularly along roadsides and rivers. These remaining small patches of vegetation are highly vulnerable to a range of threats, because of their small size and lack of connectedness. The threats include one-off events such as fire that can wipe out a whole patch, or slower degradation impacts such as invasive weeds, continued clearing, exposure to high winds, sand mining and animal pest grazing (e.g. rabbits). Proposed land use change from agriculture to urban (Roseworthy and Two Wells (Department of Planning and Local Government 2010)) and rural lifestyle blocks, consequent potential for significant clearance, is also a significant threat to the remaining small vegetation patches.

Northern Plains are less resilient to the projected impacts of climate change as they have low topographical variation and therefore fewer environmental niches for refuges. The subregion also suffers from a limited species pool being available to colonise new habitats and climates that result from climate change.

The community values the Reeves Plains sand hills as one of the few remaining sites with mallee vegetation and Southern Cypress Pine *(Callitris gracilis)* woodland in the Northern Plains.

Sand mining and pest animals continue to threaten the viability of this site.

Areas where grazing has been excluded are regenerating.

Shrubland

The plains shrubland vegetation communities are tall shrubland and common species include Senna (*Senna artemisiodides*) and Weeping Emu Bush (*Eremophila longifolia*).

Historically, the tall shrubland vegetation community (found centrally in this subregion) was fairly open. It had a low density of shrubs, as well as a grassy and herbaceous ground layer. These vegetation communities were highly suitable for grazing, and therefore used by early European pastoralists. Only very small examples of these shrubland patches remain, primarily along roadsides and in cemeteries. Those communities that do remain are different in both species composition and in the interactions between species, making them quite different from the shrubland that would have been present pre-European settlement.

A landscape health assessment has indicated a very low priority for reconstructing and reconnecting this landscape in comparison to more intact areas. The assessment was based on the long-term history of clearing, increased agricultural land use, the area and condition of remaining vegetation, and absence of indicator bird species (except for agricultural generalists) (D Rogers pers. comm. 2013).

Mallee

Mallee vegetation communities are characterised by low, usually multi-stemmed trees with a grassy or shrubby understorey.

Historically, in its pre-European condition, this vegetation would have supported a diverse range of plant and animal species by providing: tree-hollows for birds and bats; good nesting sites in the canopy for birds of prey, as well as diverse, patchy groundcovers and debris (twigs and leaves) that provided excellent habitat for ground-dwelling species (Adelaide and Mount Lofty Ranges NRM Board 2008).

Flowering events would have provided nectar and pollen as an abundant, seasonal food source. A soil crust would have held the topsoil in place and enhanced rainwater filtration rates through the soil (Adelaide and Mount Lofty Ranges NRM Board 2008).

Mallee vegetation typically occurs in low rainfall zones. In this subregion it includes:

- Yorrell (*Eucalyptus gracilis*) and Red Mallee (*Eucalyptus oleosa*) on heavier soils
- White mallee (*Eucalyptus dumosa*) and Beaked Red Mallee (*Eucalyptus socialis*) on lighter soils.

Most of the remaining remnant mallee vegetation is grazed and in poor condition, with little to no regeneration of native species, and compacted, eroding soils. Even where disturbance has been limited, tree health is declining and weeds are invading.

A landscape health assessment has indicated lower priority for reconstructing and reconnecting this landscape. The assessment was based on the long term history of clearing, increased agricultural land use, the area and condition of remaining vegetation, as well as the absence of indicator bird species (except for agricultural generalists) (D Rogers pers. comm. 2013).

Woodland

The woodland vegetation communities in this subregion are generally found along drainage lines and in clay depressions or depositional areas. The main types are:

- Mallee Box (*E. porosa*) in the southeast of this subregion
- Black or River Box (*E. largiflorens*) on the floodplains along the Gawler River
- River Red Gum (*E. camaldulensis*) along the river systems.

Population sink defined

A breeding group that does not produce enough offspring to maintain itself in coming years without immigrants from other populations.

A landscape health assessment has indicated a lower priority for reconstructing and reconnecting this landscape. The assessment was based on the long term history of clearing, increased agricultural land use, the area and condition of remaining vegetation, as well as the absence of indicator bird species (except for agricultural generalists) (D Rogers pers. comm. 2013).

Some species are dependent on woodland that makes use of the limited remaining vegetation and, it is thought, operates as a population sink from neighbouring landscapes. This may make them important for maintaining genetic diversity.

Protecting the vegetation along river systems is a priority for this subregion. These vegetation communities provide the best opportunity for habitat connection across the landscape between the coast and the hills, which is likely to be important in allowing adaptation to climate change.

Threatened species and communities in the Northern Coast and Plains

Southern Cypress Pine

Used for building and fence posts, left in the area in isolated pockets along roadsides and small remnants. Good potential for restoration through natural regeneration. Grazing pressure has significant impact on regeneration, particularly from rabbits.

Action to address threatened species and communities is required at a number of scales. In the Northern Coast and Plains, landscape scale restoration is not a priority, but specific action is still required for certain species and communities to prevent further decline and potential extinction. The geographic scope of species status does not directly equate to priority for action. The recovery of some nationally threatened species of very high national significance, will not be strongly influenced by action in the region; the management requirements of state or regional listed species (for which meaningful action can be undertaken) may be more appropriate as a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

Despite the very small areas of remnant vegetation in the Northern Plains subregion, a number of threatened vegetation communities are still recognised at a regional, state or national level, for example:

- Peppermint Box (*Eucalyptus odorata*) grassy woodland (listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act))
- Iron-grass natural temperate grassland (listed as Critically Endangered under the EPBC Act)
- Southern Cypress Pine (*Callitris gracilis*) woodland, which exists in isolated small pockets northwest of Gawler (unpublished DEWNR provision list of threatened ecosystems of South Australia)
- Black Box (*Eucalyptus largiflorens*) woodland occurs on the floodplain on the northern side of the Gawler River and small pockets further north near Roseworthy (not currently formally listed but under discussion as part of state wide review)
- Bluebush/Cottonbush (*Maireana* spp.) shrubland (not currently formally listed but under discussion as part of state wide review).

Along with the above communities, specific fauna and flora species are threatened. Deterioration in the area and condition of habitat has seen the declining status of a suite of woodland birds that favour drier systems (White-browed Babbler (*Pomatostomus superciliosus*), Bluebonnet (*Northiella haematogaster*), Red capped Robin (*Petroica goodenovii*), Jacky Winter (*Microeca fascinans*)). What remains in the

limited areas of habitat still plays an important role in supporting the surviving communities of birds. Remaining habitat also provides corridors for these species to move into the woodland of the Northern Hills subregion. It is critical to protect the remaining vegetation to ensure that these corridors remain.

Some flora species have only a single known remaining population in this subregion. The Black Cottonbush (*Maireana decalvans*) is endangered in South Australia (under the *National Parks and Wildlife Act 1972*). It grows in chenopod shrubland found on floodplains and saline coastal flats. The largest known population occurs on private property near Virginia, but as it is often mistaken for more common cottonbush species, it is possible other populations exist in the area. An isolated population of Wispy Spider-orchids (*Caladenia capillata*) can be found growing in Southern Cypress Pine (*Callitris gracilis*) and mallee systems near Roseworthy. While it is not a listed species, its limited distribution in this subregion is cause for protection of its habitat.

Water resources of the Northern Coast and Plains

Light River (lower reaches)

The Light River is an unregulated ephemeral river system, mainly used for stock and domestic purposes. There is very little data available about surface water salinity in the Light River due to its ephemeral nature and the lack of monitoring (Henschke et al. 2008). In dry periods, permanent pools increase in salinity which is concentrated by evaporation. Periodic surface flows are therefore important to flush pools and prevent build-up of salts (Henschke et al. 2008). It is likely that salinity could increase in the future under a lower rainfall climate regime with less frequent flushing of the river system.

The lower Light River has three main sections: upper, middle and estuary.

The upper section of the river, from Hamley Bridge to the Redbanks Fault, is cut down to the bedrock and has formed a series of permanent pools known locally as 'The Rockies'. The vegetation community consists of River Red Gum open forest that, because of land clearance, is in poor condition with reduced or absent understorey in much of the area. Common reeds have also increased in the river bed, probably as a result of siltation from the cleared land and upstream erosion (VanLaarhoven et al. 2004).

Light River (Hamilton)

Condition: Poor (2011)

Source: www.epa.sa.gov.au/reports_water/c0275-ecosystem-2011

At Redbanks the river changes from a gaining stream (inflow of groundwater to stream flow) to a losing stream (where stream flow contributes to groundwater). The section is a deep channel with a wide floodplain that flattens out nearer to the coast. The riparian vegetation community consists of relatively intact River Red Gum forest with some invasion by exotic species. The extent of the vegetation has been reduced (by past clearing and cropping practices) to a narrow strip along the river. Low grazing pressure leaves a stable river with few signs of erosion and regeneration of the River Red Gums.

The main threat to water resources in the Light River is the impact of increasing upstream water extraction from more farm dams.

The Light River estuary extends from the river mouth to approximately 4 km inland. The river changes from a deep freshwater channel upstream to a narrow, shallow box shaped channel (with a series of tidal channels). Two permanent pools link the freshwater section of the river to the estuary.

The geology of this estuary consists of silts and sand deposits. Estuary vegetation is low and shrubby, with Lignum and African Boxthorn noticeable weeds in the upper areas of the estuary, and samphire flats in the outer intertidal zone of the lower reaches. The mangrove forest in close to pristine condition, extending to the mouth of the river gives the estuary high ecological value. This estuary area is deemed Crown land, and public access is limited, which has helped maintain the condition.

The impact of climate change on estuaries is complicated because they will be affected by interacting climate and hydrological variables that influence both freshwater and marine systems. Potential impacts include warming of air temperatures leading to increased water temperature, nutrient cycling, evapotranspiration and frequency of hypoxia. These impacts may increase phytoplankton production and fish deaths in hot conditions; some species will be at the upper range of thermal tolerance. Decreased rainfall and freshwater flows will increase estuarine salinity and reduce water quality. There may be decreased nutrient and detrital input, as well as reduced sedimentation. This could lead to reduced species richness of fish as the saline/fresh water mix is altered, as well as decreases in fish production and recruitment (Gillanders et al. 2011).

Other impacts of climate change include increased storm surges and severe wave conditions, which will increase coastal erosion. This will affect estuary mouths and flooding. Vegetation will change due to increased sand movement and changes to the extent of seagrass, mangrove and saltmarsh habitat.

Land management threats to estuaries generally result from access to the estuary and land immediately surrounding it. Agricultural activities such as grazing and cropping can increase erosion causing sediment and nutrient migration to estuaries, which then smother seagrass and impact on water quality. Urban runoff also contributes to these issues. Changes to flow patterns, as a result of water extraction for agricultural use, can reduce flushing of the estuary and increase salt water intrusion, changing the habitat for existing species.

Agricultural, recreational and urban use of land around an estuary can increase the number of pests and weeds present, which compete with native vegetation and impact on habitats. Recreational use of estuaries such as fishing and boating can also impact on estuaries, in particular, seagrass beds, through the building of jetties or marinas and pollution from litter and fuel.

Gawler River

The Gawler River catchment covers an area of 1,047 km^2 and includes the subcatchments of the North and South Para rivers (Adelaide and Mount Lofty Ranges NRM Board 2008). What is commonly referred to as the Gawler River begins at the confluence of North and South Para rivers in Gawler and is 30 km in length. The perched nature of the river, and its flat floodplain, means floodwaters break out of the channel and flood adjacent land which may remain inundated for days or weeks after a flood event. The Gawler River across the plains is part of the Western Mount Lofty Ranges Prescribed Water Resources Area. Extraction limits and minimum and maximum threshold flow rates have been set through the water allocation plan (WAP).

The Gawler River primarily provides water for agriculture and rural living purposes. Surface water flows can vary significantly depending on position in the catchment. Water-diverting infrastructure, such as farm dams and water supply reservoirs, in the North and South Para subcatchments has also changed the quantity and pattern of flows in the Gawler River (Adelaide and Mount Lofty Ranges NRM Board 2008).

Gawler River (Gawler)

Condition: Very poor (2008)

Source: www.epa.sa.gov.au/reports_water/c0020-ecosystem-2008

Gawler River (Virginia Park)

Condition: Poor

Source: www.epa.sa.gov.au/reports_water/c0021-ecosystem-2008

The quality of vegetation (in-stream and riparian) is variable. Community interest has been increasing in preserving and rehabilitating the riparian zone, which also contributes to the open space of the subregion.

The Gawler River corridor is under pressure from a range of agriculture-related activities, including building of levies to protect agricultural assets, and urbanisation (particularly the site that bounds the proposed Buckland Park development). Threats to the river also include increased weed and pest pressure and increases in the number of landowners along the river (from a move to smaller block sizes) which increases the resources required to ensure the watercourse is being managed appropriately.

The long, narrow Gawler River estuary terminates at Buckland Park lake, with delta creeks at Port Gawler, and is classified as a tide dominated creek. Its extensive tidal flats of shelly silts, clays and sands support significant low mangrove woodland. Small areas of samphire shrubland sit at the Gawler River mouth and dense seagrass beds are located along the coastline (Adelaide and Mount Lofty Ranges NRM Board 2008).

Threats to the condition of this estuary include:

- increased urban development adjacent to the estuary and throughout the estuary's catchment
- feral animal invasion
- nutrients and sediments entering the gulf from stormwater and other industrial discharges, and threatening seagrasses
- inappropriate use of off-road vehicles and illegal dumping of rubbish are impacting extensive areas of samphire habitat
- thick potential acid sulfate soils in mangroves (high risk area if disturbed) and supratidal potential acid sulfate soils (moderate risk area if disturbed) have the potential to affect a significant number of coastal bird species (many listed under international treaties)
- a highly modified flow regime of this estuary due to significant upstream use of water
- additional reductions or changes in hydrological regimes as a result of climate change
- potential impacts from a range of recreational activities, such as fishing, crabbing and boating, using the area to access the coast and marine environment
- land based impacts from surrounding land uses mainly industrial salt evaporation ponds and agriculture.

Barker Inlet-Port River estuary complex

The Barker Inlet–Port River estuary complex is a large tide-dominated estuary that incorporates smaller estuaries such as Little Para Creek and Dry Creek. It has extensive tidal mudflats and mangrove habitats, fringed by samphire and saltmarsh flats with a number of low-lying dunes on the coastal plain (Adelaide and Mount Lofty Ranges NRM Board 2008).

This estuary is the site of:

- a permanent dolphin colony
- an important feeding area for wading and sea birds
- a nursery area for a number of significant commercial and recreational fishing species.

Barker Inlet Port River estuary

Condition: Variable

Source: Adelaide and Mount Lofty Ranges NRM Board 2007c

Freshwater and stormwater runs into the estuary through a series of small creeks, constructed stormwater filtration wetlands and Bolivar Wastewater Treatment Plant (which discharges to the marine environment through Barker Inlet).

In the Barker Inlet–Port River, acid sulfate soils have formed as a result of dredging and bunding in the area. There is moderate potential for acid sulfate soils to form in the tidal channel if they are disturbed.

In recent years this estuary has seen:

- an increase in recreational use
- decreases in pollutant load
- introduction of marine pests
- increased urban and industrial development
- changes to tidal flows as a result of levees
- encroachment by mangroves into samphire habitats, which have limited or no ability to retreat.

Future threats to this estuary include:

- sea level rise as a result of climate change, and therefore flooding of adjacent urban areas
- increased impacts from existing and projected urban development on (or adjacent too) the mangrove–samphire system, with continuing limited ability of the samphire to retreat from encroaching mangroves
- impacts of increased urban development along the Port River, at Buckland Park and Dry Creek
- water extraction for urban reuse may impact on the quality of wetland habitats if the extraction rates don't account for environmental needs.

Water quality was considered to be poor between 1995 and 2000, but has since improved, particularly in heavy metals and indicators of faecal contamination. Contributing to this improvement was the decommissioning of Port Adelaide Wastewater Treatment Plant, reduction of nutrient discharge from Bolivar Wastewater Treatment Plant, reduced suspended material discharge from a soda ash production plant, and construction of extensive wetlands to treat stormwater.

Created wetlands in Barker Inlet area

The created wetlands complex that drains into the Barker Inlet provides significant filtration benefits to improve water quality of the estuary. The created wetlands also provide significant habitat for water fowl and other water birds in the region. Nationally significant species such as the Australasian Bittern (*Botaurus poiciloptilus*) have also used this wetland complex as it was one of the few remaining refuge areas during the recent drought.

Groundwater

The groundwater resources of the Northern Plains lie within the sedimentary aquifers of the Adelaide Basin (Figure 28), which contains the Northern Adelaide Plains (NAP) Prescribed Wells Area (PWA), initially established in 1976. The boundary (extended over time) now covers the extent of the productive aquifers in this part of our region.

The groundwater supports a wide range of industries (predominantly horticulture) and is extracted primarily from the deeper Tertiary (T2) aquifer which supplies 73% of the total volume; the shallow Tertiary (T1) aquifer is less developed (25%); and the Quaternary aquifers provide the remaining 2% (Department for Water 2011b). The aquifer used is dependent on location, with T1 being the main supply aquifer south of Waterloo Corner and the T2 aquifer used in the north (where the T1 thins and pinches out).

The structure of the aquifers includes Quaternary sediments comprising predominantly Hindmarsh Clay, and mottled clay and silt with interbedded sand and gravel layers which form the Quaternary aquifers.

The T1 aquifer overlies the Munno Para Clay confining layer and consists of two major subaquifers, the Hallett Cove Sandstone/Dry Creek Sand and limestones of the upper Port Willunga Formation. The T1 aquifer has an average thickness of 70 metres in the south, but pinches out around the Gawler River, and is not present in the northeast portion of the NAP.

The T2 aquifer underlies the Munno Para Clay confining layer and occurs throughout the NAP PWA. The T2 aquifer consists of well-cemented limestone of the lower Port Willunga Formation and has a variable thickness of 80–120 metres throughout the area.

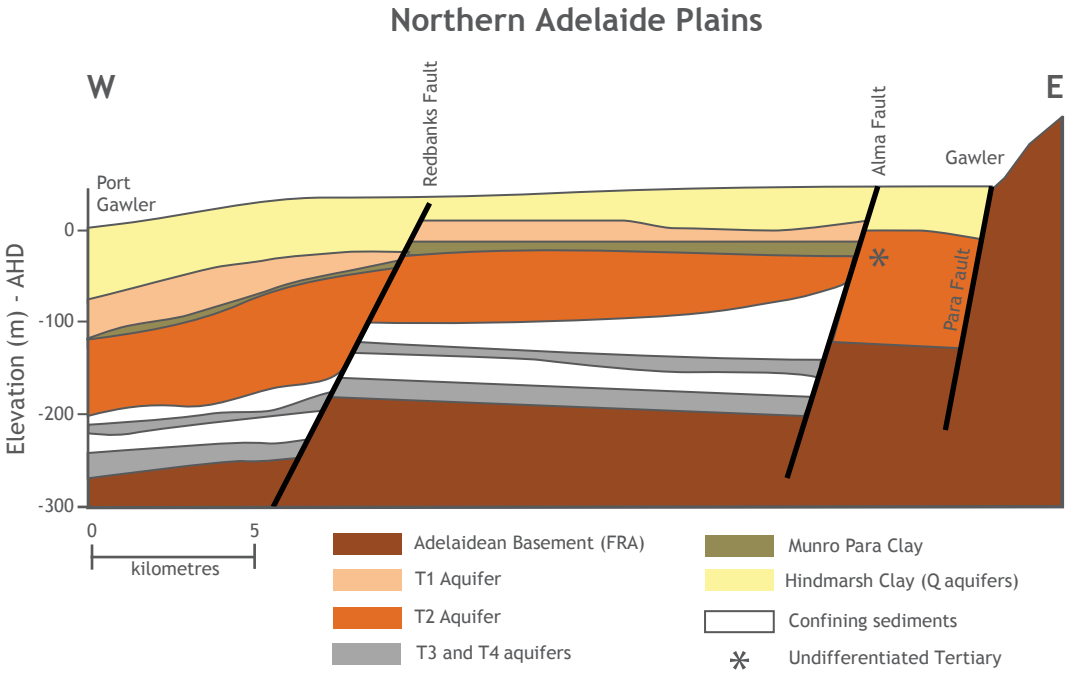


Figure 28: East-west hydrological cross-section along the Gawler River in the NAP PWA

The underlying sedimentary sequence contains the third Tertiary (T3) and fourth Tertiary (T4) aquifers which are not used due to both poor water quality and depth. The T4 aquifer consists mainly of South Maslin Sand (and occasionally North Maslin Sand) and directly overlies the Adelaidean basement rocks.

Managed aquifer recharge in various locations across the subregion, is undertaken mainly in the south and east in the T2 aquifer. The groundwater resources are managed through legislation, with the current NAP WAP adopted in 2000.

MAR defined

Artificially pumping water into the aquifer

The quality and quantity of groundwater in this subregion has varied over time. In terms of quantity (and aquifer pressure) historical use (both the spatial distribution of extractions and the annual volumes extracted) has resulted in long-standing cones of depression centred on Virginia (T2 aquifer) and the southwest corner of the PWA (T1 aquifer). These have stabilised over the last 20 years (Department of Environment, Water and Natural Resources 2012b; Department for Water 2011b).

Cone of depression

In confined aquifers the cone of depression is a reduction in the pressure head surrounding the pumped well. When a well is pumped, the water level in the well is lowered, which creates a gradient between the water in the surrounding aquifer and the water in the well. Because water flows from high to low water levels or pressure, this gradient produces a flow from the surrounding aquifer into the well.

The groundwater resources of this subregion are at the most risk from changes to extraction regimes, which are, in turn, dependent on a combination of factors. Extension of the irrigation season, while not necessarily increasing the volume of extraction, can affect the seasonal recovery ability of the aquifers and lead to an overall decrease in water level. More saline water can be then drawn in from adjacent areas through vertical leakage induced by the difference in aquifer heads. This appears to be the situation at Kangaroo Flat (Department of Environment and Natural Resources 2012). The flattening out of seasonal rainfall patterns induced by climate change may impact water levels and salinity in the long term as Tertiary aquifers are recharged by groundwater flow from the fractured rock aquifers in the Mount Lofty Ranges which receive direct rainfall recharge. Land use change may also create more concentrated areas of extraction with urban development and intensified agricultural production and industrial use in smaller areas.

Groundwater level and salinity trends

Stable or improving in T1 and T2 across most of the subregion

T2 at Kangaroo flat – some stabilisation

Overall trends indicate degradation that will compromise present use in the short term

Source: Department for Environment, Water and Natural Resources 2012a,b; Department for Water 2011

The groundwater resources of the NAP and Central Adelaide PWAs will in the future be covered by one Adelaide Plains Water Allocation Plan, currently in development.

Groundwater dependent ecosystems

Along the Gawler and Little Para rivers there are persistent pools identified as groundwater dependent ecosystems (GDEs). Groundwater may also contribute to streamflow and therefore water requirements of riparian and deep-rooted vegetation of these rivers (Department for Water 2011b; Cooling and Currie 2012).

The two important GDEs in this subregion are a coastal perched aquifer and groundwater dependent coastal wetlands (Cooling and Currie 2012).

Buckland Park Lake at the mouth of the Gawler River formed from the deposition of alluvial sediments is the site of a coastal perched aquifer. Floodwater from the Gawler River creates a lens of freshwater over saline groundwater. Here, regular surface water inflows have created a shallow perched freshwater system over a shallow saline watertable that is strongly influenced by the marine environment. The shallow aquifer is saline and not subject to use.

The coastal wetlands GDEs are represented by the Barker Inlet, St Kilda and Port Gawler area (Cooling and Currie 2012). The landscape in the vicinity of Barker Inlet is characterised by a low-lying topography and a shallow saline watertable. Groundwater in the Quaternary Aquifer flows towards this region. Its discharge creates saline mudflats that merge into the mangrove woodland of the Port River, Barker Inlet, St Kilda and Port Gawler areas. The aquifer is poorly defined, localised, ephemeral and not subject to use.

A second class of GDEs relies on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include as an example riparian forests that require a supply of groundwater within the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases and new species invade the system leading to a new structure and function to the ecosystem that does not necessarily provide the desired services required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

Groundwater dependent ecosystems are potentially impacted by climate change which compounds the problems relating to reduction in the frequency and timing of surface water inflows and recharge of the shallow aquifers as a result of groundwater and surface water extractions. The hotter, drier conditions and changing rainfall patterns will make managing these ecosystems and balancing competing demands more complex.

Livelihoods

Production in this subregion is predominantly based on high value broadacre cropping and intensive horticulture, with some intensive livestock production around Lewiston and significant rural living areas adjacent to the Gawler River. Agriculture is supported by a combination of suitable soils, a favourable climate, and access to water, labour, transport and support industries.

Primary production is heavily dependent on the natural resources of the subregion; in particular, healthy soils, healthy water and minimal agricultural pests. Healthy soils, while linked to intrinsic soil properties, are also heavily influenced by management of soils and production. The risk of soil erosion in the Northern Plains was assessed by a soil cover survey three times from December 2011 to June 2012, of land predominantly used for cropping (Young 2012). The results indicated a decrease in the number of sites at low risk of erosion from December (99.1%) to June (49.5%). The observed increase in erosion risk comes from the land use being annual cropping in the area, which creates greater soil disturbance and breakdown of crop residue. (These results combine assessments across the Northern Hills and Northern Plains; numbers for just the Northern Hills are unavailable.) Further monitoring of soil cover and erosion risk over time will provide firmer trends about land management practices to prevent erosion.

Average annual rainfall is 350–450 mm on the plains.

The water resources include the underground water resource that supports the horticulture industry in the Virginia/Two Wells area. The area contains relatively fertile soils – underlain by a series of water bearing beds of sand, gravels and limestone aquifers – which are used as a source of irrigation

water. Imported treated wastewater from Bolivar Wastewater Treatment Plant is used in the area. The underground water resource is prescribed as the NAP PWA and resource allocation is managed through the WAP.

Groundwater extraction from the T1 aquifer has been generally stable at around 3,500 ML/year (Department of Environment, Water and Natural Resources 2012b) while extraction from the T2 aquifer has decreased over the last five years from approximately 12,000 ML to 7,500 ML/year (Department of Environment, Water and Natural Resources 2012c). Extraction is still well below the current allocation of 26,500 ML.

Population growth and expansion of townships has increased the complexity of managing primary production activities in this subregion, as has shifting of types of production. For example, movement of horticulture north has the potential to impact on agricultural activities (through encroachment into traditionally agricultural land) in the subregion. It has led to concern about identifying and protecting land considered valuable for primary production activities. Figure 29 indicates key primary production areas in the Northern Plains subregion and identifies the key considerations that contributed to each area being included as valuable for primary production. The categorisation and description of these areas draws on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011a,b,c,d).

Some areas are excluded from primary production consideration because of local conditions that do not meet assessment criteria or the land is zoned for alternate uses. On-ground assessment of omitted areas may mean some is included into a neighbouring priority primary production area.

In general, land east of the Northern Expressway has not been designated as a priority primary production area even though much is currently used for horticultural activities. However, the pressures of urbanisation and the potential for future land development (for industrial or urban use) is a strong indicator of the limited lifespan of this land for horticultural use. Land managers in these areas should continue to be supported by suitable policies and practices while primary production is maintained. Education and training, to ensure land managers continue to maintain the land in a sustainable, manner should continue.

As horticultural production diminishes and urbanisation increases in these spaces, opportunities to maintain open space and land for community use should also be considered.

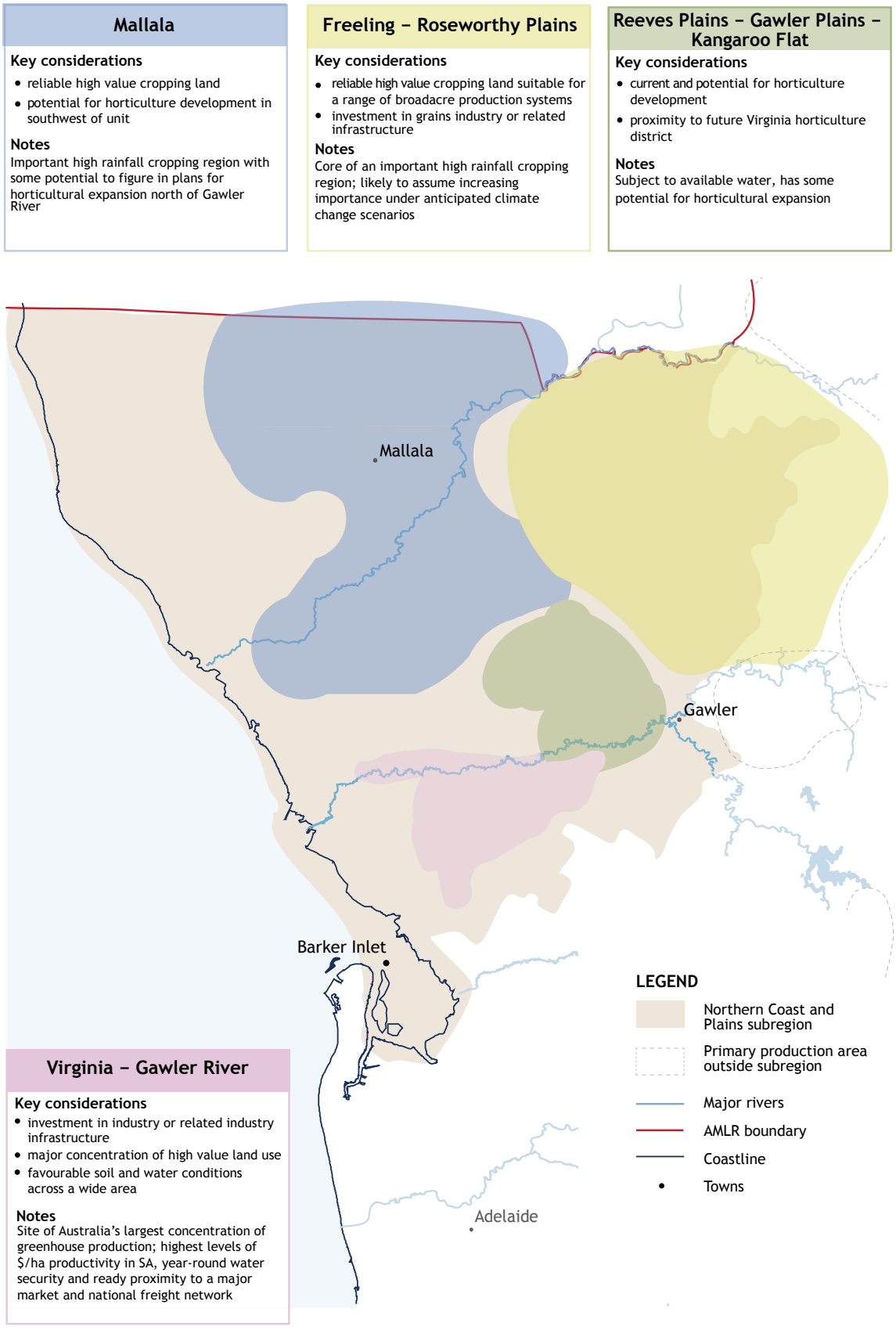


Figure 29: Priority primary production areas in the Northern Plains (modified from PIRSA 2011a,b,c,d)

Agricultural production

Agricultural production in the region is predominantly cropping and grazing with an increase in intensive livestock production (primarily poultry sheds) between Dublin and Mallala. The gross value of agricultural production in this subregion in 2011 was $434.4 million – cropping $276.8 million and livestock $157.5 million (Australian Bureau of Statistics 2012c). This subregion also includes around half of Light Regional Council, which in 2011 had a total gross value of agricultural production of $161.8 million – cropping $85.5 million and livestock $70.4 million (Australian Bureau of Statistics 2012c). Farming communities in this area are supported by the main towns of Mallala and Roseworthy. The planned expansion of Roseworthy to a city of 60,000 (Department of Planning and Local Government 2010) is likely to change the current relationship between the town and surrounding farming communities.

Soil management issues for agricultural production in this area tend to be site specific. They are more a consequence of management actions than of larger scale natural soil properties. Hard subsoils in red clays are an exception and have inherent management problems, such as poor plant growth and productivity due to restrictions on root volume (the soils are too hard for the roots to grow through).

Potential impacts of climate change on agricultural production are dependent on variations in rainfall. Factors such as reduced total rainfall, and changed timing and intensity of rainfall, all have the potential to significantly impact on dry matter production and therefore the persistence of soil surface cover by vegetation. Consequent increased soil erosion could lead to losses in productivity and increased production costs (Liddicoat et al. 2012). Other impacts of climate change on the cropping sector are discussed in the Northern Hills subregion description.

Horticultural production

Horticultural production is at its highest in the Virginia–Angle Vale–Two Wells area. It includes greenhouse (hydroponic) and in-ground horticulture (dependent on soil type and water availability). Horticultural production in this area is heavily influenced by urban and industrial expansion, impacting on day-to-day management and on investment decisions. Land use conflicts are also rising as a result of urban expansion.

Gross value of horticulture production in 2011 was valued at approximately $177 million (Australian Bureau of Statistics 2012c). In 2012 the wine grape harvest on the Adelaide Plains decreased by 14% from 2011 to 4,458 tonnes with a total value of $3.1 million ($3.4 million in 2011). The total planted area of vines in the region is 662 hectares (539 hectares in 2000); no new plantings have been recorded for the last three years (Phylloxera and Grape Industry Board of SA 2012a).

The industry is supported by good quality groundwater resources and the availability of recycled water. It is also characterised by its increasing hydroponic development. Rising watertables have become a management issue in some areas.

Climate change impacts on the horticulture industry are difficult to predict with certainty mostly because of the lack of knowledge around temperature extremes (and their effects) for a large range of horticulture crops, particularly for the vegetable sector. Physical impacts may include (Deuter 2008):

- changes to the suitability of current cultivars
- changes in optimum growing periods and locations
- changes to the distribution of existing pests and increased threat from new pests
- changes to irrigation demand due to changes in rainfall patterns and amounts (the local horticulture industry may be less affected by rainfall because it has reliable access to recycled water but its quality issues (e.g. salinity) may become more extreme)

- physiological disorders
- increases in pollination failures due to heat stress during flowering
- increased risk of soil erosion for in-ground horticulture.

Increased atmospheric CO_2 concentrations could benefit productivity of most horticultural crops, although the extent of this benefit is unknown. It is highly probable that these benefits will be felt only at lower-range predicted temperature increases, and in the long term may not continue.

Horticultural adaptation to climate change is likely to initially occur through changes in cultivars grown to those that are more drought and/or temperature tolerant; and in innovations in cultural practices. If climate change impacts exceed the capacity of growers to adapt at a specific location, then a southward shift of production following the southward shift of agroclimatic zones is more likely to occur. This is dependent on land availability and businesses having the economic ability to move. External economic impacts may affect the long-term viability of farming in this area, as land potentially becomes more valuable for non-agricultural activities.

Mining

A significant proportion of this subregion is covered by mining tenements, the biggest being the salt fields that stretch from Dry Creek to St Kilda Beach and further northward to Webb Beach at Port Parham. Average production from an area of 4,000 hectares is around 285,000 tonnes (Hough 2008).

The salt fields also serve as an important site for migratory seabirds. Current investigations into the future of the site are determining the feasibility of converting 316 hectares of salt fields at Dry Creek into a residential and mixed use development. Along with the construction of the Northern Connector (connecting the Northern Expressway with Port River Expressway) along the outer edges of the salt fields, this has the potential to negatively impact on the current flora and fauna habitat in the area. It would limit options for samphire retreat, necessary as mangroves encroach to move from rising sea levels, and disturb important migratory bird feeding sites.

The community is concerned about the future of the salt fields as external pressures could change land use. Changes from the current salt fields could significantly reduce bird habitat and impact on a large number of important bird species, including some listed in international treaties.

Salt produced at the salt fields could become surplus to industrial requirements which may lead to further questions about the future of the salt fields.

The other major mining activity along the Northern Coast is shell grit (for glass making) mining around Parham. Past community concern about this activity primarily related to the post mine rehabilitation of the site. Recent rehabilitation of mining sites are examples of best practice.

Tourism

Tourism opportunities in this subregion mainly focus around bird watching in this international wading and shorebirds site. The potential for growth of this activity is limited by infrastructure along the coast, particularly for accommodation and meals. There is good opportunity to build knowledge through education activities about the value of the environment in this area and therefore increase the demand.

A significant drawcard to Barker Inlet is the resident population of dolphins. Boat cruises and kayaking to view the dolphins are significant tourism activities in the subregion and provide opportunities to promote the importance of the natural resources in the area.

Northern Hills

In summary

Rural industry of significance to the state features in the Northern Hills subregion (Figure 30). The Barossa Valley is a famous wine region, which, with related activities, supports a high employment level; forestry around Mount Crawford is complemented by substantial areas of cropping and grazing throughout the subregion; and commuters are moving into the area to enjoy a rural lifestyle.

In the varied topography, grassland and grassy woodland once reigned but were disproportionately cleared and now are still not recognised for their intrinsic worth. Further south, heathy woodland was logged but a significant area remains particularly in the South Para connected area where the Heath Goanna finds some protection.

The watercourses of the Light and North Para rivers are naturally ephemeral but have been reduced by use for stock and irrigation in the south. Flows in the South Para River have been heavily impacted by water storage dams, which provide for northern Adelaide and the lower mid-north, and by farm dams. Flow may be reduced by as much as 60% during the low rainfall period of November–March and the catchment is now prescribed. Irrigation water in the Barossa now comes from surface water, groundwater, the River Murray (all prescribed) and recycled water.

Northern Hills - Priorities for the future

A set of priorities for the future for the Northern Hills subregion has been developed based on the information contained in this section:

- Restore and reinstate grassy ecosystems where this will help stem biodiversity declines (along the northern, western and eastern flanks of the range); this requires improved technical knowledge, community recognition and sustainable use
- Protect and improve the integrity of the shrubby forest and woodland dominated landscapes (in the South Para and Kaiserstuhl areas)
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Facilitate integrated climate change adaptation of people and the landscape
- Protect priority primary production areas from inappropriate development to maintain industry and business viability
- Support agriculture to adapt to climate change or transition to alternative business models
- Promote sustainable land management practices focusing on minimal till and maintaining soil cover
- Protect and restore the North Para, South Para and Mid Light rivers riparian zones for improved biodiversity and water quality outcomes
- Protect water resources for aquatic health and agricultural use (quality)

- manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)
- Encourage increased demand, and supply of, alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Monitor for, and control, pests that have not yet become established in the region or in the Northern Hills subregion.

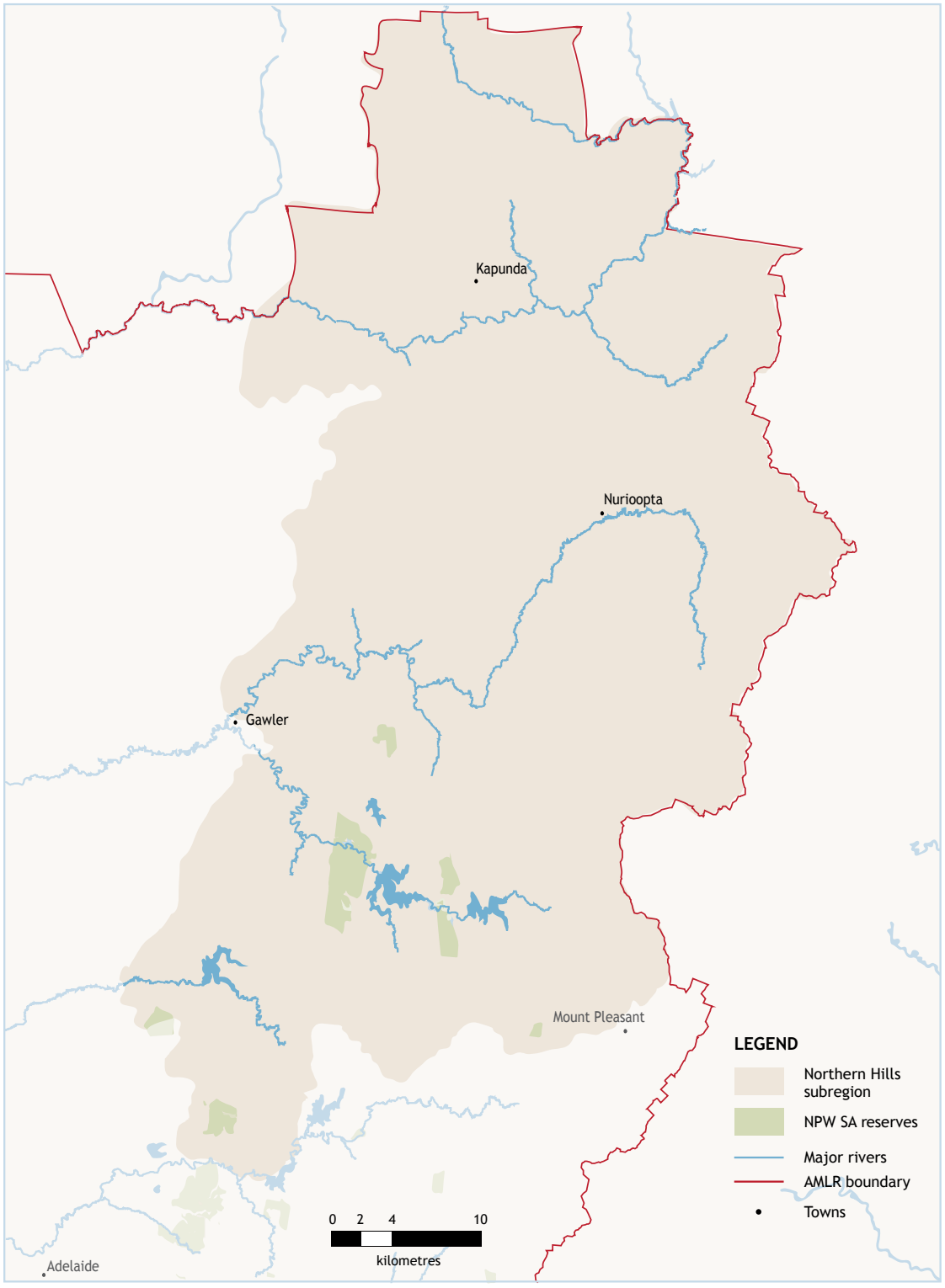


Figure 30: Northern Hills subregion

Introduction

The Northern Hills subregion, often described as the Northern Mount Lofty Ranges, begins at the northeastern boundary of the Adelaide and Mount Lofty Ranges region and is bounded by the Northern Plains subregion to the west and Central Hills subregion to the south. The Northern and Yorke NRM region shares the northern boundary; the South Australian Murray-Darling Basin NRM region shares the eastern boundary. The Northern Hills includes the Barossa Valley, South Para catchment and the Freeling–Kapunda broadacre landscape. The topography increases in steepness from north to south and the area is dissected by the Light, North Para and South Para rivers.

The subregion intersects the traditional lands of the Ngadjuri and Kaurna people.

Lifestyle

The Northern Hills includes the significant population centres of Kapunda, the Barossa Valley, Williamstown and Freeling.

Kapunda, built around Australia's first copper mine, has since grown to support a significant farming community from the surrounding landscape and more recently a commuter population wanting a rural lifestyle while working in Adelaide.

The Barossa Valley was settled by German refugees in the 1840s. It is now best known as a premier wine region and is a major centre for the Australian wine industry and the business site of two major wine companies. Approximately 80% of local economic activity is related to the wine industry, which employs 41% of the workforce. These workers are vulnerable to economic downturns as employment tends to be casual, part-time or seasonal. The wine industry underpins a significant tourism industry with more than 50 cellar door sales outlets complemented by various experiences reliant on the natural environment including the Heysen, Mawson and Kidman trails. The area also supports grain production and grazing; with many farming businesses a mix of vineyards, grazing and cropping.

Population

Kapunda	2,484
Barossa Valley*	22,169

*Council area

Williamstown was established in 1857 and developed into a service centre for the Mount Crawford timber industry. Growth in the wine industry has seen expansion of vineyards into the Williamstown area but much of the region remains in forestry and grazing. The Barossa, South Para and Warren reservoirs are in close proximity.

The small rural town of Freeling, in the western part of the Northern Hills, has traditionally supported the extensive farming community surrounding the town. Recent improvements to road infrastructure have increased its appeal as a residential address in easy commuting distance of Adelaide. The population in the Freeling district is approximately 1,591 (Australian Bureau of Statistics 2012e).

The impact of climate change on communities in the Northern Hills is likely to be varied based on the social and biophysical diversity of the area. Increased temperatures and heat related impacts on the population may be more prevalent in the warmer, drier areas around Kapunda and Freeling than in the more vegetated and higher elevated areas around Williamstown. However, the risks from more frequent bushfire events are more likely in the Williamstown area where there is significantly more vegetation. Supporting communities to adapt to a range of potential impacts will require varied and innovation solutions.

The Northern Hills subregion contains the Barossa Council and Light Regional Council, both important contributors to natural resources management. Councils are landowners of significant areas of remnant vegetation like Altona CSR Landcare Reserve (Lyndoch), roadsides, unmade roads and various reserves. They are an important partner in water management and reuse projects, pest and weed control, community education and supporting volunteer programs. A number of community groups and individual land managers are actively involved in natural resources management.

Landscapes

The Northern Hills is topographically variable with the landscape historically grading from forest in the south to grassland and grassy woodland in the north as rainfall decreases. The Mid Light, North and South Para River catchments contribute to the agricultural and environmental resources of the area.

Since European settlement, the native vegetation of the Northern Hills has been subjected to broadscale clearance and disturbance. Early settlers made immediate use of the grassland and grassy woodland covering the foothills and plains for grazing stock. Over time more intensive activities, such as horticulture and urban settlement developed on the more fertile soils.

The impacts of land use vary across the landscape. In southern parts of the subregion, around Williamstown, incremental clearance and an increase in lifestyle properties are the main development pressures. To the north, around Kapunda and Freeling, intensification of agricultural production and increases in lifestyle properties are the main development pressures. *The 30-year plan for greater Adelaide* (Department of Planning and Local Government 2010) identifies Roseworthy township (in the Northern Plains subregion) as a site for major expansion increasing the population from its current 250 to about 60,000. There may be little direct impact on Northern Hills landscapes from this increase in population and infrastructure but indirect consequences are likely in the area as a whole. Better infrastructure may make other parts of the Northern Hills more accessible, including reducing commute times to industrial areas in northern Adelaide, and thus drive demand for lifestyle blocks in areas of the Northern Hills where there is currently little demand. A larger population is also likely to make more recreational use of the landscape, which can have positive and negative impacts on the environment: increased volunteering in environmental activities, or negative impacts such as increased issues with pests (cats and dogs impacting on local fauna) and weeds (garden escapees).

Kangaroo numbers are high in the subregion attracted by the legacy of historic land use change: more water present in the landscape, more favourable habitat (farming land for grazing) and fewer natural predators. The high numbers are likely to continue. Current land use changes from larger agriculturally productive properties to smaller blocks for rural living could further increase water availability, in an increasingly difficult management and control environment of more land managers in a more complex landscape. Increasing smaller blocks may also put pressure on water resources as more water points are needed for stock or domestic supply. New dams for this purpose would need to align with the principles of the water allocation plan (WAP). High numbers of kangaroos exert increased grazing pressure (similar to the outcomes from traditional stock management on this land), reducing the regeneration of some native species.

Protected areas*

Anstey Hill Recreation Park
Hale Conservation Park
Kaiserstuhl Conservation Park
Kaiserstuhl Native Forest Reserve
Kersbrook Native Forest Reserve
Little Mount Crawford Native Forest Reserve
Mount Gawler Native Forest Reserve
Parra Wirra Recreation Park
Sandy Creek Conservation Park
Tower Hill Native Forest Reserve
Warren Conservation Park
Watts Gully Native Forest Reserve

*Protected under National Parks and Wildlife and Forestry Acts

Intensification of use of agricultural land and expansion of lifestyle blocks also generate issues of soil protection (from erosion) and rapid increase in new environmental weeds escaped from garden plantings. Longer term threats arise from climate change and the implications of a hotter drier climate on the natural, social and economic systems of the Northern Hills.

Climate change impacts will vary across the landscapes according to the level of change and the flora and fauna involved, and in particular their adaptive capacity. For example, the ability of grassy woodland ecosystems to adapt to climate change has been compromised by reduced population sizes and genetic diversity, in a degraded and fragmented ecosystem. Increased impacts from weeds and pests and changes to fire regimes (frequency, intensity) are also likely to place increasing pressure on grassy woodland systems. Structural changes (within grassy woodland) are likely to include reduced tree cover and shifts in the composition of herbaceous ground layers. Grassy woodland could shift to more favourable climates at higher altitudes but there will be competition for this ecological space from forest landscapes and other land uses in these areas.

Structural changes in forest landscapes as a result of climate change are likely to include fewer tall trees and more open space, with flow-on effects to habitats and fauna that need forest communities. Endemic species that have a narrow climate range are likely to be most affected and may decline while the suitability of habitats for some weed species may improve. Protecting refuges for endemic species with limited ability to adapt or move through the landscape will be critical for species survival. Fire regimes are also likely to alter due to climate change and this may further influence the structure and composition of vegetation communities and other ecological dynamics.

Adaptation approaches require continuing effort at protecting and buffering existing vegetation ensuring diverse plantings and bolstering genetic diversity. Carbon sequestration initiatives to improve connectivity, control pests and weeds, and improve degraded soils are all opportunities to support adaptation to climate change.

Landscape priorities for restoration in the Northern Hills

An assessment of the health of landscapes, using birds as indicator species of the state of the landscape, has identified two landscape types in the Northern Hills that are in decline and are a priority for restoration (Rogers 2011):

- closed shrublands (including some heathy forests, heathy woodlands and shrublands)
- grassy ecosystems (including some lower rainfall grassland and grassy woodland).

Working across boundaries

The landscape assessment also covers the Eastern Mount Lofty Ranges (in the SA Murray-Darling Basin region).

In terms of priority works identified, large areas that are a high priority for works are on the eastern slopes of the Mount Lofty Ranges.

It is critical that priorities and actions for the boundary region between the Northern Hills and the SAMDB region are developed and conducted in partnership with the SAMDB Board to maximise the benefits of any work undertaken.

The closed shrubland ecosystems contain woodland dominated by Blue Gum (*Eucalyptus leucoxylon*) and/or Pink Gum (*E. fasciculosa*) and moderately cool and wet forest with overstoreys dominated by either Brown Stringybark (*E. baxteri*) or Long-leaved Box (*E. goniocalyx*). Bird species associated with these systems are in decline as a result of historical clearing patterns; focused effort on protecting and reconstructing these systems is a high priority. The area of highest priority for reconstructing forest landscapes is around the Williamstown-South Para area (Figure 31) The South Para connected vegetation is particularly valuable as an existing area of connected vegetation, where increasing connectivity and condition can be enhanced to halt the decline of the system.

Higher rainfall and steeper slopes are dominated by forest landscapes; lower rainfall, flatter ground is dominated by woodland landscapes. Reconstruction of this landscape requires recognition that there are different vegetation communities that require vegetation specific actions.

The lower rainfall grassy ecosystems include the vegetation associations containing Peppermint Box (*E. odorata*), Mallee Box (*E. porosa*), Blue Gum (*E. leucoxylon*), Drooping Sheoak (*Allocasuarina verticillata*) and Grey Box (*E. microcarpa*). Grassland ecosystems can be dominated by or include a mixture of:

- iron grass (*Lomandra* spp.)
- spear grass (*Austrostipa* spp.)
- wallaby grass (*Austrodanthonia* spp.)
- Kangaroo Grass (*Themeda triandra*).

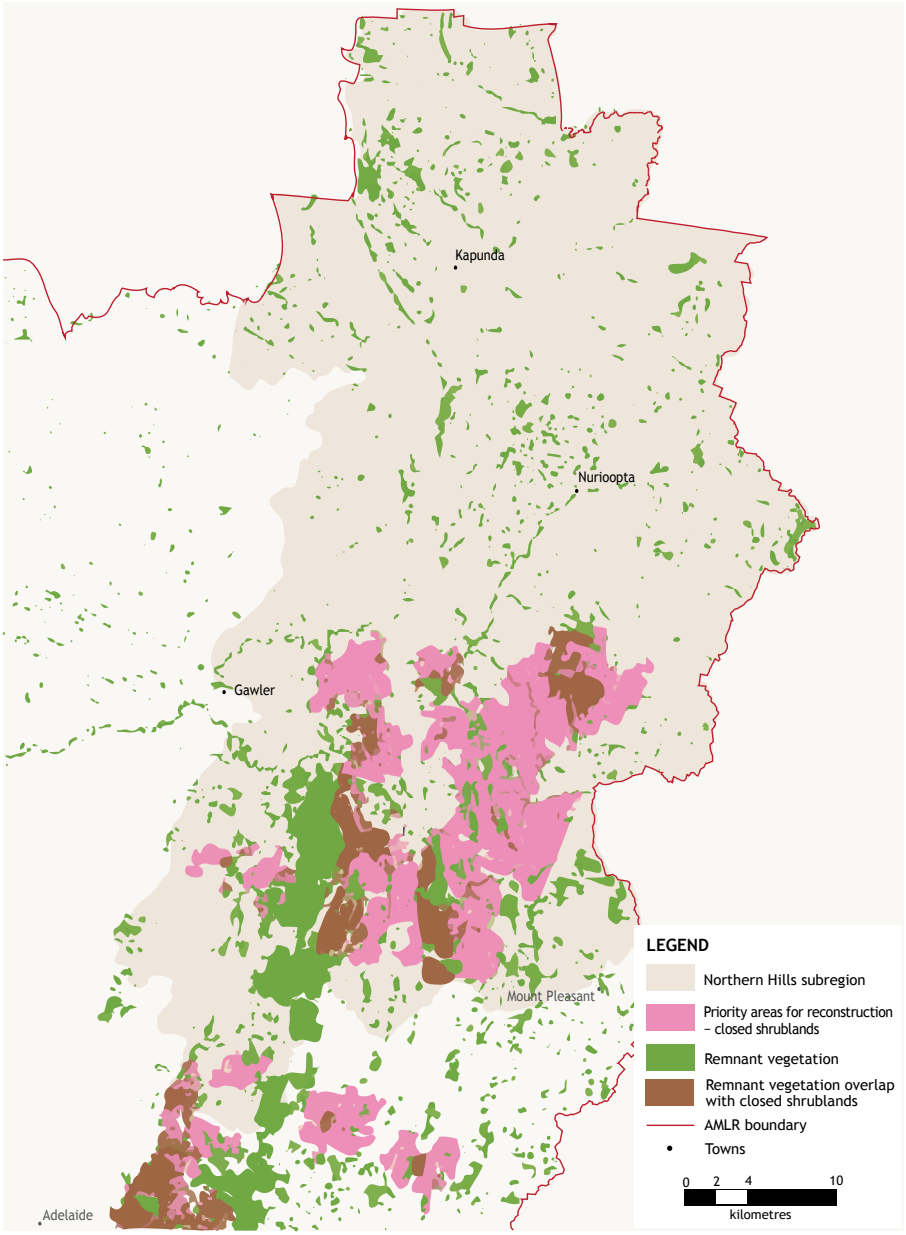


Figure 31: Priority areas for reconstruction of closed shrublands in the Northern Hills (including some heathy forest, heathy woodlands and shrubland) (Rogers 2011)

The decline of these systems is a result of historical clearing, and land use (stock grazing). Stock released directly onto the rich native pasture from the early days of settlement have had a long term impact on ecosystems. The nutrient rich soils also made these areas prime targets for more intensive agriculture. A focused effort on protecting and restoring these systems is critical to halting the decline in condition of both the vegetation associations and the flora and fauna that rely on them. The priority areas for reconstructing and protecting grassy woodland and grassland ecosystems are throughout most of the Northern Hills subregion (Figure 32) and likely to be in areas of this subregion that have not been included in the assessment.

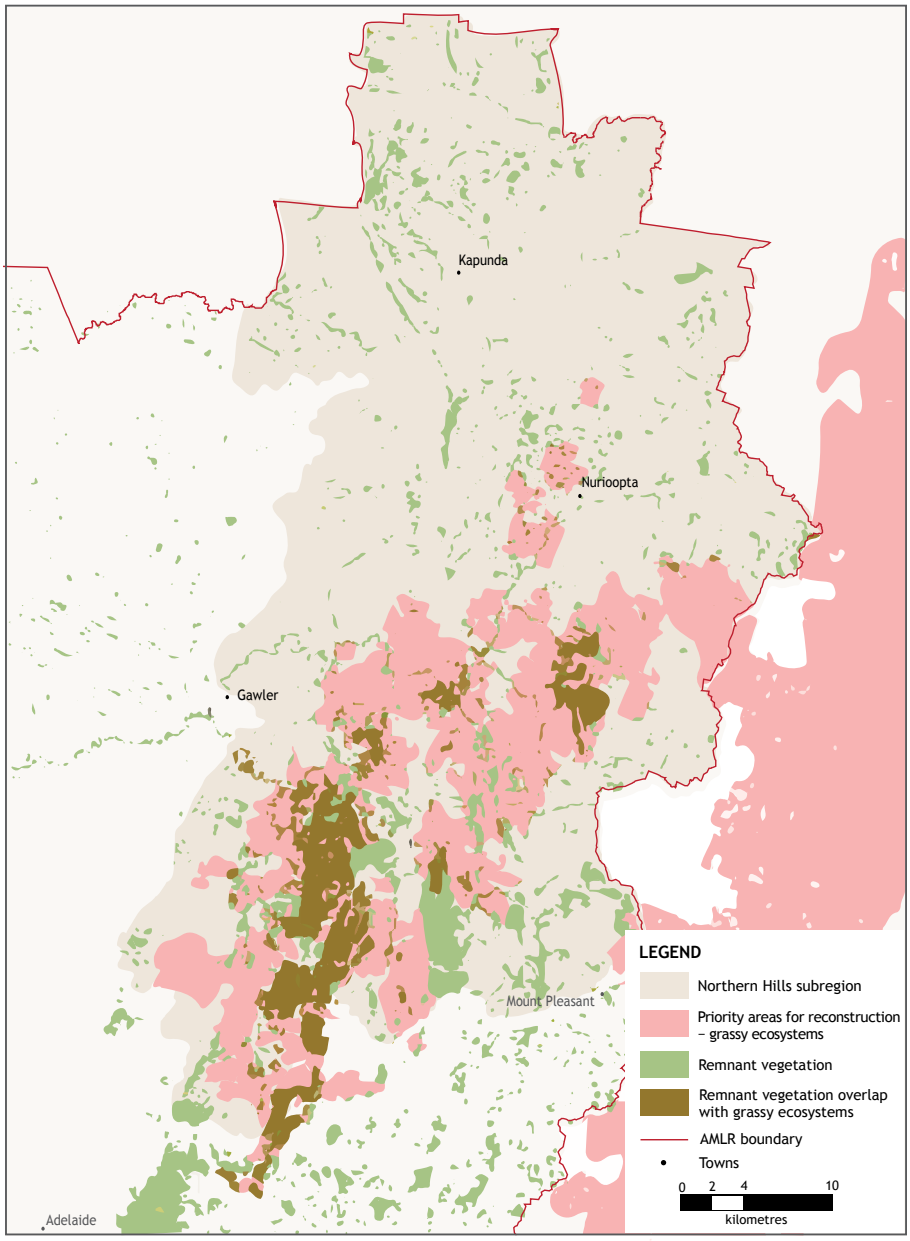


Figure 32: Priority areas for reconstruction of grassy ecosystems in the Northern Hills, including some grassland and grassy woodland (Rogers 2011)

The lower rainfall grassy systems and the closed shrubland systems form a complex mosaic in the landscape and rehabilitation will need to identify the particular species mix according to site position.

Vegetation of the Northern Hills

Grassland and grassy woodland

Importance of the South Para connected area

The community values the connected vegetation in the South Para catchment as the largest block of connected forest landscape in the area. The 10,630 hectares of vegetation includes River Red Gum river flats, pine plantations, mallee open woodland, heathy scrub and riparian areas.

This large area of remnant vegetation is important habitat for the Heath Goanna, one of our last remaining large native predators in the Mount Lofty Ranges. Heath Goanna populations require large areas of relatively intact and connected native vegetation to survive. Individual goannas can roam over several kilometres to find enough food to sustain them. The large areas of remnant vegetation in the South Para area are incredibly important.

Photo: Jean Turner

Grassland is typically treeless, with an occasional small clump of shrubs. The shrub layer is likely to be a reflection of the depth and fertility of the soil, with shrubs more common on shallow, rocky soils (Adelaide and Mount Lofty Ranges NRM Board 2008). Much of the historical grassland were cleared for agricultural or urban use, or as in the Kapunda Ranges, are highly modified through grazing practices or invasion of weeds.

Grasslands include Iron grass (*Lomandra effusa* +/- *L. multiflora* ssp. *dura*) tussock grassland (not technically a grassland as iron grasses are lilies, but takes the structural formation of a grassland and native grasses are present), and Spear grass (*Austrostipa* ssp.) Wallaby grass (*Austrodanthonia* ssp.) tussock grassland.

Grassy woodland in the Northern Hills are characterised by a grassy and herbaceous ground layer, with scattered patches of shrubs and a discontinuous tree layer. The very high diversity of native plant species is not apparent until the spring–summer flowering season when wildflowers emerge from between the grass tussocks. Grassy woodland comprise a very diverse range of grass and herb species, with up to 100 species present including orchids, daisies and lilies which emerge between the grass tussocks. Grassy woodland in the Northern Hills commonly consists of:

- South Australia Blue Gum (E*ucalyptus leucoxylon)* and Red Gum (*E. camaldulensis*) woodland over a grassy and herbaceous understorey
- Peppermint Box (*E. odorata*) woodland over a grassy and herbaceous understorey.

Historically, considerable areas of these open native grassland and grassy woodland once existed in our region. These ecosystems were disproportionally and extensively cleared for agriculture. Of what does remain, little is formally protected for conservation purposes. The flora and fauna species reliant on these ecosystems are threatened with extinction as a result of past clearing and continued degradation. Much of the remaining grassy ecosystems in the subregion are grazed for pasture, which has maintained some biodiversity value. The replacement of native grassy pastures with crops and annual or perennial pasture species is one of the many threats to grassy ecosystems. There is significant opportunity to develop sympathetic grazing management regimes that support production outcomes as well as maintain functioning grassy ecosystems.

Why protect the grassland?

The Northern Hills supports the most southerly populations known of the nationally endangered Pygmy Bluetongue Lizard. Recent studies have shown these populations and the relatively intact remnant native grasslands that support them, to be very important to species persistence under a changing climate. The habitat of more northerly populations is likely to become drier and inhospitable, placing greater reliance on southern areas to conserve the species. We need to conserve and maintain what remains of our native grassland in the Northern Hills, as well as manage the extinction risk from processes affecting the remaining fragmented populations.

Photo: Jean Turner

Heathy forest

Heathy forest is concentrated at the southern end of the Northern Hills subregion around Williamstown. They form a complex mosaic with grassy woodland systems based on soil types and topography and other factors. Heathy forest contains a wide range of habitats, with the dense shrub layer providing excellent cover for ground-dwelling fauna species. The trees and shrubs are a rich source of nectar during the winter and spring flowering season and mature trees provide tree-hollows.

The primary impact to heathy forest during early European settlement was logging, with some patches used for intensive agriculture such as fruit and vegetable crops (Adelaide and Mount Lofty Ranges NRM Board 2008). Large, intact expanses of Long-leaved Box (*Eucalyptus goniocalyx*) are found on both public and private land, with significant areas of connected vegetation in the Williamstown–Mount Crawford area contained in a mix of conservation and recreation parks, forestry reserves, water reserves, local government and private ownership.

A landscape assessment, using birds as indicator species of the state of the landscape, identified stringybark forest as a stable state (Rogers 2011). These systems are often found in less fertile soils along the spine of the ranges. The priority for stringybark forest is to maintain the systems in a stable state by focusing on threat abatement. Particular threats include pests and weeds, and planning policies that allow landscape fragmentation and make future management of sites complex due to the proximity of built assets.

Threatened species and communities in the Northern Hills

Action to address threatened species and communities is required at a number of scales. While landscape scale restoration will assist, additional specific action is required for certain species and communities to prevent further decline and potential extinction. When prioritising action there is a need to recognise that the geographic scope of species status does not directly equate to priority for action. There will be nationally threatened species which are of very high national significance, but whose recovery will not be strongly influenced by action within the region, so it may be more appropriate for the management requirements of state or regional listed species (for which meaningful action can be undertaken) to be a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

Within the landscape of the subregion, specific vegetation communities under threat require more defined and targeted protection and restoration activities, for example:

- Peppermint Box (*Eucalyptus odorata*) grassy woodland (listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act))
- Blue gum (*E. leucoxylon* spp. *pruinosa*) +/- Peppermint Box (*E. odorata*) grassy low woodland (Vulnerable state listed community)
- Iron grass grassland (listed as Critically Endangered under the EPBC Act)
- Spear grass, Wallaby grass and Kangaroo grass tussock grassland (Endangered state listed community)
- Southern Cypress Pine (*Callitris gracilis*) sandy heaths
- Red Gum (*E. camaldulensis*) grassy woodland on flats
- Bull Mallee (*E. behriana*) +/- Peppermint Box (*E. odorata*) grassy woodland (Endangered state listed community)

Peppermint Box grassy woodland

Listed as critically endangered under the Environment Protection and Biodiversity Conservation Act 1999, because of a severe decline in distribution and ongoing loss of integrity.

Hale, Sandy Creek, Warren and Kaiserstuhl conservation parks contain patches of this threatened woodland community.

The regional recovery plan also identifies the species of threatened flora and fauna that require priority actions to ensure they are protected. Examples of species of interest in the Northern Hills include: Brown Treecreepers (*Climacteris picumnus*), Diamond Firetails (*Stagonopleura guttata*) and plants such as the Mount Lofty Speedwell (*Veronica dermentiana*), Plum Leek Orchid (*Prasophyllum pruinosum*), Plump Swamp Wallaby-grass (*Amphibromus pithogastrus*), Blue Devil (*Erynguim ovium* and *E. vesiculosum*) and Spider-orchids (*Caladenia behrii* and *C. rigida*).

Water resources of the Northern Hills

Light River

The area of the Light River in the Northern Hills subregion is approximately 59,800 hectares and has an average rainfall of 450-500 mm. Its major tributaries are St Kitts, Stockwell, Allen, Ross, Hawker and Fannel creeks (VanLaarhoven et al. 2004).

Light River (North of Freeling)

Condition: Poor (2001)

Source: www.epa.sa.gov.au/reports_water/c0280-ecosystem-2011

The Light River is an unregulated ephemeral river system. Flow along it is supported by significant areas of permanent groundwater baseflow from the junction with St Kitts Creek and downstream to Kapunda. Water is used mainly for stock and domestic purposes because of the variability of water flow, which makes it less suitable for more intensive water uses. The river retains good remnants of riparian vegetation which many landowners are willing to protect and restore.

The natural vegetation of the catchment is open woodland of eucalypts and understorey species. Historically, River Red Gum forest (*Eucalyptus camaldulensis*) extended along the Light River from the estuary through to its junction with St Kitts Creek. Much of this forest has since been cleared, particularly in the Kapunda area but Red Gum remnants remain along St Kitts Creek and on Stockwell

Creek floodplain. Other vegetation associations include open woodland of SA Blue Gum (*E. leucoxylon*), Peppermint Box (*E. odorata*) and Southern Cypress Pine (*Callitris gracilis*). Sedgeland communities and reed beds can be found along the length of the river system (VanLaarhoven et al. 2004).

Increases in dam numbers, salinity and development pressures are all threats to the ongoing protection and restoration of the Light River environment. Ensuring environmental flows and permanent refuge areas in an unregulated stream is critical and requires support from the development planning system.

North Para River

The North Para catchment extends from the town of Gawler through the Barossa Valley to the dryland farming areas of the Lower North, the high rainfall areas near Pewsey Vale and Flaxmans Valley and grazing areas in the eastern Barossa Ranges. In the 80,000 hectare catchment, the dominant land uses are vineyards, cropping, stock grazing and rural living (Evans et al. 2003). This catchment contains prescribed water resources (upstream of the Yaldara gauging station), which are regulated due to concerns over dwindling supplies of surface and groundwater for irrigation and the quality of stream water. Barossa Valley groundwater resources were proclaimed in 1989 and surface water resources prescribed in 1998; Greenock Creek surface water resources were added to the prescribed area in 2005.

North Para River (4km north from Angaston)

Condition: Fair (2011)

Source: www.epa.sa.gov.au/reports_water/c0270-ecosystem-2011

North Para River (Rowland Flat)

Condition: Fair (2011)

Source: www.epa.sa.gov.au/reports_water/c0272-ecosystem-2011

The ephemeral North Para River flows through the Barossa Valley to Gawler where it meets the South Para and becomes the Gawler River. The North Para originates in the Flaxman Valley area, and is joined in its flow along the valley floor by the tributary creeks: Duck Ponds, Angaston, Tanunda, Jacob and Lyndoch. This important source of water supports the economy of the Northern Hills, particularly viticulture in the Barossa Valley.

Natural stream flow has been adversely impacted by extensive development of surface and groundwater resources, including dam construction for irrigation and stock and domestic purposes, and direct pumping from the river. Modelling indicates that dam development has reduced average stream flow in the North Para system at Yaldara gauging station by an estimated 20%, or up to 60% in years of low flow. Groundwater extraction in the Barossa area has also reduced both the volume and permanency of flow in the river, with most impacts at lower flows (baseflow and pool connection flows) (Adelaide and Mount Lofty Ranges NRM Board 2009).

The extraction and use of water from the North Para River, and the catchment, is managed through the Barossa WAP.

The North Para

The North Para River is an ephemeral river that flows through the Barossa Valley to Gawler where it meets the South Para and becomes the Gawler River. The North Para originates in the Flaxman Valley area, and is joined in its flow along the valley floor by the tributary creeks: Duck Ponds, Angaston, Tanunda, Jacob and Lyndoch. The catchment supports a diverse natural landscape including grassy woodland and grassland communities, and stringybark forest. This important source of water supports the economy of the Northern Hills, particularly viticulture in the Barossa Valley.

South Para River

The 33,000 hectare South Para catchment includes Mount Crawford Forest, and five subcatchments including the Victoria Creek, Malcolm Creek and Tenafeate Creek systems. The highly variable topography ranges from very steep slopes and gorges to broad gently sloping valleys and hills. Major land uses are commercial forestry, water harvesting, large areas of native vegetation, and sheep and cattle grazing on cleared areas. The river system is highly regulated with three water storage dams (Warren, Barossa and South Para reservoirs), which provide water for the Northern Adelaide and lower Mid North regions. Diversion of catchment water has heavily impacted on the river's natural flow regimes. Modelling indicates that surface water capture by farm dams has reduced mean runoff from the South Para River catchment by around 5.2%. On a seasonal basis the impact of water supply reservoirs and farm dams is much more pronounced, with the Warren and South Para reservoirs having the greatest impact. Modelling indicates that flows in the lower reaches of the South Para River may be reduced by as much as 60% during the low rainfall period of November to March. The combined effect of all diversions has reduced flow at the gauging station 2.6 km southeast of Gawler to an estimated 10% of the original natural flow with a current median annual flow at the station of 3,200 ML. Most of the estimated 1,166 farm dams in the South Para River catchment are smaller than 5 ML in volume. The 21 farm dams with greater than 20 ML of storage capacity represent 34% of the total volume of water in storage. Dam water is used for domestic purposes, stock watering and irrigation of pastures, horticulture and viticulture. The relatively recent expansion of viticulture in the catchment has seen a rapid increase in the farm dam storage volume. Combined farm dam and reservoir storage in the South Para River catchment totals 57,600 ML. The construction of new dams is now regulated through prescription of the Western Mount Lofty Ranges, and water use in the South Para will be regulated through the Western Mount Lofty Ranges WAP.

Above Warren reservoir the river channel is a chain of ponds connected at high flows. In-stream and riparian habitats have been degraded by forestry and grazing land uses.

While the South Para reservoir plays an important role in supplying potable water to Adelaide, it has a significant impact on aquatic ecosystems downstream. Balancing the competing demands for water in this system is an ongoing issue and trials to provide environmental flows to the South Para are an important component of this management.

South Para River (south from Gawler)

Condition: Good (2011)

Source: www.epa.sa.gov.au/reports_water/c0277-ecosystem-2011

South Para River (Gawler)

Condition: Fair (2011)

Source: www.epa.sa.gov.au/reports_water/c0053-ecosystem-2011

Groundwater

The groundwater resources of the Barossa area occur within the sedimentary aquifers of the Barossa Valley Floor and underlying and surrounding fractured rock aquifers (Figure 33). The groundwater system in the Barossa Valley comprises numerous aquifers that can be broadly grouped into the three principle aquifer systems: Upper, Lower and Fractured Rock (Figure 33). The aquifers are hydraulically connected and, depending on location in the valley, can be a source of recharge or discharge to each other with the main recharge source being excess winter rainfall.

The Upper and Lower aquifers both have complex series of interconnected sub-aquifers that can be grouped together; they are separated by a carbonaceous clay confining layer. The Upper Aquifer generally consists of sands and gravels and is confined on the eastern side of the valley where clay

covers most of the aquifer. The Lower Aquifer consists of a range of clays, sands, gravels and silts and is confined across the valley; it shows large seasonal variations in water level as a result of extraction. The basement rocks of the Adelaidean System underlie the valley floor and form the surrounding hills.

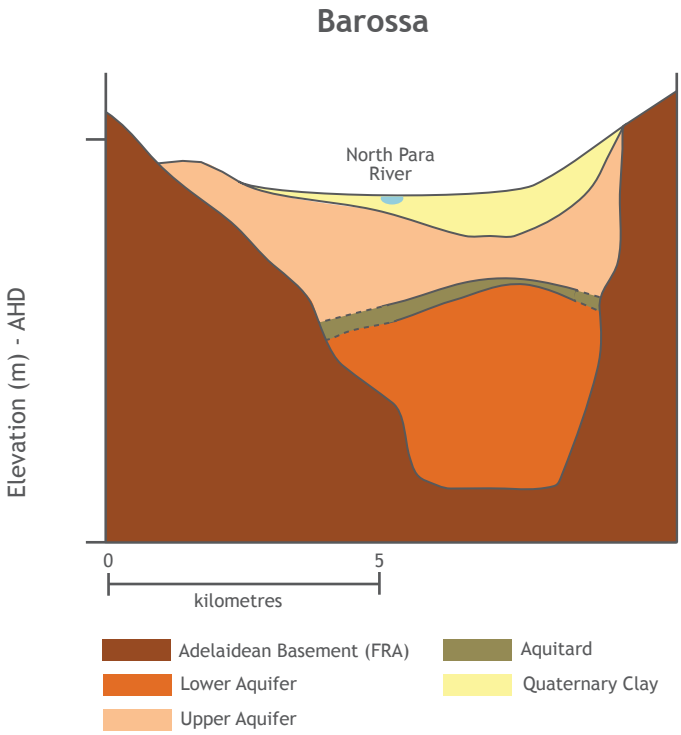


Figure 33: Cross section of the Barossa Valley groundwater system

Groundwater in the Barossa is predominantly used for irrigation. Water is extracted from the fractured rock aquifer, with the Lower and Upper aquifers of the valley floor providing a smaller proportion of the overall supply (Department of Environment, Water and Natural Resources 2012d). The source aquifer is dependent on location within the prescribed area; the Lower Aquifer is the main supply across much of the valley floor, while the Upper Aquifer is accessed in the northern portion and the fractured rock aquifer accessed in the surrounding ranges.

The Barossa Prescribed Water Resources Area (PWRA) was initially established in 1989 as a prescribed wells area and has been extended over time to incorporate surface water resources and the Greenock Creek catchment. The Barossa PWRA abuts the Marne River and Saunders Creek PWRA (SA Murray-Darling Basin NRM region) and Western Mount Lofty Ranges PWRA. The groundwater resources are managed through legislation with the current Barossa WAP adopted in 2009.

The quality and quantity of groundwater in the Barossa PWA has varied over time in both spatial distribution of extractions and annual volumes extracted. In the confined Lower Aquifer, water levels show seasonal draw downs of up to 20 metres associated with the extraction of groundwater for irrigation. There may be an indirect correlation with rainfall due to higher demand in drier years. Rising salinity trends observed throughout the Lower Aquifer may be due to interaquifer leakage and could be critical in areas where salinities are close to the tolerance for irrigation of vines (Department of Environment, Water and Natural Resources 2012d). Fractured Rock Aquifer groundwater levels show a relationship with rainfall patterns and are generally stable. Salinity trends are highly variable in the fractured rock system and reflect the complex flowpaths.

The groundwater resources of the Northern Hills are at the most risk from changes to extraction regimes, which are, in turn, dependent on a combination of factors. Extension of the irrigation season, while not necessarily increasing the volume of extraction, can affect the seasonal recovery ability of the aquifers and lead to an overall decrease in water level. More saline water can be then drawn in from adjacent areas through vertical leakage induced by the difference in aquifer heads.

Groundwater level and salinity trends

Stable or declining in the Upper Aquifer (could reflect seasonal responses to rainfall recharge and the interconnection between aquifers)

Declining in the Lower Aquifer (may be reflecting higher extraction in this aquifer)

Overall trends indicate degradation of the resource for use in the short term

Salinity trends are also variable and show some relationship with rainfall

Source: Department of Environment, Water and Natural Resources 2012d

The flattening out of seasonal rainfall patterns induced by climate change may impact water levels and salinity in the long term as all aquifers are recharged through groundwater flow from the outcropping aquifers which receive direct rainfall recharge.

Groundwater dependent ecosystems

Groundwater dependent ecosystem (GDE) types include (Sinclair Knight Merz 2011):

- fractured rock discharge and baseflow
- groundwater discharge in valleys and break of slope GDEs.

Discharge and baseflow from the fractured rock aquifers maintain persistent pools in the headwaters of Lyndoch, Tanunda, Jacobs and Greenoch creeks and the North Para River in Flaxman Valley. Discharge also supports heathy woodland in localised depressions and headwater areas as represented by Kaiserstuhl Conservation Park (Sinclair Knight Merz 2011).

Groundwater discharge maintains persistent pools and riparian vegetation in the Barossa and Greenock Creek Valley floors and break of slope discharge may maintain some terrestrial vegetation in the area of Altona CSR Landcare Reserve and Sandy Creek Conservation Park.

A second class of GDEs rely on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include riparian forests that require a supply of groundwater within the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases and new species invade the system leading to a new structure and function to the ecosystem that does not necessarily provided the services required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

Groundwater dependent ecosystems are potentially impacted by climate change: the hotter, drier conditions and changing rainfall patterns may affect the frequency and timing of direct rainfall recharge and subsequent interaquifer flow (Barron et al. 2011).

Livelihoods

Production in the Northern Hills is based mainly on the high value winegrape industry, broadacre cropping and grazing. It is supported by a combination of suitable soils, access to water, a favourable climate, and access to labour, transport and support industries.

Water resources in the Northern Hills are protected in the Barossa PWRA which includes the North Para catchment and the groundwater, and the Western Mount Lofty PWRA which includes the South Para catchment and groundwater in that area. The water resources are protected to ensure the sustainability of the production industries that rely on access to water, and to ensure adequate water availability for the environment. The prescribed water resources include underground water, surface water (collected and stored), and water pumped from watercourses. The region is also supported through the use of imported water delivered through the Barossa Infrastructure Limited (BIL) scheme, SA Water mains off-peak supply and SA Water mains peak supply. Some irrigators hold River Murray licences, which are delivered through SA Water or BIL infrastructure.

Average annual rainfall

Kapunda	493 mm
Nuriootpa	477 mm
Rosedale	468 mm
Mount Crawford Forest Headquarters	752 mm

Annual groundwater extraction from the aquifers in the Barossa PWRA has decreased by more than 50% since 2006 as a result of the transfer of supply from groundwater to imported River Murray water (Department of Environment, Water and Natural Resources 2012d). The amount of water available for import reflects rainfall conditions and hence in drier years groundwater is more heavily used. A total of approximately 1,200 ML of groundwater is estimated to have been extracted in the 2010–11 water use year, well below the allocation limit of around 7,000 ML/year.

Further detail about the Western Mount Lofty PWRA, of which South Para catchment is a part, can be found in the Central Hills section.

Healthy soils, while linked to intrinsic soil properties, are also heavily influenced by management of soils and production. The risk of soil erosion in the Northern Hills was assessed in three soil cover surveys between December 2011 and June 2012. The land surveyed was predominantly used for cropping (Young 2012). The surveys indicated a decrease in the number of sites at low risk of erosion from December (99.1%) to June (49.5%). The observed increase in erosion risk is a result of the land use being annual cropping which creates greater soil disturbance and breakdown of crop residue. (These results combine assessments across the Northern Hills and Northern Plains; numbers for just the Northern Hills are unavailable.) Further monitoring of soil cover and erosion risk over time will provide firmer trends about land management practices to prevent erosion.

Population growth and expansion of townships has increased the complexity of managing primary production activities in the Northern Hills and contributed to a move towards identifying and protecting areas of the landscape of importance for primary production now and into the future. Figure 34 identifies priority primary production areas in the Northern Hills and the key considerations that contributed to each area being included as valuable for primary production. The categorisation and description of these areas draws on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011a,b,e,f).

Concordia – Rosedale

Key considerations

- favourable soil, water and climate conditions
- supplementary water for irrigation
- largely unfragmented land base with relatively little non-farm development

Notes

Land of very high capability, suitable for a range of agricultural enterprises; major urban development proposals will limit primary industry and require active management of interface areas; adjoins Freeling - Roseworthy Plains PPA in Northern Plains

Kapunda District

Key considerations

- reliable high value cropping land suitable for a range of broadacre cropping systems
- high rainfall conditions with scope for climate change adaptation

Notes

Areas in Hamilton locality prone to waterlogging and watertable induced salinity; likely to assume increasing importance under anticipated clime change scenarios

Angaston Hills – Moculta

Key considerations

- favourable soil and water conditions across a wide area
- suitable for a wide range of primary industry activities
- high rainfall cropping land

Notes

Mix of high rainfall land suitable for cropping, viticulture and horticulture; no significant fragmentation to date but proximity to Sturt Highway may cause future pressure.

Barossa – Western Barossa

Key considerations

- favourable soil, water and climate conditions
- major concentration of high value land use integral to the Barossa wine and tourism economy
- substantional investment in related industry infrastructure.
- suitable for a wide range of primary industry activities

Notes

Substantial winery infrastructure located in the unit, which manufactures a large proportion of SA's wines, the area is one of SA's key primary production assets.

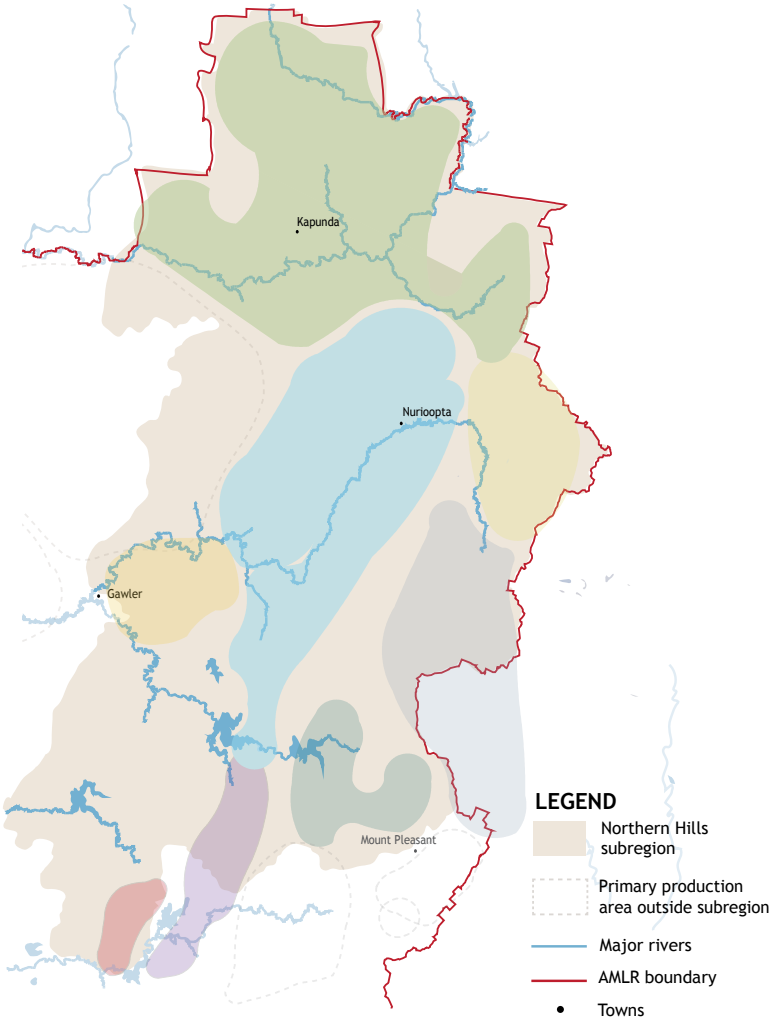
Paracombe – Lower Hermitage

Key considerations

- existing intensive land use and investments
- favourable conditions for high rainfall grazing and cool climate viticulture and horticulture

Notes

Traditional area for pear production; generally good conditions for high rainfall horticulture; urban encroachment and continuing rural living development steadily eroding scope for commercial scale production



Kaiserstuhl

Key considerations

- favourable soil, water and climate conditions
- emerging concentration of high value land use in the High Eden - Eden Vally area

Notes

Less agricultural development than in other parts of Barossa Council; holds significance because high rainfall provides for climate change adaptation, especially in viticulture

South Para – Mount Crawford

Key considerations

- high rainfall and access to groundwater, which may provide scope for more intensive development under climate change scenarios
- major concentration of forestry land use

Notes

Large areas of low capability, steep or waterlogged land; major forestry precinct with potential to support high rainfall grazing

Kersbrook

Key considerations

- major concentration of forestry land use
- high rainfall and groundwater access

Notes

Some areas of lower capability land and variable water resources; potential for perennial horticulture on better land, high rainfall grazing in areas with larger allotments and forestry

Figure 34: Priority primary production areas in the Northern Hills (based on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011a,b,e,f)

Viticulture and the wine industry

Viticulture is a significant contributor to the economy of the Northern Hills. It is supported by substantial value adding through wine production and associated activities (e.g. glass making, bottling, logistics). On average 60,000 tonnes of grapes are produced in the Barossa Valley annually. Vineyards in the Barossa Valley floor are planted mainly on yellow sands over clay (yellow duplex) soils and hard red texture contrast soils with alkaline subsoils (red duplex), some areas of deep sands and black cracking clays. The Barossa Ranges/Eden Valley area soils are shallow to moderately deep acidic soils on rock. Soil management problems associated with these soils types include hard setting and crusting which impacts on water infiltration, shallow root zones due to hard subsoils which influence irrigation management and fertility, and nutrient availability which impacts on vine growth and fruit quality.

Irrigation water is sourced from underground aquifers, dams fed by surface water, River Murray water imported into the area or recycled winery or wastewater. The availability of imported water has improved the viability of an industry at risk because of increasing groundwater salinity. It has also opened up new areas of the region for production (e.g. along Gommersal Road).

Increased population and associated urbanisation is impacting on the total number of vineyards, particularly on good soils at the edges of townships (with land prices consequently increasing). Increases in the area of viticulture resulting from the wine boom have, in turn, impacted on the total area of cropping and grazing in the region (food production).

In 2012, the Barossa Valley harvest was 51,897 tonnes, down by 11,470 tonnes (18%) on the 2011 harvest (Phylloxera and Grape Industry Board of SA 2012b). Total value of grapes in 2011 was $54.4 million ($62 million in 2011). In Eden Valley (which includes land in the neighbouring SA Murray-Darling Basin region) the harvest in 2012 was 9960 tonnes, 18.8% higher than the 2011 harvest of 12,626 tonnes. Total grape value increased slightly from $11.9 million in 2011 to $12.3 million in 2012 (Phylloxera and Grape Industry Board of SA 2012c).

The potential impact of climate change on horticulture has been identified as medium-high, with a medium capacity to adapt; the assessment is that the industry has medium-high vulnerability (Bardsley 2006). For the viticulture industry the impacts of increased temperature and variations in temperature will influence physiological processes. Ripening is likely to be earlier during warmer temperatures with potential impacts on fruit quality and compression of harvest dates between varieties. Water availability, particularly timing and amount of rainfall, will also influence irrigation with more water being required and potentially not available. Potential adaptation opportunities include change in varieties or new varieties better suited to the warmer climate. New technology and potentially genetically modified vines will also provide adaptation opportunities (Anderson et al. 2008).

The Barossa Valley in the Northern Hills is a major national centre for wine processing, storage, packaging and distribution of wine, giving the area a significant benefit in the associated job market: unemployment rates are generally lower than the state average and workforce participation rates are higher. Maintaining profitability with increasing global financial pressures, ensuring environmental sustainability, and accessing and retaining the workforce, are key challenges in the next few years. The value of manufacturing to the Northern Hills is in the order of $500 million (Centre for Economic Studies 2011).

Issues associated with wine production include increased traffic volumes at particular times of the year, heavy vehicle transport of raw materials in and packaged materials out, and storage facilities such as tank farms and warehouses. Light pollution from tank farms has recently become an issue, as has management of the significant levels of solid waste and wastewater from wine production.

Agriculture (cropping)

The Northern Hills also includes significant areas of broadacre agriculture around Kapunda, Rosedale and Freeling townships. Soil types used for agricultural (cropping) purposes are mainly hard red-brown texture contrast soils with alkaline subsoils, small areas of cracking clays and in the Kalimna area to the north of Nuriootpa, yellow duplex (sand over clay) soils. Soil management to reduce erosion has been a major focus for improving farm practices and the implementation of minimum or no-till farming practices has improved soil management and reduced soil loss from erosion. Despite this, economic pressures continue to impact on farm viability and natural resources management outcomes.

The gross value of cropping to the subregion (including all of Light Regional Council, half of which is in the Northern Plains subregion) is around $131.5 million (Australian Bureau of Statistics 2012c), plus the value adding through machinery sales, consultants and business services.

Remnant vegetation on many broadacre farms is limited as a result of large scale clearing for cropping but many sites are being rehabilitated and/or revegetated. Significant areas of vegetation remain along rivers (riparian zones) and along the hills around Kapunda.

For the Northern Hills in a climate change scenario with new rainfall regimes, the impact on the cropping sector from less soil moisture may be reduced in this area of high rainfall relative to drier areas in the north of South Australia. Reductions in yield may be moderated by projected increases in photosynthesis and dry matter production with increased carbon dioxide levels. Increased temperatures may also impact on the annual timing of grain crops, reducing the grain-filling time and decreasing kernel weight. Heat stress, increased pests, weeds and disease, and potential storm damage may also be direct effects on the cropping industry. Secondary impacts could be greater soil erosion and soil drying in a warming climate.

Adaptation opportunities will occur through new varieties bred for specific conditions and innovations in technology.

Minimum tillage cropping defined

Minimum tillage cropping is a conservation farming system, which may encompass reduced tillage, direct drilling and zero tillage. It minimises soil disturbance and retains crop residues when sowing. It has the potential to improve soil properties and increase sustainability by lifting and modifying soil biological activity that gives excellent improvements in all aspects of soil fertility, being physical, chemical and biological. These improvements lead to better farm management as well as improved sustainability.

As conversion to this cropping system can involve significant investment in specialised machinery, examples of ways that growers can modify existing seeding equipment has been identified as one strategy to increase its uptake.

Agriculture (grazing)

Livestock in the Northern Hills contributes approximately $172 million (Australian Bureau of Statistics 2012c) in gross value to the economy (including all of Light Regional Council of which half is in the Northern Plains subregion). Grazing businesses around Kapunda and Freeling are also often mixed enterprises including broadacre cropping. Soil types in this area are mainly hard red-brown texture contrast soils with alkaline subsoils. Soil cover and land management are critical sustainability issues. An assessment of soil cover in December 2011 identified a mostly low risk of erosion. Areas with poor levels of surface cover tended to be poorly managed pastures (Young 2011).

In the Kapunda and Barossa Ranges including Angaston, Mount Pleasant, Springton and towards Mount Crawford, Williamstown and Kersbrook, cattle and sheep grazing tend to be either the sole enterprise or mixed with a viticulture activity. The landscape is too steep and rainfall too high in these areas for broadacre cropping and grazing occurs mainly on improved pasture and native grassland. The southern

part of the native grassland towards Williamstown is part of the South Para connected vegetation system. The conflicts and pressures of sustainable production in a valuable native vegetation system are complex and require innovative management solutions.

The grazing industry is under pressure from increased land values (leading to increases in lifestyle and smaller land blocks that impact on business viability), poor land management (increased soil acidity, bare ground and erosion risk) and increasing economic impacts (such as cost of production and high Australian dollar).

The native grassland is under threat from grazing practices, which reduce recruitment in some species and therefore generate low species diversity. Weed pressures are also increasing. A lack of knowledge about grassland sometimes sees land managers planting trees inappropriately. Grasslands provide habitat for a wide range of invertebrate and vertebrate fauna. Less than 1% of pre-European grassland remain (though this may be an underestimate). Most were cleared for urban, agricultural and industrial development. These grassland are also significant in the Northern and Yorke, and South Australian Murray-Darling Basin NRM regions. Coordinated action across regional boundaries to protect and enhance both the natural system and the agricultural production that relies on it is critical.

Adaptation to the impacts of climate change on the grazing industry in the Northern Hills is likely to include more intensive management of stocking rates as variations in temperature and rainfall increasingly impact on pasture growth. Grazing management is also likely to require better prediction tools and models of rainfall in particular to enable suitable stock management to ensure soil cover and natural resources are not degraded. Changes to species used for pastures (including using native grasses), the timing of mating, and new breeds and cross-breeds also need to be considered (Dwyer et al. 2009).

Agriculture (forestry)

Forestry has been an important industry in the Adelaide and Mount Lofty Ranges NRM region for nearly 100 years. The region contains around 11,600 hectares of plantation forestry, of which about 9,700 hectares is softwood owned or managed by ForestrySA and about 1,900 hectares is privately owned hardwood including farm forestry. A major plantation at Mount Crawford Forest contains most of the forestry in the Northern Hills.

Commercial forestry in the region contributed $15.1 million to the Mount Lofty Ranges Gross Regional Product in 2008–09; contribution to the gross state product was $44.9 million, a figure that incorporates value adding from timber sourced from the Mount Lofty Ranges but processed elsewhere in the state (EconSearch 2010).

ForestrySA's plantation estate generates significant non-market benefits through recreation, heritage and cultural activities which attract in excess of 200,000 visitors each year. ForestrySA also manages over 5,300 hectares of native forest reserve for conservation.

The industry in the region faces competitive pressures due to the high Australian dollar and imported timber from countries with lower costs of production. The industry mainly supplies softwood (mostly *Pinus radiata*) to local saw mills for processing into sawn timber building products as well as for non-structurally graded uses such as posts for vineyard use or pergolas. Opportunities are emerging to diversify the industry through production of bioenergy using forest and saw mill residues to generate renewable, carbon neutral, energy. Also, new product innovations such as various forms of engineered wood products are being developed in various countries to meet rising demands for building products with low embodied energy (low carbon emissions and high levels of sequestrated carbon). These innovations offer potential avenues for future industry development.

Farm forestry in the region provides a means of integrating smaller scale plantations with other primary production to diversify income through timber, firewood production or potentially through carbon sequestration activities, while delivering natural resources management benefits such as mitigating soil erosion and salinity, and providing biodiversity habitat and connectivity.

One of the risks associated with forestry plantations is that they can occur in woodland and grassland areas that are not traditionally used for agriculture and therefore have significant biodiversity value. Forestry plantations are typically of limited habitat value for species in decline and can instead provide resources for already abundant species in the landscape that can compete with those in decline (e.g. Rainbow Lorikeet (*Trichoglossus haematodus*)).

Forestry plantations can acclimatise to drought, though productivity declines with decreases in water availability, as both growth rate and length of the growth season are reduced. Extreme heat events can also result in damage and mortality to plantation forests. These changes may also affect the quality of the wood produced from the plantations. Predictions for productivity for the Northern Hills are that it will remain the same, mainly due to the current higher rainfall base in this area. There may be increased risk from pests and fire with climate change (Pinkard and Bruce 2011).

Adaptation opportunities include plantation management through numbers of trees, selection of better genetics or alternative species, or potentially different sites for planting. More intensive management of plantations is also likely to be required to adapt to the impacts of pests, weeds and disease (Pinkard and Bruce 2011).

Mining

The one significant mine in the Northern Hills, with approximately half the state's limestone source, is the Angaston quarry. The mine contributes approximately $17 million to the economy and is predicted to last at least 23 years. Smaller mines extract gypsum, quartzite, sand and clay.

Tourism

Tourism in the Northern Hills is a major contributor to the subregional economy. The Barossa Valley is Australia's fifth-most visited wine region (Department of Resources, Energy and Tourism 2011). While traditionally tourism has been based around the wine industry and wine experiences, tourism experiences have diversified with increased food and historical experiences now available. The natural landscape of the area is seen as key assets that provide future opportunity to build tourism experiences around. Research has shown that visits to the natural attractions of the region (e.g. parks, bushwalking) are under-represented when compared to the Australian average, and overall interest in these activities is increasing nationally (Department of Resources, Energy and Tourism 2011). This provides an opening to build knowledge and ownership by the local community towards the natural assets of the subregion by linking them to opportunities for increasing economic input through tourism.

Threats to tourism in the region are considered to include damage to its primary production assets, loss of heritage (including food skills), competition from other wine regions, over-development, restrictive development processes and a general loss of uniqueness (Department of Resources, Energy and Tourism 2011).

Central Hills

In summary

The Central Hills, above Adelaide, consist of the landforms of hills face and foothills, central ranges, and eastern ranges and escarpment. The towns of the subregion support dairy farming, orchards particularly cherries, apples and pears, market gardens, viticulture, cattle farming and rural lifestyle blocks. Most of the subregion lies within the Mount Lofty Ranges watershed which supplies about 60% of Adelaide's water. Significant watercourses are the Torrens and Onkaparinga rivers (Figure 35).

This higher rainfall area once boasted a complex mosaic of vegetation groups with forest, big gum woodland, heathland, grassy woodland and riparian vegetation. Some systems are stable but two landscapes have been identified as priorities for restoration, based on declining woodland birds: lower rainfall grassy ecosystems and closed shrubland ecosystems. Several vegetation communities and plant species are also declining.

Central Hills – Priorities for the future

A set of priorities for the future for the Central Hills subregion has been developed based on the information in this section:

- Protect and improve the integrity of the shrubby forest and woodland dominated landscapes found along the spine of the range (from Scott Creek to Black Hill)
- Restore and reinstate grassy ecosystems where this will help stem biodiversity declines (along both the western and eastern flanks of the range); this requires improved technical knowledge, community recognition and sustainable use
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Better understand land use and land use change in a highly diverse landscape to support better development planning and management of land use conflict
- Support agriculture to adapt to climate change or transition to alternative business models
- Promote sustainable land management practices in a diverse land use and ownership environment
- Manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)
- Protect water resources for aquatic health and agricultural use (quality)
- Protect and restore riparian landscapes in the Torrens and Onkaparinga rivers to improve water quality and protect habitats
- Facilitate integrated climate change adaptation of people and the landscape
- Protect priority primary production areas from inappropriate development to maintain industry and business viability
- Encourage increased demand and supply of alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Monitor for, and control, pests that have not yet become established in the region or in the Central Hills subregion.

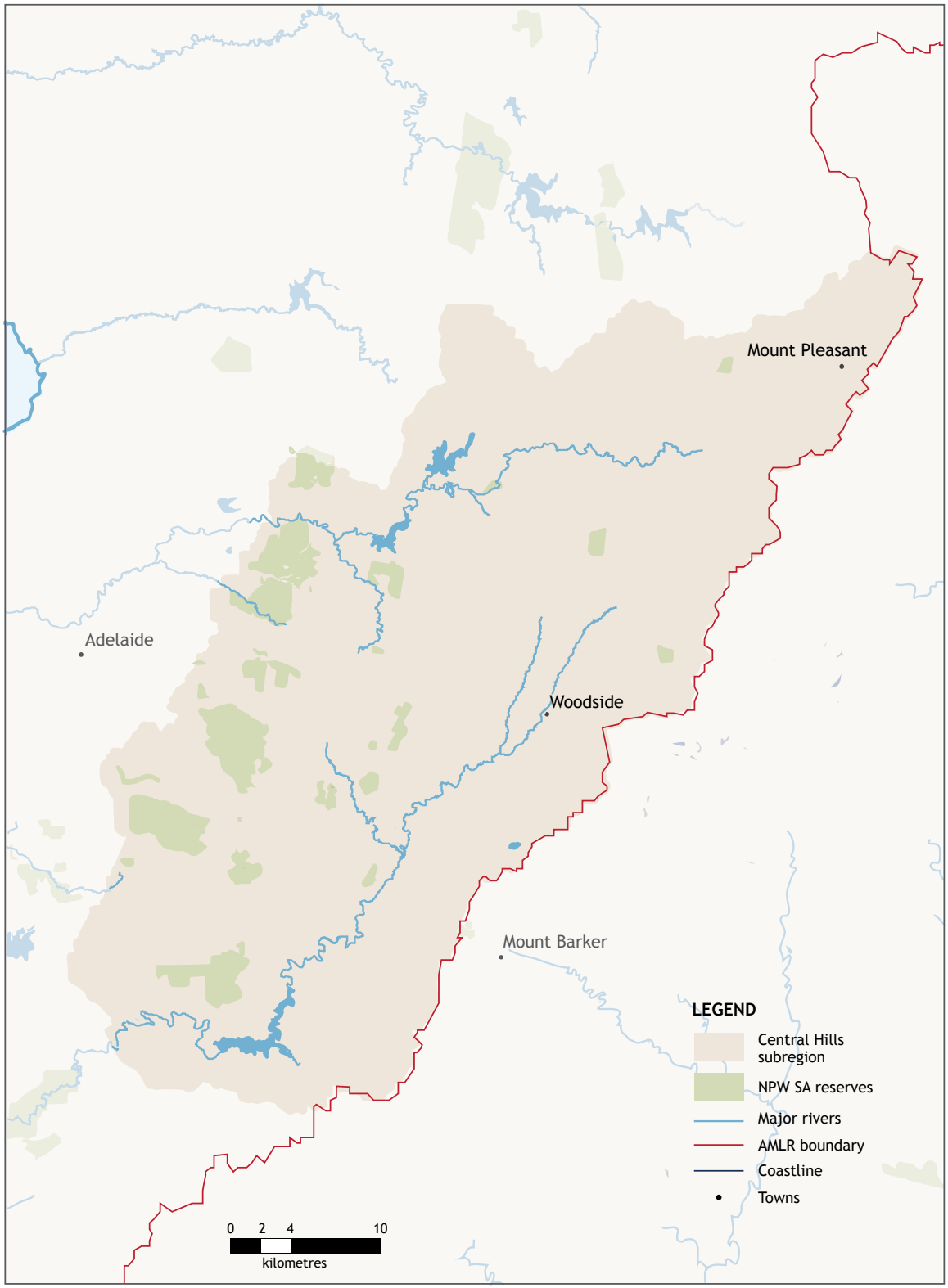


Figure 35: Central Hills subregion

Introduction

Mount Lofty Ranges watershed

Has legal status under the Development Act 1993, associated council development plans, the Natural Resources Management Act 2004 and the Environment Protection Act 1993.

Protection of the watershed allows land management and development controls to protect existing and future water supplies.

It covers an area of approximately 1640 km^2, encompassing Adelaide's existing and possible future water supply catchments.

The Central Hills rise up above the city of Adelaide and contain the low-lying Mount Lofty Ranges, which form the backdrop to metropolitan Adelaide and have a significant cultural, social, economic and environmental role in the daily lives of the people who live and work in and near them. The variety of landscapes include deep gorges, steep rocky slopes with dense forest, low rolling hills with scattered tall gum trees, and open wooded grassland with a myriad small to medium sized horticultural operations and farms and small to medium size villages and towns. The Central Hills contains the catchment area for the metropolitan water supply (Mount Lofty Ranges watershed).

The Central Hills consist of three major landforms: hills face and foothills, central ranges, and eastern ranges and escarpment. The hills face and foothills are the most prominent feature of the Central Hills, and contain the Hills Face Zone which is characterised by large areas of natural vegetation held in conservation parks. The Central Hills is bounded by the Northern Hills, Metropolitan and Willunga Basin social-ecological systems and the SA Murray-Darling Basin NRM region. The subregion intersects the traditional lands of the Peramangk, Ngadjuri and Kaurna people.

Adelaide's Hills Face Zone

Is defined by the western face of the Mount Lofty Ranges, extends for approximately 90 km from Sellicks Hill south of Adelaide to Gawler, north of Adelaide.

This zone has been protected from subdivision and intensive agriculture and horticulture for almost 40 years to protect the natural heritage values of the Mount Lofty Ranges. Generally development is controlled within the zone, to limit visual intrusion, particularly when viewed from roads in the zone or from the Adelaide Plains.

Lifestyles

The complex mosaic of land use and landscapes in the Central Hills includes the regional centre of Mount Barker (outside the Adelaide and Mount Lofty Ranges region boundary), Adelaide suburbs (e.g. Stirling), smaller townships and villages, and agricultural communities. The subregion is almost entirely within the Adelaide Hills Council with small areas of the District Council of Mount Barker, City of Onkaparinga, City of Mitcham and Barossa Council in the subregion. These local governments manage and maintain significant areas of remnant vegetation and open space in the subregion. The population in Adelaide Hills Council area is 38,628 (Australian Bureau of Statistics 2012f).

Small towns and villages in the Central Hills were settled to support farming and mining. To the north, land is used mainly for grazing, dairying, market gardens and quarrying. This area is supported by the townships of Mount Pleasant and Birdwood. Cherries and strawberries are the main land uses around Gumeracha and Kenton Valley. Land uses in the Onkaparinga Valley include dairy farming, orchards, market garden, viticulture, cattle farming and rural lifestyle blocks. Apple and pear growing, mainly around Lenswood, makes up almost 90% of the state's production of these fruits. The landscape around Uraidla-Summertown, which has a population of around 550, is used mainly for orchards and market gardening, with some hobby farming and viticulture.

Population

Adelaide Hills*	38,628
Aldgate/Stirling	17,319

*Council Area

Source: ABS 2011 Census

Around the South Eastern Freeway, the Central Hills becomes more urbanised with the large-lot suburbs of Stirling, Aldgate and Crafers. Proximity to the freeway, and therefore the city, is evidenced by the population of approximately 17,300. Towards the southern end of the subregion, land use moves to timber, farming and sheep grazing around Echunga and towards Kangarilla.

The 30-year plan for Greater Adelaide

Identifies targeted growth areas for the Central Hills, mainly focused on Mount Barker. Although Mt Barker is outside the region, expansion will still impact on natural resources in this subregion because of its proximity.

Smaller townships also have some planned expansion. The significant commuter populations are confirmed by 2006 data indicating that more than twice as many people who live in the subregion work outside the Central Hills than in it.

The majority of the Central Hills lies within the Mount Lofty Ranges watershed. The watershed's 10 individual catchments together supply an average of 60% Adelaide's water (Environment Protection Authority 2011). Of this, approximately 40% is derived from reservoirs in the Centrals Hills such as Millbrook, Kangaroo Creek and Mount Bold. The remainder of Adelaide water supply is pumped from the Murray River.

As temperature increases as a result of climate change, the cooler climate of the Central Hills is likely to become a retreat for humans, agricultural industries and ecosystems. This will add to the already high diversity of land uses in the area, and is likely to lead to conflicts between land uses.

Landscapes

The Central Hills historically supported diverse heathy woodland, forest and grassy woodland landscapes. The subregion contains the upper Torrens and Onkaparinga catchments, significant river systems to the region from a cultural, economic and environmental perspective.

Since European settlement, the native vegetation on fertile, arable land in the Central Hills has been subject to broadscale clearance and disturbance to provide land for agricultural production. Much of the remaining remnant vegetation is found in conservation and recreation parks, water reserves and native forest reserves. These reserves contribute to a connected vegetation landscape in the Mount Lofty Ranges. This includes Belair National Park and Brown Hill Creek Recreation Park and 17 conservation parks. However, grassy woodland are underrepresented in the protected area network.

The long history of a diverse range of land uses, combined with high rainfall and proximity to the weed source of metropolitan Adelaide has yielded diverse and abundant weed populations, which are a threat to both native vegetation and production areas.

Changes in land use from agricultural production to lifestyle blocks have contributed to degradation of the condition of remaining native vegetation and further increased the weed burden. Current development policy also means significantly more dwellings could be built in the Central Hills with resulting incremental clearance of vegetation.

More people, more closely concentrated may have a number of impacts on the natural resources of the subregion: more recreational use of protected areas which if not managed carefully can have negative impacts; and influence on the management of fire, and the use of prescribed burns for both ecological benefit and asset protection, as potential risk to property becomes higher with more properties.

The 30-year plan for greater Adelaide (Department of Planning and Local Government 2010) proposes only minor increases in township size for some towns in the Central Hills, but Mount Barker (outside the Adelaide and Mount Lofty Ranges region) is identified for significant population expansion. This is likely to have flow-on effects as both agricultural and native landscapes are converted to urban areas.

Protected areas*

Belair National Park
Black Hill Conservation Park
Brown Hill Creek Recreation Park
Charleston Conservation Park
Cleland Conservation Park
Coralinga Native Forest
Cromer Conservation Park
Cudlee Creek Conservation Park
Cudlee Creek Native Forest
Eurilla Conservation Park
Giles Conservation Park
Greenhil Recreation Park
Horsnell Gully Conservation Park
Kenneth Stirling Conservation Park
Mark Oliphant Conservation Park
Montecute Conservation Park
Morialta Conservation Park
Mount George Conservation Park
Mt Gawler Native Forest
Mylor Conservation Park
Porter Scrub Conservation Park
Scott Creek Conservation Park
The Knoll Conservation Park

*Protected under National Parks and Wildlife and Forestry Acts

The presence of a significant urban centre with major services at Mount Barker makes rural lifestyle living more attractive. Given the number of land titles currently without dwellings, but with the potential for dwellings to be built under current development planning policy, the increased population will have significant impacts on the natural landscape, requiring cooperation and compromise among a large group of stakeholders.

The disease *Phytophthora cinnamomi* is also a major threat to vegetation in the subregion, particularly with more recreational activities. *P. cinnamomi* is dispersed through soil on shoes, wheels, animal feet etc, and there is no currently known method for eradication. The only form of control is to contain it to existing areas, educate the community on its dangers and implement adequate hygiene controls.

Across the Central Hills, climate change impacts will be influenced by both the level of change and the flora and fauna involved, in particular their adaptive capacity. For example, the ability of grassy woodland ecosystems to adapt to climate change has been compromised by their reduced population sizes and probable genetic diversity in a degraded and fragmented ecosystem.

Increased impacts from weeds and pests and changes to fire regimes (frequency, intensity) are also likely to place increasing pressure on grassy woodland systems. Structural changes (within grassy woodland) are likely to include reduced tree cover and shifts in the composition of herbaceous ground layers. Grassy woodland may be able to shift to more favourable climates at higher altitudes but there will be competition for this ecological space from forests.

Structural changes in forests from climate change are likely to include fewer tall trees and more open space, with likely flow-on effects to habitats and fauna that need more trees. Endemic species that have a narrow climate range are likely to be most affected by climate changes. Fire is likely to play a critical role in shaping changing forests, which could be further exacerbated by an increase in invasive species that alter the fuel loads and ecological dynamics. Protecting refuges for endemic species with limited ability to adapt or move through the landscape will be critical for species survival.

Adaptation approaches require continuing effort at protecting and buffering existing vegetation ensuring diverse plantings and bolstering genetic diversity. Carbon sequestration initiatives to improve connectivity, control pests and weeds, and improve degraded soils are all opportunities to support adaptation to climate change.

Belair National Park

Belair was the first park to be dedicated in South Australia; it is the home of Old Government House and the State Flora Nursery.

The 840 ha park contains valuable remnant bushland, formal recreation facilities and a number of commercial operations.

Its two readily definable areas are notable for their different degree of human modification. The central and western area has been extensively developed for recreation purposes; the balance of the park to the east has been maintained essentially as natural bushland.

Landscape priorities for restoration in the Central Hills

A landscape health assessment was undertaken for the region based on declining woodland bird species. The landscape assessment of the Mount Lofty Ranges (Rogers 2011) identified two landscape systems as priorities for restoration:

- grassy ecosystems (including some lower rainfall grassy woodland ecosystems)
- closed shrublands (including some heathy forests and heathy woodlands).

The grassy ecosystem areas identified as a priority for ecosystem restoration (Figure 36) are along both the western and eastern flanks of the range and are connected to similar vegetation landscapes in the Northern Hills and the South Australian Murray-Darling Basin region. Areas of grassy woodland have also been identified along the Hills Face Zone through observation. The protection and management of this area is identified as a potential gap in restoration planning.

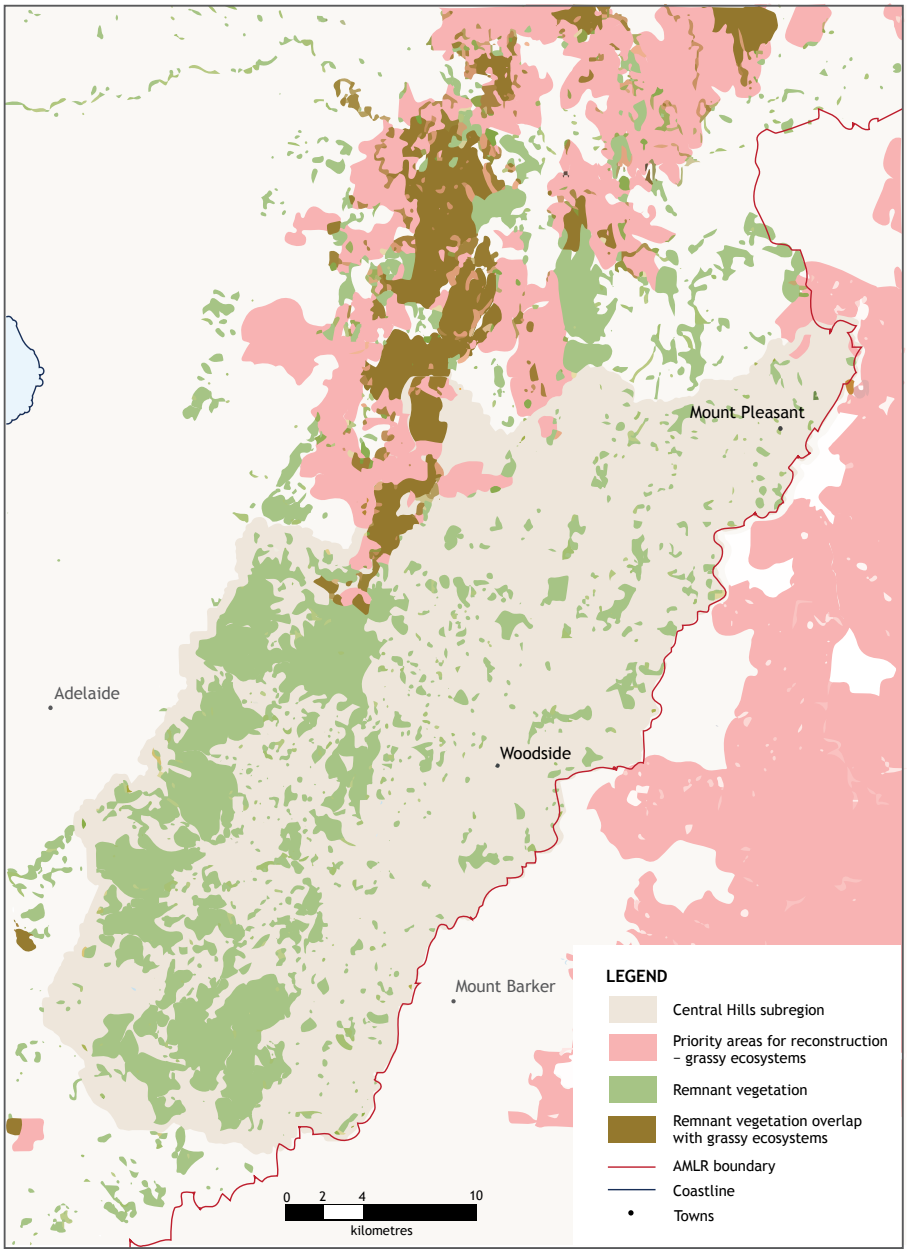


Figure 36: **Priority areas for reconstruction of grassy ecosystems in the Central Hills (including some grassy woodland and grasslands) (Rogers 2011)**

The closed shrubland systems are declining due to historical impacts, improving the ecological integrity of these systems is a high priority. They contain woodland with shrubland understorey dominated by Pink Gum (*E. fasciculosa*), and moderately cool and wet forest with overstoreys dominated by either Brown Stringybark (*E. baxteri*) or Long-leaved Box (*E. goniocalyx*). The areas of priority activity are around Belair National Park and Cleland Conservation Park, and the Lenswood and Lobethal area (Figure 37). Outside these priority areas, any activity that aims to protect and reconstruct these systems in the Central Hills will add value to the landscape and improve the condition and connectedness of closed shrubland.

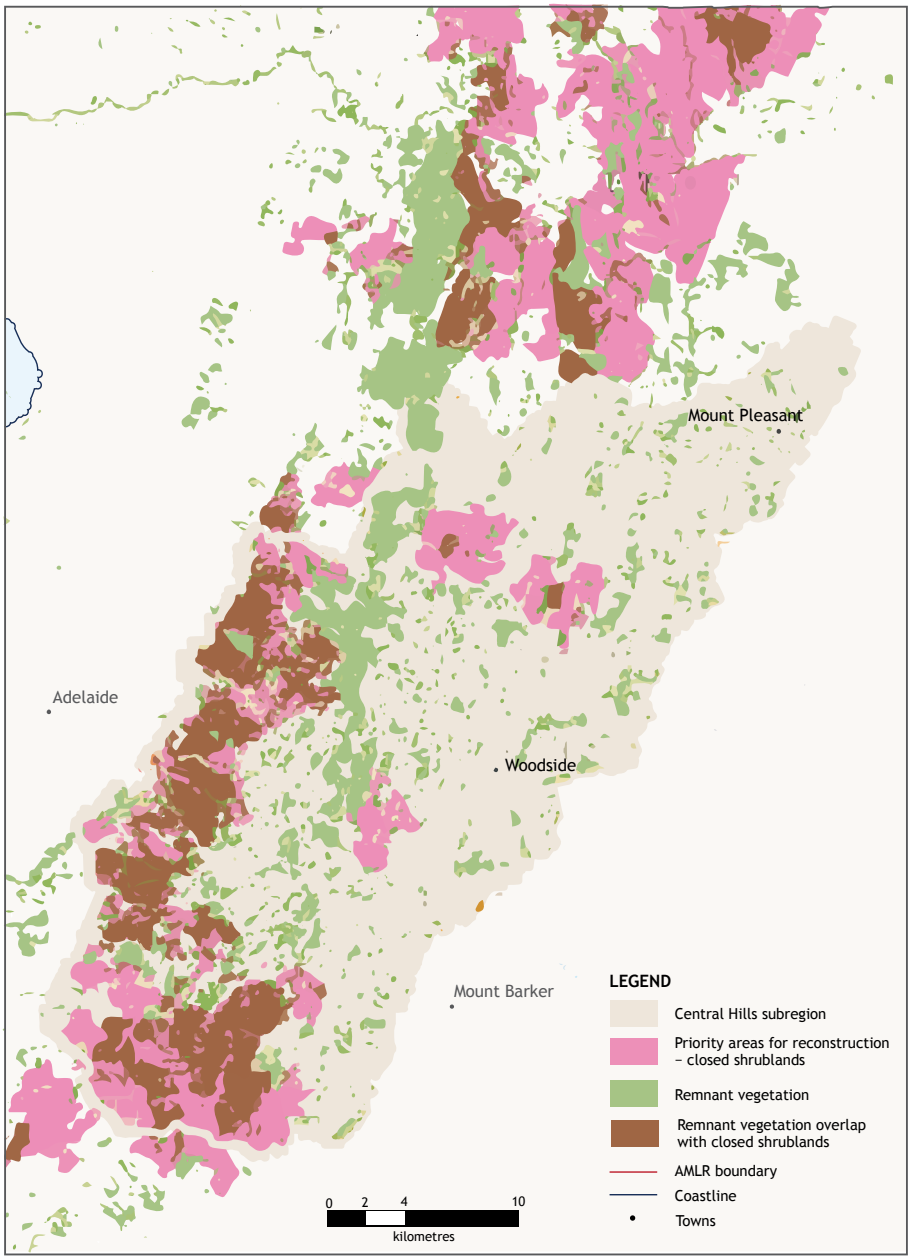


Figure 37: **Priority areas for reconstruction of closed shrubland in the Central Hills (including some heathy forests and heathy woodlands) (Rogers 2011)**

Vegetation of the Central Hills

The higher rainfall Central Hills has a diverse suite of vegetation groups that form a mosaic across the landscape depending on, among other things, soil type, slope and aspect.

Olive threat to native habitats

Dense olive infestations pose a significant threat to the native habitats of the subregion, particularly grassy woodland ecosystems. Olives can outcompete eucalypts and also shade out associated areas of native grasses. This change often occurs gradually and the problem is often not recognised until olives are the dominant species.

Heath and heathy forest

On the more fertile deeper soils wetter slopes are Candlebark (*Eucalyptus dalrympleana*) and Manna Gum (*E. viminalis*) forest. Heathlands are found on slopes and ridges while Pink Gum and Oak-bush (*Allocasuarina muelleriana*) and Stringybark (*E. obliqua*) heathy forest and woodland occur along the spine of the ranges.

Based on a landscape scale assessment (using birds as indicator species), closed shrubland (e.g. stringybark forest) systems have been classified as being in a stable state (Rogers 2011). These systems are often found in less fertile soils along the spine of the ranges. The priority for these systems is to maintain the stable state by focusing on threat abatement. Particular threats include pests and weeds, and planning policies that allow landscape fragmentation and make future management of sites complex due to the proximity of built assets.

Scott Creek-Mount Bold conservation cluster

The community values the Scott Creek-Mount Bold conservation cluster as the largest area of remnant vegetation dominated by heathy woodland in the Central Hills.

This valuable area contributes to landscape scale restoration of heathy woodland, as well as protecting threatened and vulnerable animal and plant species in the subregion.

Grassy woodland

The hills face is dominated by Mallee Box (*E. porosa* and Grey Box (*E. microcarpa*) grassy woodland. Pink gum (*E. fasciculosa*) grassy woodlands are found on the eastern slopes of the range. Big gum woodland containing Blue Gum (*E. leucoxylon*), River Red Gum *(E. camaldulensis)* and Manna Gum (*E. viminalis*) species were prevalent historically. Many of the big gum environments are now dominated by only the most robust and resilient tree species, the River Red Gum; many of the other species have been lost as they are generally shorter lived or less robust. The River Red Gums are left more exposed to insect attack as many birds that would normally consume such insects can no longer occupy these areas without the full complement of trees. Restoring some of these areas is likely to improve the health of bird communities and in turn the scattered trees.

The riparian vegetation found in the Central Hills depends on where in the landscape the watercourse is. Along the steeper slopes and ridges of the ranges the vegetation is dominated by tall open forest of Candlebarks, Manna Gums, Blackwoods and Stringybarks; along the drainage lines of the foothills the

riparian zone is dominated by River Red Gums. Riparian zones also typically contain dense vegetation with understorey, shrublayer and overstorey. The condition of Central Hills riparian vegetation is generally considered to be poor with widespread woody weed and exotic tree infestation, and bed and bank erosion caused by stock access (which also impacts on water quality and ecosystem health).

Grey Box grassy woodland

Grey Box grassy woodland is a nationally threatened vegetation community found in the AMLR region. The Hills Face Zone is one area of the region that contains the largest patches and contiguous remnants of this community. This vegetation is found on public or local council owned land (Mitcham, Belair, Marion) and on private land in the hills face ranging from residential properties to larger 'lifestyle' blocks. Historically this land was used for grazing, but in many instances land use has changed to reserves and open space as urbanisation of the area has increased. Grey Box grassy woodland is under increasing pressure from pest and weed invasion and increased recreational use of parks. However, there is significant opportunity to protect and restore areas of remnant vegetation in the Hills Face Zone through engaging the community and land managers to improve their knowledge and understanding of this vegetation community.

Threatened species and communities of the Central Hills

Action to address threatened species and communities is required at a number of scales. While landscape scale restoration will assist, additional specific action is required for certain species and communities to prevent further decline and potential extinction. The geographic scope of species status does not directly equate to priority for action. The recovery of some nationally threatened species of very high national significance, will not be strongly influenced by action in the region; the management requirements of state or regional listed species (for which meaningful action can be undertaken) may be more appropriate as a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

In the Central Hills specific vegetation communities and flora and fauna species are threatened and require more specific and targeted actions alongside of the broader ecosystem reconstruction for the two priority landscapes. The threatened vegetation communities are:

- Grey Box (*E. microcarpa*) grassy woodland (listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act))
- Box woodland (*E. porosa* (Mallee Box) and *E. microcarpa* (Grey Box)) are Threatened in the Adelaide and Mount Lofty Ranges region
- Candlebark (*E. dalrympleana*) and Manna Gum (*E. viminalis*) forest (Endangered state listed species)
- Big gum (Blue Gum (*E. leucoxylon*), River Red Gum (*E. camaldulensis*) and White Gum (*E. viminalis*)) woodland
- Blue Gum (*E. leucoxylon*) grassy woodland
- Teatree (*Leptospermum continentale*) perched swamps (Mount Lofty bogs).

Examples of threatened fauna in the Central Hills include in particular the Chestnut-rumped Heath Wren and Southern Brown Bandicoot. Both are nationally endangered species that inhabit heathy woodland and forest.

These vegetation systems can contain high fuel loads. In areas of high bushfire risk there is a need to balance fuel reduction requirements (through prescribed burning) with the need to ensure there is sufficient habitat for these fauna species. Determining an appropriate balance can be challenging, particularly in semi-urban environments where bushfire risks can be high and habitat remnants are often small. However, some prescribed burning in these habitat types is likely to be required to maintain habitat quality, as well as minimising bushfire risks to human life and property. Prescribed burning can play an important conservation role in reducing the risk of bushfires burning entire tracts of habitat which could result in localised fauna extinctions.

Other threatened species include the birds Yellow Tailed Black-Cockatoos (*Calyptorhynchus funereus)*, Scarlet Robin (*Petroica boodang)*, Crested Shrike-tit (*Falcunculus frontatus*) and Varied Sittella (*Daphoenositta chrysoptera*), and the amphibian, the threatened Brown Toadlet (*Pseudophryne bibronii*).

The Central Hills is characterised by a diverse range of smaller flora in the higher rainfall and wide range of microclimates, such as these examples of threatened flora:

- Leafy Greenhood (listed as endangered under the EPBC Act) – a grassy woodland species
- King Fern (Endangered state listed species) – grows in Mount Lofty swamps and bogs
- Tall Daisy (Rare state listed species) – grows in Blue gum/Pink gum grassy woodland
- Mount Lofty Phebalium (Rare state listed species) – grows in stringybark forest and woodland.

Protecting watercourses for Brown Toadlet habitat

Brown Toadlet requires smaller ephemeral creek lines and shallow gently sloping watercourses characterised by a build up of grassy and leafy debris to survive. Maintaining large areas of intact and connected native vegetation in the Central Hills will help protect the hydrology of these small creek lines and watercourses, and thus Brown Toadlet habitats. Males care for clutches of eggs and the tadpoles are released from their eggs when their nest is inundated by water, typically after a heavy rainfall event. Tadpoles continue their development in temporary pools formed near their nest until they metamorphose into juvenile toadlets.

Water resources of the Central Hills

River Torrens

The 62 km^2 River Torrens catchment has its upper catchment in the Central Hills and lower catchment in Metropolitan Adelaide.

The upper catchment, extending from the eastern headwaters near Mount Pleasant to Gorge Weir at Athelstone, contains urban and rural areas, water supply infrastructure, Kangaroo Creek and Millbrook reservoirs, and Gorge and Gumeracha diversion weirs.

Aquatic health monitoring indicates that the upper Torrens River catchment is in fair to good health (see condition boxes). This catchment is also part of the Mount Lofty Ranges watershed, an area of approximately 342 km^2 that supplies approximately 20% of metropolitan Adelaide's potable water. This area of the watershed is largely rural but contains the towns of Mount Torrens, Birdwood, Gumeracha, Forreston and Kersbrook.

The 85 km long Torrens River serves as:

- amenity to rural and urban lifestyles
- an irrigation source
- a drinking water source
- a transfer aqueduct conveying River Murray water for use in Adelaide
- recreation
- stormwater control and management.

River Torrens (1 km from Birdwood)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0267-ecosystem-2011

Sixth Creek (near Castambul)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0248-ecosystem-2011

Land management practices such as maintaining soil cover to reduce erosion and minimising nutrient contamination into the waterway through restricting stock access have improved water quality in the Torrens River. Pest and weed control are still major issues for both agriculture and natural ecosystems. The rise of the rural lifestyle land manager and the rate of ownership turnover continue to pose challenges to effective natural resources management in the Central Hills.

The watercourse is prescribed as part of the Western Mount Lofty Ranges Prescribed Water Resources Area (PWRA) which aims to ensure a sustainable water resource that can be used for drinking purposes, irrigation and productive agriculture and meet environmental requirements.

The importance of the watershed

The Mount Lofty Ranges watershed covers an area of approximately 1640 km^2, encompassing Adelaide's existing and possible future water supply catchments. Whilst each year varies, on average 60% of Adelaide's existing mains water supply requirements are sourced from the watershed. Ninety percent of the watershed is privately owned and will always be subject to multiple uses including urban areas, rural townships, horticulture, viticulture, market gardens, forestry, dairy farming and grazing. Management of land within the watershed is important to maintain the quality of water resources.

Onkaparinga River

The 564 km^2 Onkaparinga River catchment originates near Mount Torrens in the Mount Lofty Ranges, at an elevation of around 530 m, approximately 30 km east of Adelaide. The river flows southwesterly to Gulf St Vincent at Port Noarlunga. The upper catchment contains the headwaters to Mount Bold reservoir and includes the townships of Lobethal, Woodside, Oakbank, Hahndorf, Echunga and Stirling. A number of feeder creeks and tributaries, each with a variety of distinct ecosystems and agricultural management regimes, feed the 95 km Onkaparinga River (the third longest watercourse in the state). It changes from a chain of ponds in the upper section to a more continuous stream towards Mount Bold reservoir. Many tributaries are deeply incised and have intermittent flow. The valley structure is generally asymmetric, with steep northwesterly slopes and a narrow floodplain. To the west of the river the landscape is dominated by hilly uplands; the eastern side of the catchment is characterised by undulating to hilly high plains.

This catchment is part of the Mount Lofty Ranges watershed, an area of approximately 342 km^2 that supplies approximately 20% of metropolitan Adelaide's potable water. Approximately 9% of the catchment is irrigated, supplied by both surface and groundwater. The impact of farm dams on flow in the upper catchment is more pronounced between November and March where flow reductions can be greater than 20%. Below the Hahndorf dissipater, where River Murray water is discharged into the system, the flow is typically constant for weeks or even months at a time, often during the period that the river would naturally cease to flow.

Landowners taking up more urban and rural living land can have limited knowledge of their responsibilities and generate more land management issues. Water quality issues arise from runoff from agricultural land (fertiliser, animal waste, pesticides/herbicides) and infrastructure runoff and seepage.

The watercourse is prescribed as part of the Western Mount Lofty Ranges PWRA which aims to ensure a sustainable water resource for drinking purposes, irrigation and productive agriculture, and meeting environmental requirements.

Onkaparinga River (Woodside)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0268-ecosystem-2011

Onkaparinga River (near Hahndorf)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0045-ecosystem-2008

Groundwater

The groundwater resources of the Central Hills primarily lie within the fractured rock aquifers of the Adelaidean System basement rock that forms the Mount Lofty Ranges and shallow aquifers found in the alluvium on the valley floors and along drainage lines. The Western Mount Lofty Ranges PWRA was established in 2007 and the groundwater resources are managed through legislation with the Western Mount Lofty Ranges Water Allocation Plan (WAP).

Groundwater in the Central Hills is predominantly used for irrigation and also for stock and domestic purposes. In the fractured rock aquifers groundwater moves as both local and intermediate flow systems and yields are highly variable, depending on location: the underlying geology often determines the amount of fracturing and quality of the groundwater. Most of the Central Hills area is underlain by the consolidated sediments of the Adelaidean System with smaller areas of the older Barossa Complex and younger Kanmantoo Group rocks (Figure 38). Good quality water and high yields can be found in the Adelaidean sediments whereas the Barossa Complex and Kanmantoo Group rocks tend to provide low yields and high salinity groundwater. The aquifers of the Central Hills discharge into the sediments of the plains, watercourses to maintain baseflow and persistent pools, and as localised springs and seeps.

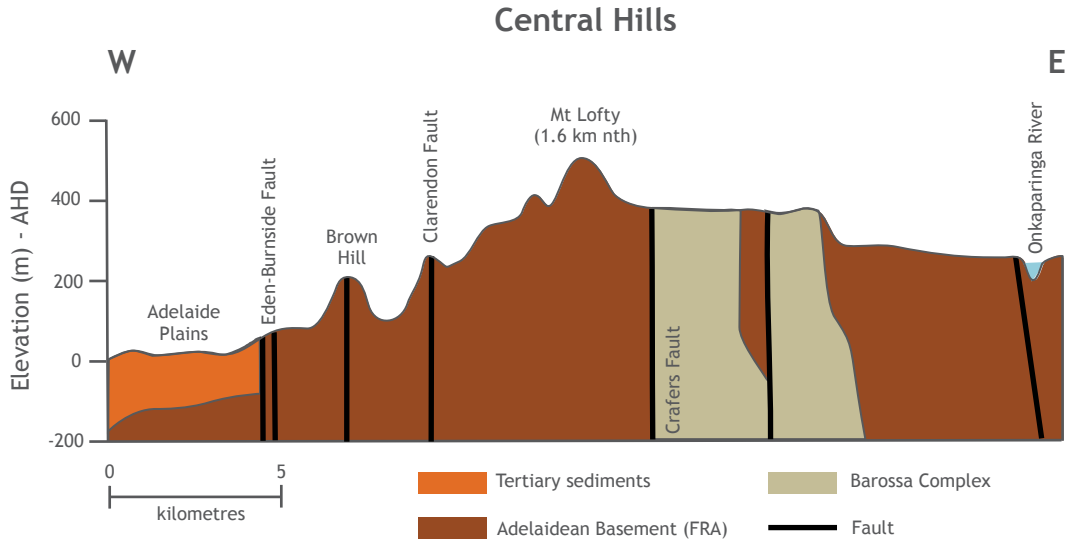


Figure 38: Cross section of the Central Hills groundwater system

The quality and quantity of groundwater in the Central Hills is variable reflecting the differing underlying geology and rainfall patterns across the area. With the primary use of agricultural irrigation, overall groundwater extraction is related to a demand which can fluctuate from year to year depending on rainfall and the corresponding length of the irrigation season. Drier years see higher demands for water and decreased use may be related to lower demand when rainfall is above average.

Groundwater levels and yields in the fractured rock aquifers are highly variable: from less than 1 L/sec to more than 10 L/sec where extensive fracturing occurs. Similarly, salinity can vary but is generally good with groundwater of less than 1,000 mg/L found throughout the Central Hills particularly in the area between Gumeracha and Mylor (Adelaide and Mount Lofty Ranges NRM Board 2006).

The groundwater resources of the Central Hills are at the most risk from reductions in rainfall and changes to extraction regimes. Extension of the irrigation season, while not necessarily increasing the volume of extraction, can impact on the ability of the aquifers seasonal recovery and lead to an overall decrease in water level.

The flattening out of seasonal rainfall patterns induced by climate change may impact water levels and salinity in the long term as aquifers recharge through groundwater flow from the outcropping aquifers that receive direct rainfall recharge.

Land use change may also create impervious surfaces and more concentrated areas of extraction with urban development and intensified agricultural production in smaller areas.

Groundwater dependent ecosystems

The groundwater dependent ecosystems (GDEs) in the Central Hills are predominantly fractured rock aquifer spring discharge and baseflow. The dependency of ecosystems on direct groundwater inputs at a local scale is largely unknown, although investigations show that it is likely that a significant proportion of watercourses, persistent pools and wetlands in the region are at least partially maintained through direct groundwater inputs (VanLaarhoven 2012).

Fractured rock spring discharge and baseflow occurs throughout the area where the saturated fractures outcrop and supports persistent pools, wetlands and riparian vegetation. Wetlands can be found scattered throughout the Central Hills, particularly in the area around Bridgewater and Mylor (Adelaide and Mount Lofty Ranges NRM Board 2013).

A second class of GDEs relies on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include riparian forests that require a supply of groundwater within the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases; new species invade the system leading to a new structure and function to the ecosystem that does not necessarily provide the services required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

The GDEs of the Central Hills are potentially impacted by climate change with reduced frequency and changed timing of surface water inflows and recharge of the shallow aquifers in hotter, drier conditions and changing rainfall patterns (Barron et al. 2011). In areas of outcrop, urban development can reduce natural surfaces able to receive direct rainfall recharge.

Livelihoods

Production in the Central Hills is predominately agriculturally based, and is characterised by high quality soil in mid to high rainfall zones. The main crops are perennial horticulture, (particularly apples, pears, cherries) and viticulture. Over time, land use has changed from annual horticulture to viticulture and rural living has increased.

Primary production is heavily dependent on the natural resources of the subregion; in particular, healthy soils, healthy water and minimal agricultural pests. Healthy soils, while linked to intrinsic soil properties, are also heavily influenced by management of soils and production practices. Soil acidity, erosion and compaction are the main soil management issues; and pest animal and plant control is a significant issue for the area as a whole. Soil surface cover monitored in December 2011 identified that the risk of erosion in the Central Hills is generally low with small isolated patches of moderate to high risk. The areas of higher risk tended to be vineyards with fallow or poor pasture cover or pastures with poor cover (Young 2011). Monitoring conducted from December 2011, until June 2012 observed a drop in the proportion of sites at low risk of erosion from 93.9% to 85.8%. A consequential increase in the proportion of sites at moderate or moderate-high risk of erosion was observed over the same time period potentially due to planting of winter crops resulting in cultivated areas at the time of the risk assessment (Young 2012).

Recent population growth and urban development has increased the complexity of managing primary production activities in the Central Hills and led to a move towards identifying and protecting land considered valuable for primary production activities now and into the future. Figure 39 identifies priority primary production areas in the Central Hills and the key considerations that contributed to each area being included as valuable to primary production. The categorisation and description of these areas draws on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011e,f,g).

Annual average rainfall

Cleland CP	1,148 mm
Gumeracha	800 mm
Echunga	880 mm

Lenswood – Forest Range

Key considerations

- favourable soil, water and climate conditions for horticulture
- substantial investment in related industry infrastructure
- limited options for this type of cool climate horticulture in other parts of the AMLR region

Notes

Most of South Australia's cool climate tree fruit production; has natural resource conditions that will help industry adapt and adjust to climate change

Mid Torrens Valley

Key considerations

- favourable soil and climate conditions for horticulture/viticulture
- favourable soil and climate conditions for grazing
- existing intensive land use and investment

Notes

Potential to support new, more intensive industries, including horticulture; good soils, water resource options, cool climate conditions and relatively large property size, will help industry adapt and adjust to climate change

Upper Torrens Mt Pleasant

Key considerations

- favourable soil and climate conditions for horticulture/viticulture
- Favourable soil and climate conditions for grazing

Notes

Better land than further north but more fragmented and more likely subject to development pressures; lies wholly within MLR water catchment area

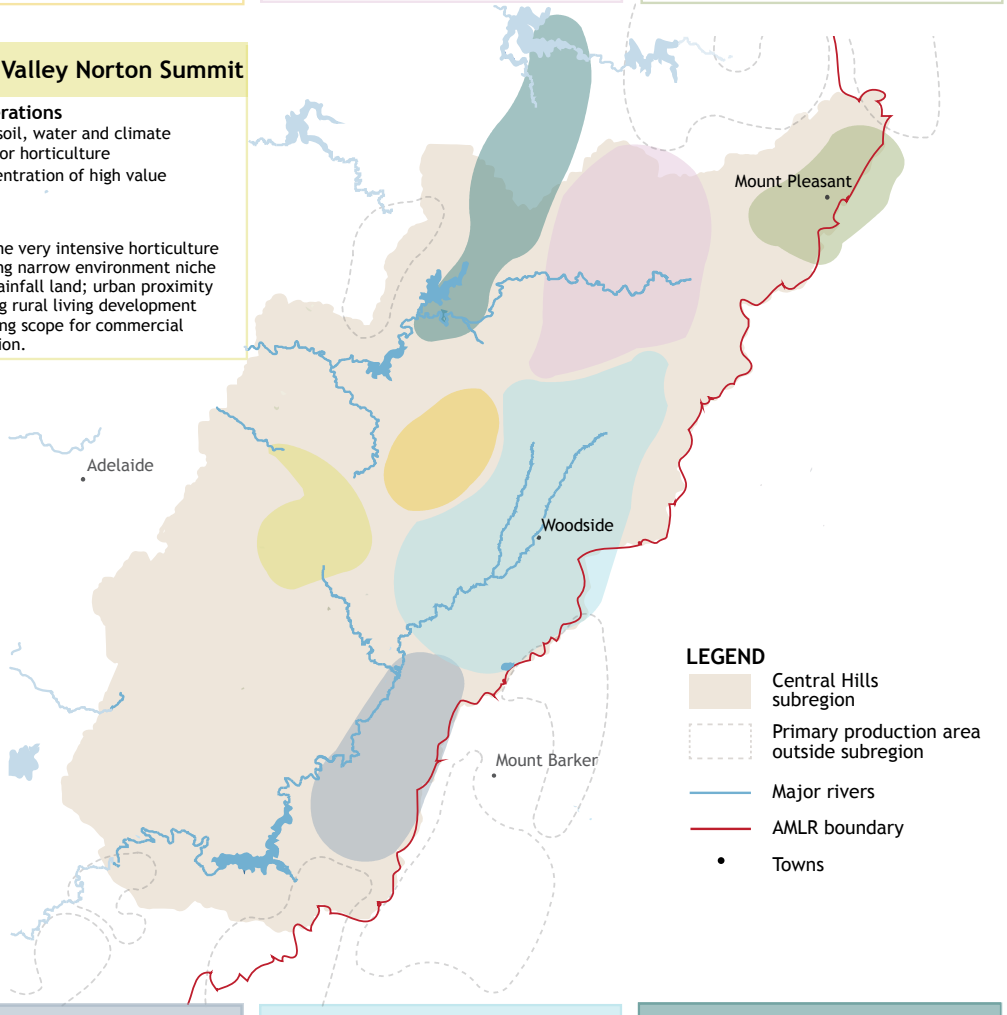
Piccadilly Valley Norton Summit

Key considerations

- favourable soil, water and climate conditions for horticulture
- major concentration of high value land use

Notes

Cluster of some very intensive horticulture industries using narrow environment niche of very high rainfall land; urban proximity and continuing rural living development steadily eroding scope for commercial scale production.



Hahndorf – Echunga

Key considerations

- favourable soil and water conditions for cool climate horticulture/viticulture
- favourable soil and climate conditions for grazing
- existing intensive land use and investment

Notes

Some of the better land in subregion; fragmentation and encroachment of rural living may limit scope for primary production development in north of this unit

Upper Onkaparinga Valley

Key considerations

- favourable soil and climate conditions for horticulture/viticulture
- favourable soil and climate conditions for grazing
- existing intensive land use and investment

Notes

High value land use. Potential to support new, more intensive industries, including horticulture; good soil, water resource options and cool climate conditions will help industry adapt and adjust to climate change

Kersbrook

Key considerations

- high rainfall and groundwater access
- major concentration of forestry

Notes

Some areas of lower capability land and variable water resources; potential for perennial horticulture on better land, high rainfall grazing in areas with larger allotments, and forestry

Figure 39: Priority primary production areas in the Central Hills (based on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011a, e,f,g))

Viticulture

The wine region in the Central Hills is classed as cool climate; the highest vineyards are sited at 600–650 metres altitude. Viticulture occurs in and around Crafers, Summertown, Piccadilly and Carey Gully. Viticulture is a significant contributor to the economy of this subregion, including the associated substantial value adding through wine production and tourism.

Vineyards in the area are planted mainly on a mixture of sandy loams, loams and clay loams over clay subsoils that vary in structure. It is not unusual to find these soils combined with shale and ironstone. Soils are generally acidic and in some cases neutral in pH, but rarely alkaline. Irrigation water is sourced from both groundwater and dams fed by surface water. Increased population and urbanisation is impacting on the number of vineyards, particularly on good soil on the edges of the townships (with land prices also increasing as a result). Increases in viticulture have in turn impacted on the level of annual and perennial horticulture (food production).

Data on the value, tonnage harvested and area planted in the subregion includes some production that occurs in the SA Murray–Darling Basin NRM region around Meadows and Mount Compass. The total value of grapes decreased significantly from $24.2 million in 2011 to $20.5 million in 2012 while the total planted area of vines increased by 38 hectares to 4030 hectares (Phylloxera and Grape Industry Board of SA 2012d). Between 2000 and 2011, the harvest increased in the Central Hills subregion by 62% from 8,298 tonnes to 21,871 tonnes, the grape value increased by 43% from $13.8 million to $24.2 million, and the area planted increased by 44% from 2,217 hectares to 3,992 hectares.

For the viticulture industry the impacts of increased temperature and variations in temperature will influence timing of physiological processes such as timing of budburst. This is likely to include earlier ripening during warmer temperatures with potential impacts on fruit quality, and compression of harvest dates between varieties. The impact of climate change on water availability particularly timing and amount of rainfall will also influence irrigation with more water being required and potentially not available. As the Central Hills is classed as cool climate, impacts of temperature may mean traditional cool climate varieties will not grow successfully. However, there is scope for changes in varieties to those that are currently grown in warmer climates (Anderson et al. 2008).

Horticulture

The two main horticultural crops in the subregion are cherries and pome fruit (apple and pears). Approximately 100 cherry growers have 560 hectares of more than 50 varieties of cherries. Around 2,000 tonnes of cherries are harvested each year. Of the four main areas of cherry orchards, the largest is around Forest Range–Lenswood, and another lies around Basket Range–Ashton–Summertown. The cherry industry has a farm gate value of $14–20 million (Cherry Growers Association of SA 2013).

The pome fruit industry produced approximately 19,300 tonnes of apples and 4,940 tonnes of pears in 2008 – or about 84% of the state's production. All the pears and the majority of apples are sold domestically. Urban expansion is rapid in the areas identified as prime targets for future apple and pear production needs.

Horticulture is likely to be impacted by climate change in a number of ways. Higher temperatures and increased frequency of extreme temperatures may increase the frequency and severity of disorders such as sunburn browning. Water supplies may also be affected with potential reductions in stream flow of 20-30% (Apple and Pear Australia 2008).

The total gross value of horticulture to the Central Hills is approximately $56 million per year.

Source: Australian Bureau of Statistics 2011b

Several potential adaptation strategies can minimise the adverse effects of higher temperatures. These include hail netting to reduce air and fruit temperatures, dormancy breaking compounds to combat the effects of insufficient chilling hours, and new varieties better adapted to warmer and drier climates. Similarly, several strategies can be applied to improve water use efficiency or to maintain production when water is limited. These include rootstock selection, efficient irrigation systems, irrigation strategies and crop load manipulation. Significant work on the impacts and potential adaptation to climate change for the apple industry is contained in the document Room to Move: Towards a strategy to assists the Adelaide Hills apple industry adapt to climate change in a contested peri-urban environment (Houston and Rowland 2008).

Grazing and dairy

The gross total value of the grazing industry in the Central Hills is $11 million, mostly through prime lambs and beef cattle. Dairying contributes another $4 million in gross total value to the subregion. Grazing occurs on improved perennial pastures which can be a mix of native grasses and introduced pasture species. Industry viability is subject to external factors such as export conditions and cost of production. Impacts on land price from increasing populations and demand for housing land is prompting conversion of some farms to rural lifestyle blocks.

In 2011 there were 28 dairy farms in the Central Hills. The dairy industry has undergone a significant transformation and milk prices continue to be the significant driver of business profitability.

Climate change impacts on the grazing industry are likely to result in more intensive management of stocking rates as variations in temperature and rainfall impact on pasture growth. Winters are predicted to be warmer with fewer frosts and so growth rates could be higher and using nitrogen fertiliser during winter may become more effective. Summers are predicted to be hotter, beginning earlier and finishing later – potentially causing heat/moisture stress over summer, while shortening the peak of spring growth and delaying the start of 'autumn'. Short rotation pasture systems and winter fodder crops may become more attractive than irrigating pasture over summer. Grazing management is also likely to require better prediction tools and models, particularly for rainfall, to enable suitable stock management to ensure soil cover and natural resources are not degraded. Changes to species used for pastures (including using native grasses), the timing of mating and new breeds and cross-breeds will also need to be considered (Rebbeck et al. 2007).

For the dairy industry the above grazing impacts and adaptation responses also require consideration and management of climate impacts on cows. Cows have evolved a range of mechanisms to off-load heat, but problems can occur if temperatures and humidity remain high. Response to heat also differs between breeds. Temperatures above 25°C reduce the ability for cows to produce milk and get in calf. Provision of shade, minimising the distances walked, and active cooling by sprays are important heat stress management tools (Howden et al. 2008).

Climate change projections predict lower rainfall, higher evaporation, changes in seasonal patterns and more frequent/longer droughts. These factors generally cause runoff to be reduced at more than double the rate of rainfall reduction. This results in decreased volumes available for farm water supplies, with businesses that rely on surface runoff for irrigation potentially facing severe water shortages. However, runoff estimates are not always reliable because runoff depends on timing and intensity of rainfall as well as rainfall amount. Reductions in the reliability of supply will vary but are likely to be greatest where surface water extraction is already high, and where climate change is predicted to have the largest impact on water availability.

Forestry

The Adelaide and Mount Lofty Ranges NRM region contains around 11,600 hectares of plantation forestry, of which about 9,700 hectares is softwood owned or managed by ForestrySA, The remaining 1,900 hectares is privately owned hardwood forestry, including farm forestry. Further information about the commercial forestry industry in the Adelaide and Mount Lofty Ranges NRM region can be found in the Northern Hills subregion section.

Climate change impacts on forestry include productivity declines with decreases in water availability, as both growth rate and length of the growth season are reduced. Extreme heat events can also result in damage and mortality to plantation forests. There may also be some influence of these changes on the quality of the wood produced from the plantations. There may also be increased risk from pests and fire with climate change (Pinkard and Bruce 2011).

Adaptation opportunities include plantation management through numbers of trees, selection of better genetics or alternative species, or potentially different sites for planting. More intensive management of plantations is also likely to be required to adapt to the impacts of pests, weeds and disease (Pinkard and Bruce 2011).

Willunga Basin

In summary

The gentle hills and plains of the Willunga Basin sit beneath the Willunga escarpment and surround the Onkaparinga River and its estuary. The highly modified landscape, cleared mostly for grazing, was once Box woodland, grassland and sand heath communities, which now remain only along roadsides and in parks and reserves, making up less than 10% of the subregion. Several plant communities, and species, are listed as threatened and the pressure continues from the southward creeping suburbs of Adelaide and lifestyle residents (Figure 40).

The viticulture industry in the McLaren Vale winegrowing area promotes primary production, tourism, lifestyle opportunities and employment. It is supported by good quality groundwater and recycled water from the Willunga Basin Water Company. Groundwater and surface water are prescribed through the McLaren Vale Prescribed Wells Area (PWA) and managed through the McLaren Vale Water Allocation Plan (WAP). The agricultural nature of the area is protected under the *Character Preservation (McLaren Vale) Act 2012*.

Willunga Basin – Priorities for the future

This set of priorities for the future for the Willunga Basin subregion has been developed based on the information contained in this section.

Subregion wide

- Restore and reinstate grassy ecosystems where this will help stem biodiversity declines (particularly along the western flanks of the range, which includes areas containing the nationally threatened Grey Box grassy woodlands)
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Connect communities to their environment (both local and more remote)
- Connect communities to sustainable food production
- Protect, restore and buffer the vegetation of the Aldinga Scrub Conservation Park and the washpool, and aim to provide connections between the two
- Improve the condition of the Onkaparinga estuary
- Encourage increased demand, and supply of, alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)
- Protect water resources for aquatic health and agricultural use (quality)
- Support agriculture to adapt to climate change or transition to alternative business models
- Protect priority primary production areas from inappropriate development to maintain industry and business viability
- Facilitate integrated climate change adaptation of people and the landscape
- Promote sustainable land management practices focusing on maintaining soil cover and sustainable primary production practices
- Monitor for and control pests that have not yet become established in the region or in the Willunga Basin subregion.

Coastal specific

- Protect and rehabilitate priority areas of the Willunga Basin subregion coast (including coastal heath and dune environments as Port Willunga, Aldinga, Silver Sands, Sellicks, Aldinga Scrub Conservation Park and the samphire ecosystem at the Washpool)
- Monitor and manage migratory and resident shorebirds at the Washpool, and at key beach-nesting birds (Hooded Plovers) breeding sites including Maslin Beach, Port Willunga, Aldinga/Silver Sands.

Figure 40: Willunga Basin subregion

Introduction

This subregion consists of three landforms, the Willunga escarpment, the basin and Onkaparinga River. The Willunga escarpment - the scarp of the still active Willunga Fault – sweeps down from Kangarilla in the hills to overlook the plains that form the basin. The basin is a series of gently undulating hills in the northern part of this subregion and changes to a flatter landscape towards the south coast at Sellicks Beach. It is bordered by the Central Hills, Metropolitan Adelaide, Southern Coast and Fleurieu subregions, and by the SA Murray-Darling Basin NRM Board. This subregion intersects the traditional lands of the Kaurna people.

This subregion also contains the Hills Face Zone. The first part of the zone is its continuation from the Central Mount Lofty Ranges hills face, along the Onkaparinga River. The second part is discontinuous from the main zone and protects the Willunga escarpment. It then continues along the Willunga ranges to Sellicks Beach where the Willunga Basin ends.

Lifestyles

This subregion is entirely within the City of Onkaparinga local government area, a diverse council area that includes the agricultural activities of the Willunga Basin, as well as significant urban areas such as Aberfoyle Park, Reynella and Noarlunga, which are considered under the Metropolitan Adelaide subregion. The City of Onkaparinga manages significant open space areas and plays a major role in stormwater management and reuse in this subregion.

The township of McLaren Vale, centre of the local viticulture and wine industry, has more than 65 cellar doors. It has become a base for a wider range of food and cultural industries in the recent past because of its attractiveness as a tourist destination. This is supported by the rural and coastal scenery, and proximity to Adelaide. This proximity to major roads into Adelaide has also made it an attractive area for commuters wanting a rural lifestyle.

Originally a slate mining town, Willunga now supports viticulture, cellar doors, art and food. It sits at the base of the Willunga Hill whose peak is 382 metres above sea level.

The coastal section of the Willunga Basin includes the suburbs of Port Noarlunga, Seaford Rise, Maslin Beach, Aldinga Beach and Sellicks Beach and borders the Metropolitan Adelaide subregion. The population of the coastal suburbs along the Willunga Basin increased by 30% between 2001 and 2011 (Australian Bureau of Statistics 2012d). This additional population pressure affects the coastal environment and other natural resources in the area – such as parks, water resources and land availability.

The predicted impact of climate change on the Willunga Basin is similar to the rest of the wider region, with on average higher temperatures, more extreme temperature days, lower rainfall and more intense rainfall events. Impacts on human health from high temperatures and changes in the range of disease vectors (such as mosquitoes) are likely. Increased risks from more frequent bushfire events may also impact on parts of the Willunga Basin. Adaptation of communities to these environmental changes is a key requirement to enable ongoing support for natural resources in the area.

Population

McLaren Vale	5,727
(18% increase since 2001)	
Willunga/Sellicks Hill	3,286
(11% increase from 2001)	

Landscapes

Historically, this subregion was dominated by Box woodland and grassland. Its major landscape feature is the Onkaparinga River and estuary. Other smaller creeks cross the subregion to the coast.

The landscape is now highly modified due, in part, to its close proximity to metropolitan Adelaide. The long history of irrigated horticulture on the plains has left very little remnant vegetation, and it is mostly confined to roadsides or in parks. These remnants protect threatened species in this subregion and help connect coastal habitats to the Mount Lofty Ranges. The isolation of these small scattered patches from each other makes them vulnerable to threats and shocks.

The grassy hills of the Willunga Basin have been extensively used for grazing. However, they still retain biodiversity value, as the native species have not been replaced by annual or perennial pasture species, as in other parts of our region. Farm forestry has become a feature of the grassy hills, and in some instances, is replacing grazing. Creek lines in the area are generally degraded but rehabilitation activities are increasing.

The coastal areas in the Willunga Basin are heavily modified by agriculture and increasing urbanisation. The landform along the coast changes from dunes to cliffs, starting around Hallett Cove and Port Stanvac and continuing until Snapper Point at Aldinga. From Snapper Point to the Washpool, the landform becomes a sand beach backed by dunes that go for approximately 2 km inland in areas that have not yet been significantly urbanised. This section includes Aldinga Scrub Conservation Park which contains a great variety of vegetation types and the Washpool, a coastal wetland with bird habitat.

The northeastern part of this subregion (Onkaparinga National Park area) has significant remnant vegetation; however, it is the area of the subregion most impacted by increased urbanisation and higher populations adjacent to the park. The challenge is to engage this community in valuing, protection and restoring the systems of the Onkaparinga National Park to improve the prospects of threatened communities and species.

The historic, and ongoing, changes in land use in this subregion (urbanisation and changes to farming systems) have reduced the potential for habitat restoration. The formal protection of the area for its agricultural character, through the Character Preservation (McLaren Vale) Act, may help protect remaining remnants from increasing urbanisation. The change in the Willunga Hills from grazing to farm forestry, with dense tree plantings, also reduces the potential to restore grassy ecosystems.

Climate change could impact more significantly on biodiversity in this subregion than (for example) the Mount Lofty Ranges. The lower topographical variation and small remaining areas of remnant vegetation offers fewer refuge and retreat opportunities. The slopes of the west facing Willunga Hills will become drier and urbanisation is restricting the ability of coastal vegetation to retreat and migrate.

Protected areas*

Aldinga Scrub Conservation Park
Knott Kill Native Forest Reserve
Mount Panorama Native Forest Reserve
Onkaparinga River National Park

*Protected under National Parks and Wildlife and Forestry Acts

Landscape priorities for restoration in the Willunga Basin

An assessment of the health of the landscape has been undertaken based on bird indicator species. Most of the remnant vegetation in the Willunga Basin has been lost. The subregion contains less than 10% original vegetation, which is considered relictual, and therefore has a low priority for landscape scale reconstruction (D Rogers, pers. comm.). The vegetation loss is a result of long-term, broadscale clearing and change of land use to agriculture. Thus the focus for the Willunga Basin is on protecting and buffering the remaining remnant vegetation, and ensuring the threatened vegetation communities, flora and fauna remain and contribute to the system as a whole.

While landscape scale restoration is limited, the Onkaparinga River National Park is identified as a priority area for restoration works of lower rainfall grassy ecosystems, as determined by assessing the state of a range of indicator bird species (Rogers 2011). As the national park also contains a mosaic of vegetation types (due to topography), ensuring the correct species and habitats are restored in the 'right' places is important.

Vegetation of Willunga Basin

Grassland and grassy woodland

Grassland are found on the west facing slopes of the Willunga Hills and in the Onkaparinga River National Park, where transitional woodland associations can also be found. This national park also contains River Red Gum (*Eucalyptus camaldulensis*) communities along the Onkaparinga River. Much of the riparian vegetation is degraded or cleared, although important areas of intact vegetation are located in the gorge between Clarendon and Old Noarlunga. Remnants of Box (*E. porosa* and *E. microcarpa*) grassy woodland can be found through the Willunga Basin.

Recognition and knowledge of grassland and grassy woodland is low, and little of the area is formally protected. Threats to these systems include:

- inappropriate revegetation
- intensification of land use such as farm forestry
- increased pasture improvement
- encroachment of weed species
- increased urbanisation
- drying associated with climate change.

Within the area identified as grassy woodland in the Willunga Basin subregion are pockets of habitat described as heathy woodland. These woodland are heavily influenced by the sandy soils on which they typically occur. The Aldinga Scrub Conservation Park is an example of a heathy woodland community and is dominated by sand heath with Pink gum (*E. fasciculosa*) and/or Sheoak (*Allocasuarina verticillata*) overstorey.

Vegetation of the coast

Coastal vegetation associations are often small in size relative to the scale of inland vegetation; however, they are critical as refuges for site specific flora and fauna. The degree to which the coastal vegetation of the subregion has been impacted by human activity is site dependent.

The vegetation of the coast is under threat from:

- increased recreational use
- urban expansion
- agricultural and industrial land use
- increased weed and pest impacts
- climate change.

Descriptions of coastal vegetation (Croft et al. 2006) and its condition at specific sites comes from baseline vegetation condition monitored in coastal worksites (Mahoney 2011). It is not representative of the vegetation communities as a whole as the sites are actively managed in some way. Each site has been monitored once over the last three years to provide the condition information, and will be revisited over the next three years in the same chronological order to determine trends in condition. The information presented here is an amalgamation of the data for all the sites of that particular vegetation community (Adelaide and Mount Lofty Ranges NRM Board 2012).

Coastal vegetation in the subregion includes the broad vegetation types of samphire, coastal cliffs and dunes, and coastal fringing communities. A number of specific vegetation communities in these broad vegetation types are discussed below.

Coastal shrubland and tall shrubland

This vegetation community features shrubs 1–3 metres high and often densely spaced. It generally occurs on secondary dunes (often second and third dunes back from the coast) and has a relatively high area of bare ground, usually up to 20%. Dominant overstorey species include Coast Daisy-bush (*Olearia axillaris*), Coastal Wattle (*Acacia sophorae*), Coast Beard-heath (*Leucopogon parviflorus*), Coast Sword-sedge (*Lepidosperma gladiatum*) and Sea-berry Saltbush (*Rhagodia candolleana*). Examples of this vegetation community are found at Aldinga Beach, Minda Dunes and Grange Dunes. Vegetation condition monitoring at these three sites shows variable results. Some vegetation is in quite good condition across all three sites, and some in moderate and poor condition. This is probably a reflection of the level of recreational use and modification at each site.

Aldinga Scrub

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

These communities are dominated by non-eucalypt trees and a diverse number of life forms unless Dryland Teatree is the sole dominant forming low open forest or low closed forest. This community has relatively little bare ground (<10%) and generally occurs on the relatively stable hind dunes. Dominant overstorey species include Drooping Sheoak (*Allocasuarina verticillata*), Southern Cypress Pine (*Callitris gracilis*), Coastal Wattle and Dryland Teatree (*Melaleuca lanceolata*). Examples of this vegetation community can be found at Hallett Cove and Aldinga Scrub. Weeds are an issue at both sites and will require ongoing control and monitoring.

Coastal samphire +/- Saltbush, Bluebush shrubland

With low to moderate species diversity and life form diversity, this vegetation community occurs at higher elevations than coastal samphire shrubland, in moderate salinity, and is irregularly and infrequently inundated. It contains salt tolerant plants only and samphires and other chenopods dominate; overstorey species include samphire species, Heathy Bluebush (*Maireana oppositifolia)* and Marsh Saltbush (*Atriplex paludosa*). Examples of this vegetation community are found at the Onkaparinga Estuary, where it is generally in good condition at the site monitored. The very poor recruitment of species at the site may have implications for the future condition of this vegetation. Weed pressures are also high at this site, but feral animal and grazing impacts are low.

Threatened species and communities in the Willunga Basin

Action to address threatened species and communities is required at a number of scales. Within the Willunga Basin, landscape scale restoration is not a priority, but specific action is still required for certain species and communities to prevent further decline and potential extinction. When prioritising action

there is a need to recognise that the geographic scope of species status does not directly equate to priority for action. The recovery of some nationally threatened species, which are of very high national significance, will not be strongly influenced by action in the region, so it may be more appropriate for the management requirements of State or Regional listed species (for which meaningful action can be undertaken) to be a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

Examples of specific threatened vegetation communities in the Willunga Basin include:

- Grey Box (*Eucalyptus microcarpa*) grassy woodland (listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999*)
- Box woodland (*E. microcarpa* (Grey) and *E. porosa* (Mallee)) are Threatened in the Adelaide and Mount Lofty Ranges region
- Silky teatree (*Leptospermum lanigerum*)/Phragmites swamps (Endangered state listed community)
- grassland communities (Endangered state listed communities).

Grey Box grassy woodland

Existing remnant vegetation mainly in the Onkaparinga Gorge National Park has significant potential for restoration.

Vegetation supports ground feeding birds.

Increased kangaroo numbers are impacting on the regeneration of understorey grasses.

Vegetation condition is under increasing pressure from pest and weed invasion, and recreational use of parks.

Examples of threatened fauna in the Willunga Basin include the Peaceful Dove (found in both Aldinga Scrub Conservation Park and Onkaparinga River National Park) and the Cunningham Skink which uses rocky crevices along Onkaparinga Gorge.

Two of the threatened flora species in the Willunga Basin occur nowhere else in the world. The Aldinga Dampiera (*Dampiera lanceolata* var. *intermedia*) shrub and the Aldinga Beard-orchid (*Calochilus cupreus*) both occur in the Aldinga Scrub Conservation Park. The protection and buffering of the park to improve the viability of the plant and animal populations is a priority.

Why protect the Cunningham Skink?

The habitat requirements of the Cunningham Skink are an example of the importance of vegetation connectedness in the landscape. The skinks appear to live in relative isolation from each other because they inhabit steep rock faces and boulder slopes (which are naturally fragmented and discontinuous). However, dispersal between their rocky 'island' homes suits their mating preference of favouring unrelated partners. Clearance of native vegetation between the rocky islands is making dispersal for mating increasingly difficult. The breeding rate is likely to decrease and, over time, extinction of the isolated populations is more likely. Improving connectivity between the populations through restoration of appropriate vegetation, particularly along drainage lines, will help dispersal for many populations.

Water resources of Willunga Basin

Onkaparinga River

The Onkaparinga River catchment covers an area of approximately 564 km^2. The river rises near Mount Torrens in the Mount Lofty Ranges, at around 530 metres elevation and flows southwesterly to Gulf St Vincent at Port Noarlunga. The section of the river in the Willunga Basin extends from Mount Bold reservoir, where it winds its way through the ranges into Clarendon weir. Much of the flow is diverted to Happy Valley reservoir at that point. The river continues through Onkaparinga Gorge to Old Noarlunga – where it briefly enters the plains – before flowing through the estuary and out into Gulf St Vincent. Flows in the lower Onkaparinga River changed significantly with the construction of Mount Bold reservoir and Clarendon weir. Approximately 75% of flow has been extracted before the river enters the estuary.

Before European settlement, the river was ephemeral (did not flow all year round) and stopped flowing during summer, drying to a series of permanent deeper pools. Today, water is pumped from the River Murray into the Onkaparinga River between Hahndorf and Clarendon Weir, ensuring a continual flow all year round. Flow regimes were further altered (especially high flows) with the construction of Mount Bold reservoir. Further information about the upstream section of the Onkaparinga River can be found in the Central Hills subregion.

The estuary at the mouth of the Onkaparinga River, the state's third largest, is classed as a river-dominated estuary and is an Estuary of National Significance due to the presence of migratory birds of international significance. It is located adjacent to Port Noarlunga and extends 10 km inland to near Old Noarlunga township and includes a sand spit known as Southport Dune, Onkaparinga River mouth and adjacent cliffs, the tidal section of the river (to Old Noarlunga), Onkaparinga River floodplain including areas of samphire and Port Noarlunga Reefs Aquatic Reserve, protected in 1971. It is an important feeding, breeding and nursery for many species of fish, crustaceans and birds. Hooded Plovers have been reported on Port Noarlunga beach and Southport Dune is considered a system of high biodiversity value. The complex ownership of land surrounding the estuary increases the difficulty of adequately protecting it and managing the floodplain (Hydro Tasmania Consulting and Eco Management Services 2006).

Onkaparinga River (downstream from Mount Bold reservoir)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0279-ecosystem-2011)

Onkaparinga River (west from Blewitt Springs)

Condition: Good

Source: www.epa.sa.gov.au/reports_water/c0273-ecosystem-2011

Onkaparinga River estuary

Condition: Fair

Source: Coleman 2013; T. Flaherty (DEWNR) pers. com.

The reduced river flow in the Onkaparinga is having a significant effect on the condition of the estuary. There is some evidence that returning environmental flows to the river and therefore the estuary is improving estuarine condition. Much of the estuary's vegetation has been modified by stock grazing and clearance for agriculture but significant remnants remain. Increases in recreational use of the estuary, including diving on the reef and walking dogs, pose a threat to this system, as does significant weed invasion.

Willunga Basin rivers

Willunga Basin is dissected by a number of small rivers and subcatchments including Pedler Creek, Ingleburn (Maslin) Creek, Willunga, Silver Sands and Sellicks subcatchments. Only Pedler Creek catchment has gauged surface water flow data but flow loss through watercourse channels is considered to be significant. Changes in flow (due to farm dam storage and use) have reduced the availability of water to maintain healthy aquatic ecosystems in the Blewitt Springs area of Pedler Creek subcatchment, as well as at the outlet of Willunga Creek. Little is known about water flows through the rest of the catchment.

Pedler Creek (near Moana)

Condition: Poor

Source: www.epa.sa.gov.au/reports_water/c0047-ecosystem-2008

Groundwater

The groundwater resources of the Willunga Basin lie within the sedimentary aquifers of the Willunga Basin and the underlying and adjacent fractured rock aquifers (Figure 41). The McLaren Vale PWA abuts the Central Adelaide PWA to the north and now falls within the Western Mount Lofty Ranges Prescribed Water Resources Area (PWRA). The McLaren Vale PWA, established in 1999, encompasses the Willunga Basin and the recharge area of the Adelaidean System fractured rock aquifers along the adjacent hills. The current McLaren Vale WAP was adopted in 2007.

Groundwater in the McLaren Vale PWA is predominantly used for irrigation of grapevines. It is extracted from the Port Willunga Formation aquifer followed by the Maslin Sands and fractured rock aquifers. The Quaternary aquifers and Blanche Point Formation provide a very small portion of irrigation supply (Department of Environment, Water and Natural Resources 2012e).The source aquifer is dependent on location with aquifers being variably confined, unconfined and outcropping across the area. Managed aquifer recharge is undertaken in various locations of the PWA, mainly in Port Willunga Formation and fractured rock aquifers.

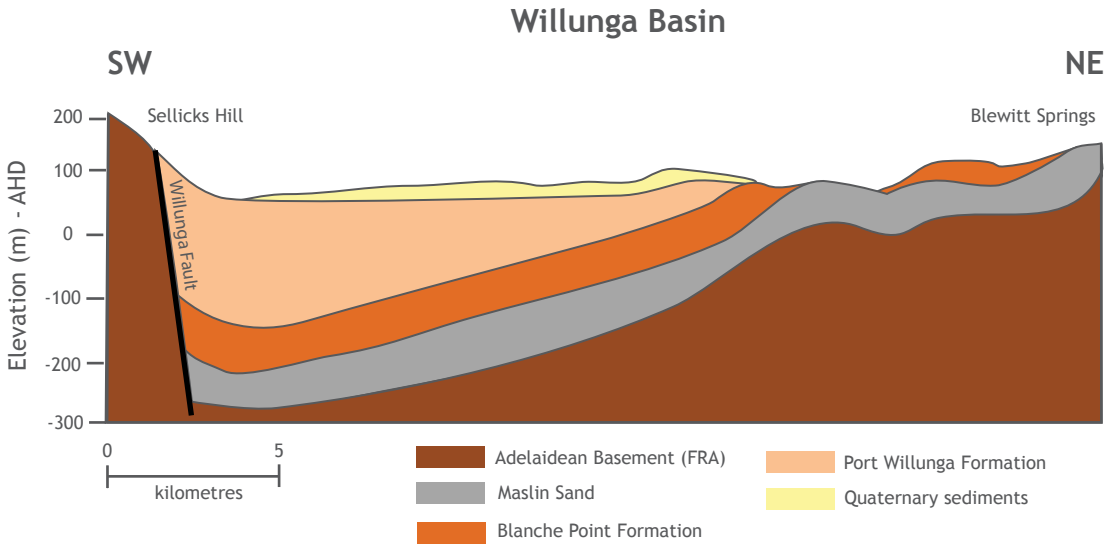


Figure 41: Groundwater cross section of the Willunga Basin

The Quaternary aquifer comprises sands and interbedded clays that form shallow unconfined aquifers, which are generally low yielding and provide mostly stock and domestic supplies, with limited extraction for irrigation. It sits in areas where there is thick Quaternary cover, mainly south of Pedler Creek, and as small perched aquifers along the edges of the basin. Recharge is predominantly derived from local rainfall and runoff from streams.

The Port Willunga Formation aquifer consists of sands and limestones and is generally high yielding. It is unconfined in its northern extent near McLaren Vale and McLaren Flat, but is confined by Quaternary sediments in the south and southwestern parts of the PWA. Recharge from rainfall primarily occurs where it is unconfined.

The Blanche Point Formation underlies the Port Willunga Formation and consists of low-permeability marine mudstone and limestone. It is an aquifer in some locations within the Basin where it can yield useful groundwater quantities and elsewhere it forms an aquitard separating the Port Willunga Formation and Maslin Sands aquifers.

The Maslin Sands aquifer directly overlies basement rocks and comprises fine to coarse sands and clays. It outcrops in the northeast of the PWA (where it is recharged by rainfall), and is confined over the rest of the Basin and separated from the overlying Port Willunga Formation Aquifer by the Blanche Point Formation aquitard.

Fractured rock aquifers in the Adelaidean System basement rocks underlie the sedimentary aquifers in the Willunga Basin and form the ranges to the east of the Willunga Fault and also along the Onkaparinga Gorge. Infiltration of rainfall recharges the fractured rock where it outcrops.

The quality and quantity of groundwater in the McLaren Vale PWA has varied over time, reflecting rainfall response in each of the aquifers and historical use in terms of both the spatial distribution of extractions and the annual volumes extracted.

Within the Maslin Sands, groundwater level trends differ between the unconfined and confined parts of the aquifer. In the unconfined aquifer area to the northeast, observed groundwater levels show a close relationship with rainfall patterns influenced by the topography of the Mount Lofty Ranges (Department of Environment, Water and Natural Resources 2012e).

The fractured rock aquifer system tends to have groundwater level trends that follow rainfall patterns, particularly in areas of outcrop. Seasonal highs and lows are observed but in general the low level of use does not have a significant impact on water levels (Department of Environment, Water and Natural Resources 2012e).

Salinity trends vary in all McLaren Vale PWA aquifers. The area is currently the subject of a considerable groundwater research program to determine the relationship between rainfall trends and aquifer recharge and aquifer interconnectivity. In various locations, average salinity rises of around 150 mg/L/year have been observed in all aquifers. Some sampling locations indicate stabilising or decreasing salinity trends; some continue to show a rising trend. The groundwater salinity rise may become critical in some areas where salinities are currently close to the limit of tolerance for grapevines at around 1500 mg/L (Department of Environment, Water and Natural Resources 2012e).

Groundwater level and salinity trends

Port Willunga Formation

Seasonal variation as the aquifer provides around 70% of groundwater demand. Declines of 5 metres have been observed historically but with reduced extraction there are indications of water level stabilisation.

Maslin Sands Formation

Stable since 2000 (due to low extraction levels particularly in the confined area in the south of the McLaren Vale PWA)

Salinity trends are variable

Source: Department of Environment, Water and Natural Resources 2012c

The groundwater resources of the Willunga area are at the most risk from reductions in the hills recharge zones, reductions in rainfall and changes to extraction regimes, which are in turn dependent on a combination of factors. Extension of the irrigation season, although not necessarily increasing the volume of extraction, can impact on the ability of the aquifer for seasonal recovery and lead to an overall decrease in water level. More saline water is then drawn in from adjacent areas as vertical leakage is induced by the difference in aquifer heads.

The flattening out of seasonal rainfall patterns, predicted under climate change, may impact water levels and salinity in the long term. This is because the aquifers are recharged through groundwater flow from the outcropping aquifers that receive direct rainfall recharge.

Land use change may also create impervious surfaces, and more concentrated areas of extraction with urban development and agricultural production intensification in smaller areas.

Groundwater dependent ecosystems

Several groundwater dependent ecosystem (GDE) types that are surface expressions of groundwater are found in the Willunga Basin:

- **Fractured rock spring discharge and baseflow** occurs throughout the area where the saturated fractures outcrop – such as at the Sellicks Hill Range and the southern bank of the Onkaparinga Gorge. Pedler Creek also flows through an outcrop of fractured rock. This discharge supports persistent pools, wetlands and riparian vegetation. It has also been found to make a significant contribution to streamflow in many of the area's watercourses, particularly in the upper reaches (Adelaide and Mount Lofty Ranges NRM Board 2007a; Cooling and Currie 2012).
- **Break of slope GDEs** are found at the base of hill slopes where high relief fractured rock basement grades to sedimentary foothills. The plains and the watertable can frequently intersect the surface topography, creating groundwater discharge sites. Examples of break of slope GDEs in the subregion are the base of Chapel Hill and Blewitt Springs in McLaren Vale (Cooling and Currie 2012).
- **The coastal perched aquifer** within the Semaphore Sand is underlain by the Hindmarsh Clay aquitard at the Aldinga Scrub. Here, the range of plant associations partly reflects the depth and salinities of groundwater in the perched aquifer. A number of permanent and temporary groundwater fed waterholes provide watering points for terrestrial fauna (Adelaide and Mount Lofty Ranges NRM Board 2007a).
- **Coastal wetlands** are represented by the Aldinga Washpool and the wetlands adjacent the Onkaparinga Estuary as groundwater in the Quaternary aquifer flows towards this region and discharge creates saline mudflats (Adelaide and Mount Lofty Ranges NRM Board 2007a).
- **Estuarine GDEs** are represented by the Onkaparinga estuary and the mouths of Pedler Creek and Maslin Creek. Groundwater contributes freshwater discharge to these brackish environments and maintains permanent lagoons (Adelaide and Mount Lofty Ranges NRM Board 2007a; Cooling and Currie 2012).

A second class of GDEs rely on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include riparian forests that require a supply of groundwater within the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases and new species invade the system; the new structure and function of the ecosystem may not necessarily provide the services

required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

The hotter drier climate and changing rainfall patterns, expected in a changed climate, could reduce the frequency and timing of surface water inflows and recharge of the shallow aquifers (Barron et al. 2011). This will impact on the GDEs as water becomes less available or available at different time of the year.

Urban development can also have an impact where fractured rock springs discharge as there is a reduction in natural surfaces able to receive direct rainfall recharge.

Livelihoods

This subregion's livelihoods are mainly based on the high value winegrape industry, which is supported by a combination of suitable soils, access to water, a favourable climate and access to labour, transport and support industries.

Average annual rainfall

McLaren Vale	500 mm
Sellicks	500 mm
Willunga	646 mm

Primary production is heavily dependent on the natural resources of the subregion; in particular, healthy soils, healthy water and minimal agricultural pests. Healthy soils, while linked to intrinsic soil properties, are also heavily influenced by management of soils and production. The risk of soil erosion in Willunga was assessed in a soil cover survey three times from December 2011 to June 2012 (the assessment included sites in the Willunga Basin and Fleurieu Peninsula, so the results below are a combination from both areas). Land use surveyed in the Fleurieu Peninsula subregion was used mainly for livestock grazing (Young 2012), although in this subregion, land use is more likely to be viticulture or horticulture. The results from those surveys indicated a decrease in the number of sites at low risk of erosion from December (94%) to June (86%). Further monitoring of soil cover and erosion risk will provide firmer trends in land management practices to prevent erosion.

Groundwater is a critical natural resource for the viticulture industry. Overall groundwater extraction in all aquifers has decreased since the 2008-09 water use year with approximately 2,500 ML of metered use in 2010-11, which is well below that allocation limit of 6,600 ML/yr. Decreased use may be related to reductions in demand due to above average rainfall in some areas and the additional water supplies available from the Willunga Basin Water Company.

Recent population growth, and urban development, has increased the complexity of managing primary production activities in this subregion. It has also contributed to a move towards identifying and protecting areas of the landscape that are of importance for primary production now and into the future. Figure 42 identifies priority primary production areas in the Willunga Basin and the key considerations that contributed to the inclusion as a priority area for primary production. The determination of these areas was based on a project by Primary Industries and Regions SA (PIRSA 2011a,h).

Blewitt Springs

Key considerations

- favourable soil and water conditions for viticulture
- presence of a major concentration of high value land use
- substantial investment in related industry infrastructure

Notes

Some areas of tourism related activities and small pockets of rural living

Clarendon Hills

Key considerations

- favourable soil and climate conditions for grazing
- favourable soil and climate conditions for viticulture/horticulture
- existing intensive land use and investment

Notes

Small and largely undeveloped unit with generally favourable land and water conditions; linked to McLaren Vale wine region; potential to support new, more intensive industries, including horticulture

Willunga Basin

Key considerations

- favourable soil and water conditions
- presence of a major concentration of high value land use
- substantial investment in related industry infrastructure
- suitable for a range of primary industry activities

Notes

Significant winery infrastructure and tourism-related development to support primary production; area is one of SA's key primary production assets

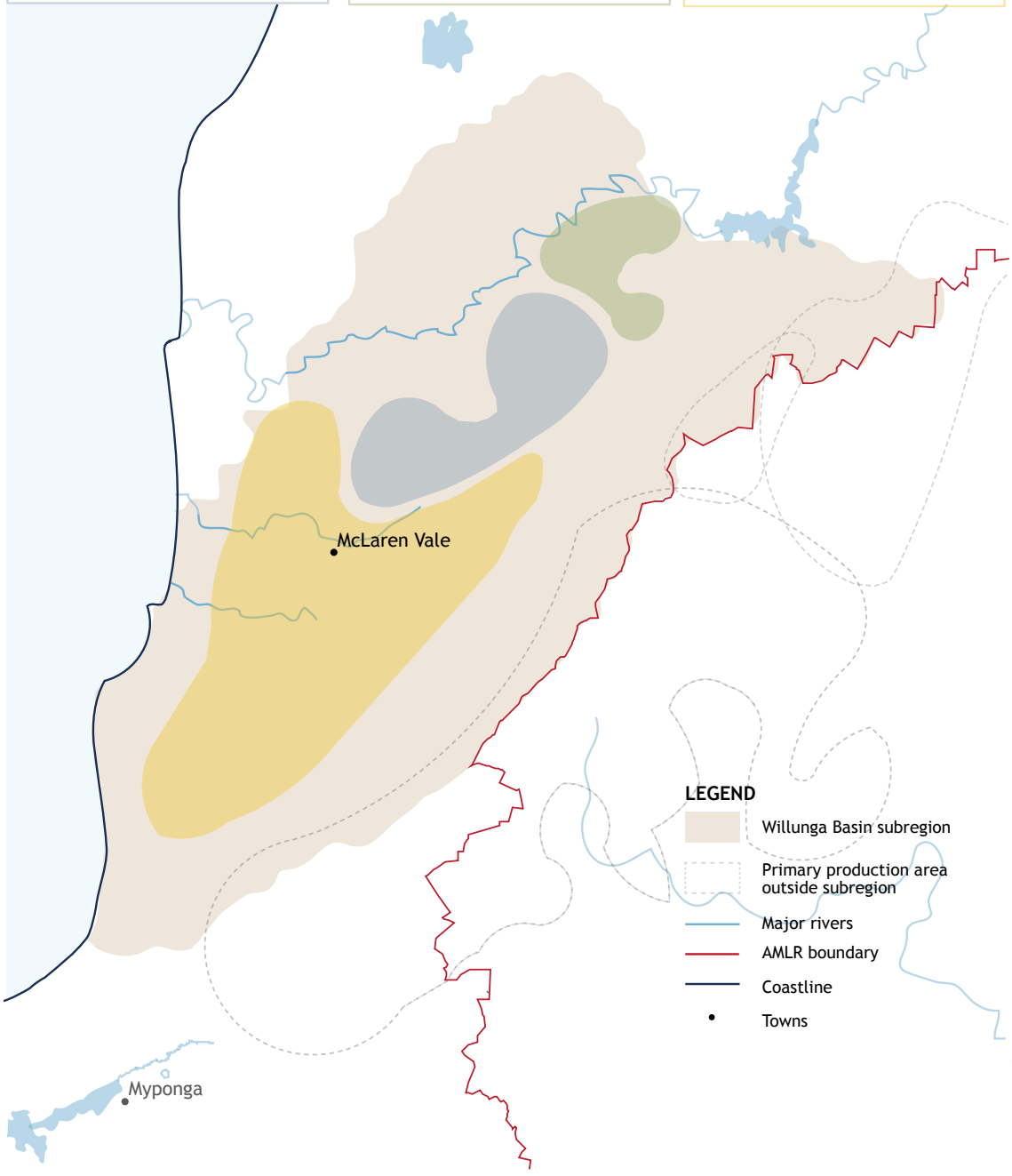


Figure 42: Priority primary production areas in the Willunga Basin (PIRSA 2011a,h)

A small area of the southeast facing backslopes of the Sellicks Hill Range and low lying land in the Kuitpo Valley has been identified as a priority primary production area in the Willunga Basin. This landscape connects to a more significantly sized area in the SA Murray-Darling Basin NRM region that consists of the mid-Finniss catchment and the headwaters of the Myponga River. Policy management relevant to this area needs to account for cross-boundary issues and consider decision making in the context that, even though a small area, it has the potential to contribute significantly to primary production when connected with the rest of the landscape.

Viticulture

Viticulture is a significant contributor to the economy of Willunga Basin. It is supported by value adding through wine production and niche market food manufacturing. Vineyards in the area are planted mainly on sand over clay, deep loamy texture contrast soils with brown or dark subsoils, hard red-brown texture contrast soils with alkaline subsoils and calcareous soils as you move closer to the coast. Areas around Willunga are also well known for their black cracking clays. These soils have particular attributes that expand when wet and shrink when dry. This occurs to such an extent that large cracks can form and posts have been known to move due to soil shrinking.

The viticulture industry is supported by good quality groundwater and the availability of recycled water from the Willunga Basin Water Company. Groundwater and surface water resources are prescribed through the McLaren Vale PWA and the Western Mount Lofty Ranges PWRA (surface water). The extraction, use and trading of water, is therefore managed through a WAP.

Increased population and urbanisation has impacted on the operations of vineyards and on the cost of land in the region, particularly on the edges of townships and with the downturn in the wine industry. The Character Preservation (McLaren Vale) Act has been enacted to protect rural zoned land in the Willunga basin from urban expansion by limiting any further urban development to current boundaries.

The harvest from McLaren Vale in 2012 was 31,755 tonnes, down by 30% from 2011 and the total value of the grapes decreased to $39.7 million in 2012 down from $47.5 million in 2011 (Phylloxera and Grape Industry Board of SA 2012e). The total planted area of vines in the region fell from 7,371 hectares to 7,327 hectares. Since 2000, total tonnes harvested had increased by 21%, the total area of vines planted had increased by 36%, and the value of grapes harvested had decreased by 17% from $57.4 million. This reduction in value places significant pressure on the industry and can have flow-on effects for natural resources management - when finances are limited, demand for land for rural living makes it attractive to convert land use.

The impact of climate change on viticulture will be observed mainly through the impacts of increased temperature and variations in temperature which will influence timing of growth including ripening processes. This is likely to result in earlier ripening during warmer temperatures with potential impacts on fruit quality and compression of harvest dates between varieties. The impact of climate change on water availability (particularly timing and amount of rainfall) will also influence irrigation. With more water being required, and potentially not available, access to alternative water resources, such as recycled water, becomes even more important. Potential adaptation opportunities include change in varieties (or new varieties) better suited to the warmer climate. New technology and potentially genetically modified vines, will also provide adaptation opportunities (Anderson et al. 2008).

The community values the McLaren Vale wine region as it is a diverse and proactive community with connection between primary production, tourism, lifestyle opportunities and employment contributing to the success of the region.

The subregion has seen diversification of industry activity including micro-breweries, olive production and expanded food and tourism opportunities.

The subregion has managed and continues to manage many changes in the environment it operates in.

Agriculture

The rural area of the Willunga ranges and escarpment (and those rural areas not under viticulture production) are used mainly for grazing purposes, with a total gross value of $7.5 million (Australian Bureau of Statistics 2012c). Approximately 250 hectares are used for broadacre cropping in the area. Grazing can be a threat to native vegetation, particularly along the coast where privately owned farmland bounds a small area of coastal reserve.

Both grazing and cropping are under threat from increases in population and subsequent urbanisation of the landscape.

While the potential impacts of climate change on the cropping and grazing sector are many and varied, a number of adaptation options are available. As cropping and grazing form such a small component of the agricultural activity in the region, it is possible that climate change will see these activities disappear completely in this subregion. They may also diversify or be substituted with other production types, for example if water availability was not a concern, annual and/or perennial horticulture. Land management, particularly soil cover to prevent erosion would also become an issue in a drier, warmer climate.

The cropping sector will adapt through new varieties bred for specific conditions and innovations in technology. Adaptation in the grazing industry is likely to include more intensive management of stocking rates to match pasture growth changes. Grazing management is also likely to require better prediction tools and models (regarding rainfall in particular) to enable suitable stock management to ensure soil cover and natural resources are not degraded. Changes to species used for pastures (including using native grasses), the timing of mating and new breeds and cross-breeds will also need to be considered (Rebbeck et al. 2007).

Fleurieu Peninsula

In summary

At the southernmost end of the Adelaide and Mount Lofty Ranges NRM region, the Fleurieu Peninsula contains the iconic Fleurieu Swamps and a diverse natural landscape of plateaus, valleys and ranges, hosting natural vegetation communities largely cleared for grazing (Figure 43).

Victor Harbor, the largest urban centre on Fleurieu Peninsula, has one of the fastest population growth rates in South Australia and highest median age of any local government area, principally driven by 'sea change' retirees. However, the overall population of the subregion is low, leaving a small pool from which to source volunteers for a large area with much natural resources management work to be done. Closed shrubland and lower rainfall grassy woodland are in decline, and several plant communities, and flora and fauna species, are threatened.

Local watercourses, such as the Hindmarsh, Inman and Myponga rivers, are used for irrigation and stock watering; the area is prescribed as part of the Western Mount Lofty Ranges Prescribed Water Resources Area (PWRA).

Fleurieu Peninsula - Priorities for the future

A set of priorities for the future for the Fleurieu Peninsula subregion has been developed based on the information contained in this section. The priorities have been identified for the whole subregion and specifically for the coasts.

Subregion wide

- Protect and improve the integrity of the shrubby forest, woodland and heathland dominated landscapes found along the spine of the range (including Deep Creek, Parawa Plateau, Newland Head, and Spring Mount to Myponga highlands), and increase the area around the parks (Newland Head and Deep Creek) managed primarily for the conservation of natural vegetation communities
- Restore and reinstate grassy ecosystems where this will help stem biodiversity declines (along both the western and eastern flanks of the range; this requires improved technical knowledge, community recognition and sustainable use
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines (including Fleurieu Swamps, Myponga River landscape, and Fleurieu estuaries)
- Manage the allocation and use of water resources to provide water for the environment and for sustainable use by industry (quantity)
- Improve land management practices to reduce impacts on water quality, aquatic and marine health, with a particular focus on priority watercourses, including Myponga, Waitpinga, Hindmarsh, and Bungala and Inman rivers and their estuaries
- Facilitate integrated climate change adaptation of people and the landscape
- Encourage increased demand and supply of alternative water sources for fit-for-purpose uses (stormwater and recycled water)
- Protect water resources for aquatic health and agricultural use (quality)

- Protect intact landscapes (particularly schlerophyll stringybark forest) from ongoing threats such as fragmentation and pest invasion
- Promote sustainable land management practices focusing on maintaining soil cover and management of acid soils
- Support agriculture to adapt to climate change or transition to alternative business models
- Increase understanding around land use interface issues between agriculture (existing and new industries), rural living and urban needs
- Protect priority primary production areas from inappropriate development to maintain industry and business viability
- Monitor for and control pests that have not yet become established in the region or in the Fleurieu Peninsula subregion

Coastal specific

- Use development controls to protect scenic cliffs and coastal landscapes from population increases and development pressures
- Increase education and awareness programs for land managers and users of the coastal environment on the value of the coastal landscape
- Include water sensitive urban design outcomes in all urban development to minimise impacts on the coastal environment
- Protect and rehabilitate priority areas of the southern coast including: beaches and lower slopes of Fishery Beach, Lands End, Cape Jervis and Morgans Beach; cliffs and cliff tops from Newland Head to the Bluff; priority small estuaries; and Normanville Dunes and Tokuremoar Reserve.

Figure 43: Fleurieu Peninsula subregion

Introduction

The Fleurieu Peninsula is the southernmost part of the Adelaide and Mount Lofty Ranges region and is bounded by the Willunga Basin and Central Hills subregion, with the South Australian Murray-Darling Basin NRM region forming the eastern boundary and the Marine subregion the western boundary. The Fleurieu Peninsula contains the iconic Fleurieu Swamps and a diverse natural landscape of plateaus, valleys and ranges. From the spine of the South Mount Lofty Ranges through the Fleurieu Peninsula, a series of flat-topped ridges extends to the south coast. A number of creeks run through estuaries to Gulf St Vincent to the west and to Encounter Bay and open water to the south. The Myponga, Carrickalinga Head, Bungala and Yankalilla rivers flow west and the Inman and Hindmarsh rivers and Middleton Creek flow south. The subregion intersects the traditional lands of the Kaurna and Ngarrindjeri people.

The coastal part of this subregion is a unique ecosystem that extends from Sellicks Beach and around the Fleurieu Peninsula, to our region's southern boundary. The topography is a mix of steep cliffs (Sellicks Cliffs, Myponga, Second Valley, Newland Head, Rapid Head and north of Rapid Bay, Cape Jervis, Deep Creek), dunes and beaches (Normanville and Waitpinga), beaches and dunes backed by slopes and degraded cliffs (Carrickalinga, Lady Bay and Tunkalilla Beach), and coastal slopes (Fishery Beach).

The 30-year plan for greater Adelaide identifies a significant area around Victor Harbor and Port Elliot for future urban growth, which will place increased pressure on the local coastal environments.

Lifestyles

The subregion is supported by the regional centre of Victor Harbor and a number of smaller townships.

Victor Harbor is the largest urban centre on Fleurieu Peninsula. The town has one of the fastest population growth rates in South Australia, principally driven by 'sea change' retirees. It has the highest median age of any local government area and a large absent/part-time population, with 40% of ratepayers residing outside the area (City of Victor Harbor 2010).

South of Hindmarsh estuary, to the eastern border of our region, are sand beaches backed by dunes and a low coastal plain almost entirely under residential development; with the exception of some areas of farming at Bashams Beach. The rapid urbanisation of the Middleton to Victor Harbor area has had significant impacts on the health and extent of coastal dune systems and increased beach use is also eroding dunes, disturbing local birds and fauna, and encouraging pest animals such as rabbits. This urbanisation also poses problems for the rural industry that surrounds it, as it can impact on land prices and the ability to conduct farming operations.

Importance of the coast to the community

The community values the Middleton to Victor Harbor coastline, describing it as the interface between residential development, coastal dune systems, and the beach and ocean.

This traditionally farming area has erosion issues resulting from historical land clearing. Dramatically increased urban development is placing pressure on the remaining natural areas along the coast. Erosion, vegetation clearance, and pests and weeds are impacting on natural habitats. Sea level rise is also predicted to impact on the natural habitat as urbanisation around the coast has left no room for coastal habitat retreat.

The townships of Myponga, Yankalilla and Normanville support surrounding agricultural industries, mainly dairy, beef and prime lamb. Rural lifestyle blocks, which are becoming more common in the areas surrounding townships, are driven by the proximity to Adelaide and the ease of commuting to its southern suburbs.

The Fleurieu Peninsula contains the local government areas of the City of Onkaparinga, City of Victor Harbor, District Council of Yankalilla and a small area of Alexandrina Council. These local governments manage and maintain significant areas of remnant vegetation and open space in the subregion, such as Normanville Dunes and Tokuremoar Reserve.

Along the coast, privately owned land (particularly from Carrickalinga to Rapid Bay and from Deep Creek to Parsons Beach) is mostly cleared of native vegetation. The cliff tops at Carrickalinga Head and Myponga, the area around Cape Jervis from Rapid Head to Fishery Beach, and The Bluff, a significant recreational site used for whale watching, are all under public ownership. The Bluff contains a number of endemic plant species and is a significant bird habitat, under pressure from increasing recreational use.

This 'sea change' movement is becoming significant for many parts of this subregion, and infrastructure is being built to support the burgeoning populations, with impacts on habitats and existing land use. Planning and urban design are critical in this environment to protect remnant vegetation and allow for its extent to increase, and ensure stormwater is managed to reduce the impacts of increased runoff and pollution to the marine environment. This change is also likely to have long term and lasting impacts on the biodiversity of the region as increased urbanisation leads to a change in the diversity of plants which is likely to favour increases in already abundant species within the area, which in turn may disadvantage many threatened or declining species.

The comparatively lower population in many areas of this subregion increases the complexity of community engagement for protecting natural resources; it is a large area with a small number of people as a source of volunteers. Individuals, particularly individual landowners, are an increased focus for protection and restoration efforts. The increase in population around Victor Harbor could yield more community resources.

The impact of climate change on communities in the Fleurieu Peninsula will be similar to that felt over the rest of the region with increased temperatures, more extreme heat days, less rainfall but potentially more extreme rainfall events likely. The sand dune systems of the coastal areas of the Fleurieu are particularly vulnerable to erosion from sea level rise and higher intensity storm surges (Caton et al. 2007). In Victor Harbor, a number of houses are close enough to the shoreline to be affected by sand dune erosion in the absence of measures to protect the coast. Increases in storm magnitude may also contribute to coastal and cliff erosion, impacting on remnant vegetation along these areas. Changes in land use (and competition for land use) may also stop coastal habitats from migrating inland as sea level and temperature rises. Increases in urbanisation, and increases in extreme rainfall events, will also have the potential to impact on the coastal and marine environment through high stormwater flows down rivers and into the marine environment. An increase in the frequency of storm surge inundation is also likely to prompt urban and farming communities to seek flood protection.

Population (2011)

Victor Harbor* (18% increase since 2001 Census)	13,841
Yankalilla	1,018
Normanville	1,356

*Council area

Landscapes

The Fleurieu Peninsula is a mosaic of plateaus with nutrient poor soils and valleys of glacial origin with deeper more fertile soils. This mosaic coupled with high rainfall supported a rich diversity of habitats including open grassy country and woodland. Vegetation clearance began soon after European settlement, firstly in the open grass country favoured by graziers and then later in fertile wooded valleys and more recently the poorer slopes and plateaus. Relatively large properties are still a common feature of the Fleurieu Peninsula, unlike the Central Hills where property sizes have reduced in a landscape changing from a production focus to rural living.

Protected areas*

Deep Creek Conservation Park
Newland Head Conservation Park
Eric Bonython Conservation Park
Gum Tree Gully Conservation Park
Mount Billy Conservation Park
Myponga Conservation Park
Nixon-Skinner Conservation Park
Spring Mount Conservation Park
Stipiturus Conservation Park
Talisker Conservation Park
Waitpinga Conservation Park
Yulte Conservation Park
Congeratinga Native Forest Reserve
Kalumunda Native Forest Reserve
Springs Road Native Forest Reserve

*Protected under National Parks and Wildlife and Forestry Acts

Clearance has reduced native vegetation cover to a series of remnants in which vegetation types of the plateaus and poorer soils predominate. Little is left of the big gum woodland of the valleys and their associated riparian systems and of the open grassy Pink Gum (*Eucalyptus fasciculosa*) and sheoak woodland. The threats to the isolated remnants - patch isolation, system simplification and weed invasion, among others – have resulted in species decline and extinction.

The coastal environment is a unique mix of coast specific vegetation grading to grassland, forest and woodland away from the coast. Specific coastal vegetation includes samphire, coastal cliffs and dunes, and coastal fringing communities. Though less populated than the metropolitan areas of the coast, the coastal environment is used recreationally to a significant degree. Some parts of the coastline along the very south of the peninsula remain more intact because of their inaccessibility.

Active subdivision of land from larger to smaller management units as well as movement to more intense farming systems, are increasing the pressure on remnant vegetation. Increased weed threats, poor land management practices and increased water extraction are examples of negative impacts on remnant vegetation as a result of changes in land use and are likely to be further exacerbated by the predicted impacts of climate change in the Fleurieu Peninsula. Species distribution will be impacted further as climate change reduces the extent of suitable habitats and conflicts in land use will continue to increase. The Fleurieu Swamps are particularly vulnerable to the impacts of climate change as they cannot migrate. It is likely that some of these ecosystems will disappear.

Hindmarsh Tiers

Hindmarsh Tiers includes several large areas of native vegetation in both public and private ownership, including Mount Billy Conservation Park, Hindmarsh River Reserve, Hindmarsh Falls Reserve, Spring Mount Conservation Park and Gum Tree Gully Conservation Park. These areas of public land are connected by numerous properties working towards conserving nature throughout the area. Many landholders and community groups have made considerable effort to achieve landscape-scale outcomes.

Landscape priorities for restoration in the Fleurieu Peninsula

An assessment of landscape health has been undertaken for the region, based on declining woodland bird species. The assessment identified two systems as priorities for restoration (Rogers 2011):

- grassy ecosystems (including some grassland and grassy woodland)
- closed shrublands (including some heathy forests, heathy woodlands and shrublands).

The areas of priority restoration work for grassy ecosystems (Figure 44) link to large areas identified as priorities in the SA Murray-Darling Basin NRM region and contain Drooping Sheoak (*Allocasuarina verticillata*) grassland. Priorities and actions for this part of the subregion should be developed and conducted in partnership with that NRM region to maximise the benefits of this work.

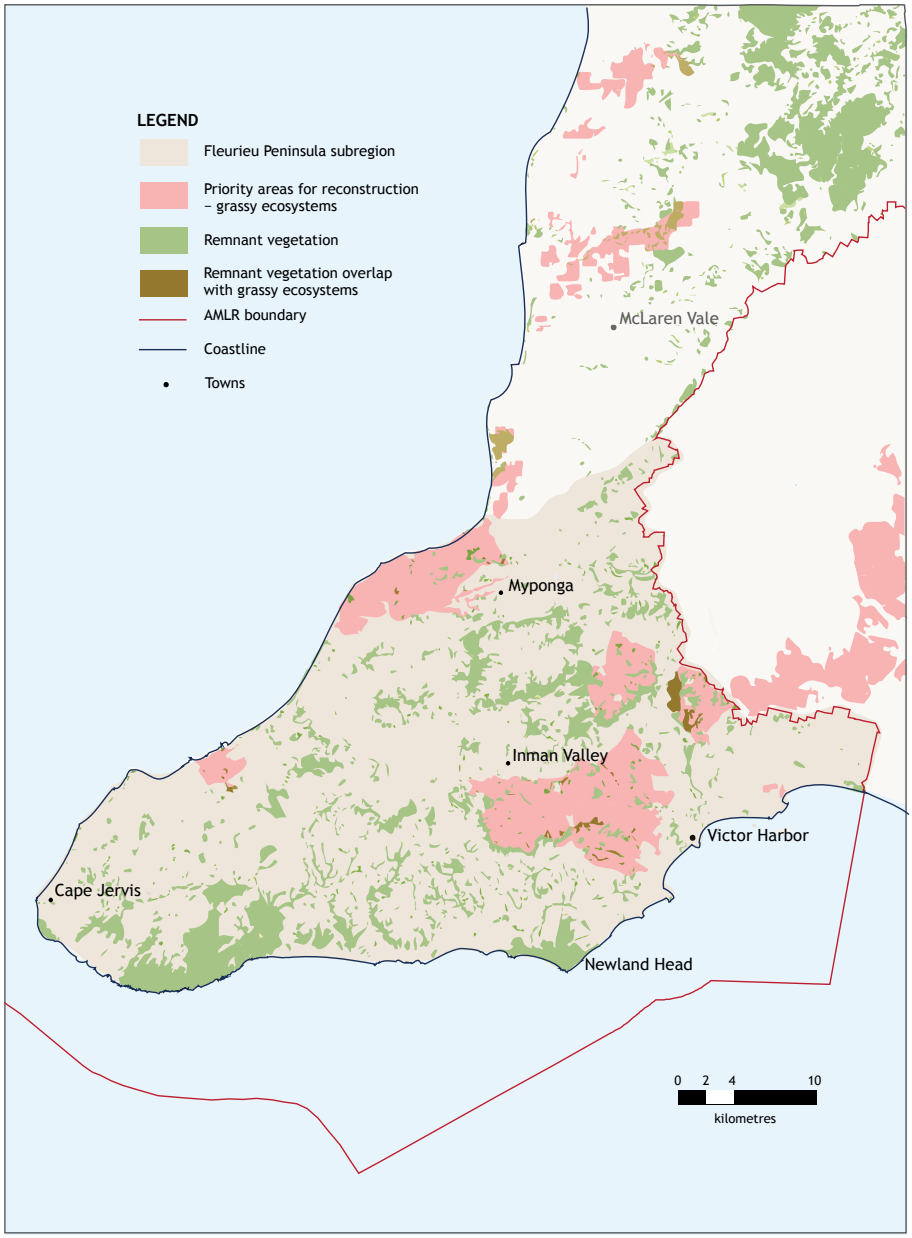


Figure 44: **Priority areas for reconstruction of grassy ecosystems, including some grassy woodland, in the Fleurieu Peninsula (Rogers 2011)**

The closed shrubland is a priority for restoration works, particularly in the Hindmarsh Tiers, Hindmarsh Valley and along the southern coast from Second Valley to Encounter Bay (Figure 45).

Beyond these priority areas, any activity that aims to protect and reconstruct these systems in the Fleurieu Peninsula will add value to the landscape and improve the condition and connectedness of closed shrubland.

The grassy ecosystems and closed shrublands form a complex mosaic in the landscape and rehabilitation will need to identify the specific species mix according to site position.

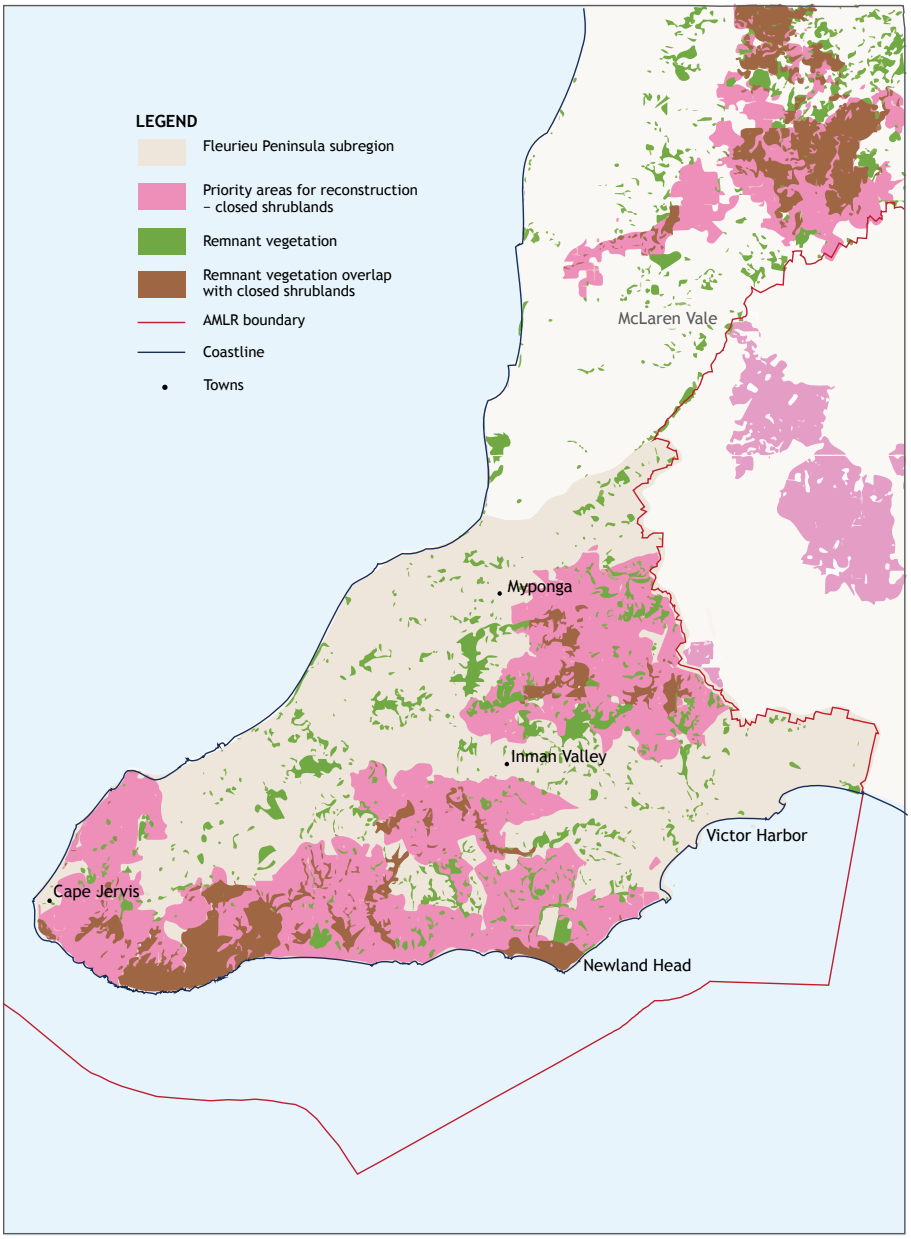


Figure 45: **Priority areas for reconstruction of closed shrublands, including some heathy forest, in the Fleurieu Peninsula (Rogers 2011)**

Vegetation of the Fleurieu Peninsula

Grassland and grassy woodland

Grassland and grassy woodland ecosystems in the Fleurieu Peninsula contain:

- Pink Gum (*E. fasciculosa*)/Blue Gum (*E. leucoxylon*) woodland
- Drooping Sheoak (*Allocasuarina verticillata*)/Dryland Teatree (*Melaleuca lanceolata*) woodland and grassland.

Heath and heathy forest

The Fleurieu Peninsula contains Messmate Stringybark (*Eucalyptus obliqua*) heathy forest and Brown Stringybark (*E. baxteri*) low sandy heaths. Some of these heath communities are associated with the coastal areas of the Fleurieu Peninsula, for example in Deep Creek Conservation Park.

A landscape assessment, using birds as indicator species to determine the state of the landscape, identified stringybark forest as a system in a stable state (Rogers 2011). These systems are often found in less fertile soils along the plateaus of the Fleurieu. The priority for stringybark forest is to maintain the systems in a stable state by focusing on threat abatement. Particular threats include pests and weeds, and planning policies that allow landscape fragmentation and make future management of sites complex due to the proximity of built assets.

Vegetation of the coast

Coastal vegetation associations are relatively small in size (compared to inland vegetation types). However, they are critical as refuges for site specific flora and fauna. A number of specific vegetation communities in these broad vegetation types are discussed below.

Descriptions of coastal vegetation (Croft et al. 2006) and their condition at specific sites comes from baseline vegetation condition monitored in coastal worksites (Mahoney 2011). It is not representative of the vegetation communities as a whole as the sites are actively managed in some way. Each site has been monitored once over the last three years to provide the condition information, and will be revisited over the next three years in the same chronological order to determine trends in condition. The information presented here is an amalgamation of the data for all the sites of that particular vegetation community (Adelaide and Mount Lofty Ranges NRM Board 2012).

Coastal tussock grassland

Coastal tussock grassland generally occurs on foredunes (the first dunes facing the coast). This vegetation type has a relatively high percentage of bare ground, a very high proportion of herbs and grasses, and a lack of tall shrubs. Dominant plant species include Rolling Spinifex (*Spinifex sericeus*), Knobby Club-rush (*Ficinia nodosa*), Coast Cushionbush (*Leucophyta brownii)*, Sea Spurge (*Euphorbia paralias*) and Two-horned Sea Rocket (*Cakile maritime*). Examples of this community are found at Bungala estuary and Bashams Beach.

Coastal shrubland and tall shrubland

Features of this vegetation community include shrubs 1–3 metres high and often densely spaced. This community generally occurs on secondary dunes (often second and third dunes back from the coast) and has a relatively high area of bare ground (up to 20%).

Dominant overstorey species include Coast Daisy-bush (*Olearia axillaris*), Coastal Wattle (*Acacia sophorae*), Coast Beard-heath (*Leucopogon parviflorus*), Coast Sword-sedge (*Lepidosperma gladiatum*) and Sea-berry Saltbush (*Rhagodia candolleana*). Examples can be found at Carrickalinga, Tokuremoar Reserve, Middleton, Normanville and Victor dunes, and Newland Head.

Overall, this vegetation community is in reasonable condition in the subregion. However, recruitment of new plants, which is necessary for vegetation to maintain structural and species diversity and habitat connectivity, is often poor. The poorest example was found at Carrickalinga North where recruitment and structural diversity of groundcover and plant life was poor. The impact of the key threats is quite variable across the sites monitored. Some had quite low impacts from grazing and feral pests, which contributed towards a good result in the condition monitoring. All sites had high or very high impacts from weeds; continued monitoring is needed to observe and minimise their impact on core attributes.

Normanville Dunes

Condition: Fair

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Newland Head

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Coastal cliff low shrubland, hummock grassland and very low open woodland

This vegetation community most often occurs on coastal cliffs and rocky headlands and includes a wide variety of vegetation associations. It is dominated by low growing vegetation <2 metres tall (and often <1 metre tall) that are usually shrubs but also include hummock grasses and stunted trees.

The dominant canopy cover is principally mid-dense (30–70% foliage cover). Exposed or surface rock is often a significant component of groundcover. Dominant species in this community include Pale Turpentine Bush (*Beyeria lechenaultii*), Prickly Ground-berry (*Acrotriche patula*) and Mallee Pomaderris (*Pomaderris paniculosa*). Examples of this vegetation community can be found at Sellicks Cliffs and Victor Harbor Bluff.

All monitored sites were in good condition but all are under significant threat from weeds, grazing and feral animals. These threats have the potential to significantly degrade condition and ongoing monitoring is vital (Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011).

Sellicks Cliffs

Condition: Good

Source: Adelaide and Mount Lofty Ranges NRM Board 2012; Mahoney 2011

Samphire shrubland

Coastal Swamp Paperbark low open forest and tall shrubland

This vegetation community is dominated by the Swamp Paperbark (*Melaleuca ericifolia*). It often forms a dense closed canopy with salt tolerant plants prominent in the understorey, particularly samphires and sedges, and occurs on regularly inundated flats and depressions on light to medium clays.

Coastal samphire +/- Saltbush, Bluebush shrubland

This vegetation community occurs at higher elevations than coastal samphire shrubland, in moderate salinity, and is irregularly and infrequently inundated. It contains salt tolerant plants only, and samphires and other chenopods dominate. Overstorey species include samphire species, Heathy Bluebush (*Maireana oppositifolia*) and Marsh Saltbush (*Atriplex paludosa*). Examples of this vegetation community are found at Inman River estuary.

Non-eucalypt coastal low woodland

These communities are dominated by non-eucalypt trees and a diverse number of life forms (unless Dryland Teatree is the sole dominant) forming low open forest or low closed forest. This community has relatively little bare ground (<10%) and generally occurs on the relatively stable hind dunes. Dominant overstorey species include Drooping Sheoak (*Allocasuarina verticillata*), Southern Cypress Pine (*Callitris gracilis*), Coastal Wattle and Dryland Teatree (*Melaleuca lanceolata*). Examples of this vegetation community can be found at Normanville Dunes.

Threatened species and communities in the Fleurieu

Action to address threatened species and communities is required at a number of scales. While landscape scale restoration will assist, additional specific action is required for certain species and communities to prevent further decline and potential extinction. The geographic scope of species status does not directly equate to priority for action. The recovery of some nationally threatened species of very high national significance will not be strongly influenced by action in the region; the management requirements of state or regional listed species (for which meaningful action can be undertaken) may be more appropriate as a higher priority. Further detail on threatened communities and species can be found in the regional recovery plan for the Adelaide and Mount Lofty Ranges (Wilson and Bignall 2009), particularly the specific priorities and actions required to protect and restore these communities.

Why protect the Mount Compass Oak-bush and Marsh Gum?

The Mount Compass Oak-bush (*Allocasuarina robusta*) and Marsh Gum (*Eucalyptus paludicola*) are two nationally endangered species found on the Fleurieu Peninsula.

Mt Compass Oak-bush is found only on the Fleureiu and nowhere else in the world. The Oak-bush has mainly survived on roadsides and fewer than 1200 plants remain. The Marsh Gum is one of the rarest eucalypts in Australia with fewer than 700 trees remaining.

A recovery program for these species was established in 2011 and more than 2000 Oak-bush and 500 Marsh Gum were planted in 2012 in a collaborative effort to save these species. Efforts are also being made to protect and enhance natural populations on roadsides and private land.

Examples of threatened vegetation communities in the subregion include:

- Fleurieu Peninsula Swamps (*Environment Protection and Biodiversity Conservation Act 1999* listed community)
- Drooping Sheoak (*Allocasuarina verticillata*) grassy woodland
- Swamp Gum (*Eucalyptus ovata*) and Manna Gum (*E. viminalis*) wet woodland
- Blue Gum (*E. leucoxylon*) grassy woodland
- River Red Gum (*E. camaldulensis*) and Manna Gum (*E. viminalis*) woodland on fertile flats.

Examples of threatened fauna of the region include the Western Pygmy Possum (*Cercartetus concinnus*), the western most distribution of the Yellow-footed Antechinus (*Antechinus flavipes* - native marsupial), Heath Goanna (*Varanus rosenbergii*) and Yellow-bellied Water Skink (*Eulamprus heatwolei*). Threatened birds include the Southern Emu Wren (*Stipiturus malachurus*), Beautiful Firetail (*Stagonopleura bella*), Southern Mount Lofty Ranges Emu Wren, and White-naped Honeyeater (*Melithreptus lunatus*).

Much of the specific threatened flora in the Fleurieu Peninsula is endemic or near endemic to the subregion. Species of note include:

- Hindmarsh Valley Greenhood (*Pterostylis bryophila)* which is largely confined to Mt Billy Conservation Park and remnant vegetation at Hindmarsh Tiers
- Deep Creek Correa (*Correa eburnean*), endemic to Deep Creek Conservation Park and an example of a highly restricted but locally abundant species, which makes it particularly vulnerable to shocks although at this stage it is well conserved in the park
- Hindmarsh Correa (*Correa calycina* var. *calycina*) endemic to the Fleurieu Peninsula and known to occur only in Myponga Conservation Park and Hindmarsh River. The work to restore the landscape of Hindmarsh Tiers is also focusing on restoring riparian habitat along the Hindmarsh River to protect and enhance the populations of Hindmarsh Correa.

Protecting the Hooded Plover

Hooded Plovers (*Thinornis rubricollis*) can be seen at a number of the regions's sandy beaches. They nest on the sand between the high-water mark and the base of the sand dunes during spring and summer, which is also the busiest time of year on our beaches.

Significant advances have been made by community protecting nests from trampling and disturbance. The next challenge for their conservation is to determine the best way to help chicks survive until they can fly

Listed as vulnerable under the National Parks and Wildlife Act, chicks and eggs are at risk from disturbance and trampling when people and their pets visit the beach. Disturbance of nesting adults can also affect the survival of chicks and eggs. People and their pets can unknowingly be their greatest threat. But there is some good news – helping the birds at your local beach this year is easy

Water resources of the Fleurieu

The Fleurieu Peninsula includes the Hindmarsh, Inman and Myponga rivers, as well as a number of smaller rivers and catchments. Water use in these catchments is mainly for urban water supply, irrigation and stock purposes and the area is prescribed as part of the Western Mount Lofty Ranges PWRA.

Myponga River

The Myponga River catchment, approximately 70 km south of Adelaide on the Fleurieu Peninsula, is used for grazing, dairying, market gardening, forestry and urban development. The river contains the Myponga Reservoir, which provides water to the Southern Fleurieu Peninsula. As a consequence of all these activities, the quality of its watercourses has declined since European settlement. Downstream of the reservoir, the river passes through a relatively short steep gorge section with bedrock substrate before opening into a very short alluvial floodplain (1-2 km). The river extends a further 2 km before entering Gulf St Vincent at Myponga Beach (McNeil et al. 2009).

The riparian zone of the Myponga River has a higher proportion of Blue Gum (*Eucalyptus leucoxylon*) associations. The river has not experienced the same level of erosion as the Inman river system. The Myponga catchment is also a less steep catchment and therefore has lower energy flow from water movement, which reduces the likelihood of erosion.

Protecting the critically endangered Southern Pygmy Perch

Populations of the critically endangered Southern Pygmy Perch exist in two creeks in the Inman and Hindmarsh River systems. They have a very limited and confined distribution. Grazing practices that allow stock access to the creeks are a significant threat, as are over-extraction of water resources, loss of riparian vegetation (leading to erosion and poor water quality) and introduction of pest fish species. Further information about actions to support the protection of this species can be found in the Action Plan for South Australian Freshwater Fishes (Hammer et al. 2009)

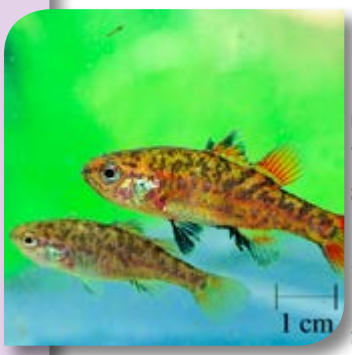


Photo: Nature Glenelg Trust

Inman River

The Inman River flows southeast across the catchment from its headwaters near Bald Hills.

The Inman riparian ecosystem is generally River Red Gum (*Eucalyptus camaldulensis*) communities. On the Inman River, flow characteristics have been modified from a flood-out river to an in-channel river, generating an extremely erosive system. Much of the vegetation and ecosystems have been lost as a result of the increased sediments loads due to the increased bed and bank erosion. Swamp Gum and Manna Gum are likely to have been disproportionately lost from much of the area due to their shorter lifespan and more palatable juvenile foliage.

The Inman River estuary comprises downstream reaches from Swains Crossing to the mouth at Encounter Bay in Victor Harbor. Upstream of the estuary, the river flows through a predominantly agricultural catchment with small acreages of rural residential, areas of irrigated pasture and areas of native vegetation conservation (in the headwaters).

Land use adjacent to the estuary is predominantly public road reserve, recreation (Victor Harbor Golf Course), SA Water land with the old wastewater treatment plant and horse agistment. Beyond that is residential development. The narrow coastal reserve is a highly popular recreational resource for residents and visitors.

The mouth area features sand dune habitat, an artificial lagoon and a patch of low closed forest of swamp paperbark, which provides habitat for a variety of terrestrial, migratory and aquatic birds. Dense seagrass beds around the estuary are a nursery and breeding area for fish.

Threats to the estuary result from the proximity and size of nearby residential areas. The small linear remnant vegetation blocks along the estuary have a large edge to interior ratio and increased weed pressures, particularly from aggressive invasive weeds. Recreation use is high and the estuary entrance is blocked with increasing frequency due to low flows (Sinclair Knight Merz 2010a).

Inman River (2 km upstream from Victor Harbor Golf Course)

Condition: Poor

Source: www.epa.sa.gov.au/reports_water/c0031-ecosystem-2008

Inman River estuary

Condition: Poor

Source: COOE 2012

Inman River (off Inman Valley Road, near Victor Harbor)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0274-ecosystem-2011

Hindmarsh River

The Hindmarsh River flows south across the catchment from its headwaters near Hindmarsh Tiers.

The Hindmarsh River estuary extends from near Victor Harbor Ring Road to the river mouth at Encounter Bay, in Victor Harbor. Upstream, the Hindmarsh River flows through a predominantly agricultural catchment, with areas of irrigated pasture and native vegetation conservation.

Land use adjacent to the estuary is predominantly public open space reserve, with residential development beyond. A key feature is a permanent lagoon on the northeast of the river mouth which formed as a result of changes in the river's course over many years. The mouth area features sand dune habitat, lagoon and low closed forest of Swamp Paperbark (*Melaleuca halmaturorum*), and habitat for a variety of terrestrial and aquatic birds.

Threats from the high level of urbanisation around the estuary are similar to those identified for Inman River estuary. However, the coastal reserves are more substantial, and thus more likely to maintain habitat (Sinclair Knight Merz 2010b).

Tributary of the Hindmarsh River (2 km east of Hindmarsh Tiers)

Condition: Fair

Source: www.epa.sa.gov.au/reports_water/c0234-ecosystem-2011

Hindmarsh River estuary

Condition: Poor

Source: COOE 2012

Bungala River

The Bungala River in the central Fleurieu Peninsula east of Yankalilla, flows westward discharging to the gulf at Normanville. Its upper catchment has been extensively cleared for agriculture and the lower catchment is becoming increasingly urbanised – changes that have modified the estuarine environment at the Bungala estuary at Normanville. A diverse range of habitats are supported by the estuary (AECOM Australia 2010), which is intermittent (the mouth is seasonally barred with sediment) because water extraction upstream has reduced environmental flows. When the mouth is closed for extended periods the estuary loses its connection with the marine environment.

The land surrounding the estuary is predominantly rural with urban development to the north, and a caravan park, tourist accommodation and light industrial activity. Future land use change includes current residential zoned land being fully developed, increased tourist and recreational use, and changes to zoning to increase residential opportunities.

The vegetation around the estuary has been mostly removed, decreasing the stability of the bed and banks, buffering capacity and the quality of fish habitat. Weed pressure is heavy.

Threats to the estuary include (AECOM Australia 2010):

- nutrients from increased stormwater runoff from current and planned urban areas
- erosion and sedimentation from pollution, agriculture and poor bank stability
- reduced freshwater inflow through upstream extraction and reductions in rainfall as a result of climate change impacts
- pest plants and animals impacting on habitat
- agricultural and rural development impacting on water quality and habitat availability
- proposed urban development in or adjacent to the floodplain.

Groundwater

The groundwater resources of the Fleurieu Peninsula primarily lie within the sedimentary aquifers of the Tertiary Limestone and Permian Sand. The area is part of the Western Mount Lofty Ranges PWRA established in 2007. Groundwater resources are managed through the Western Mount Lofty Ranges Water Allocation Plan (WAP).

Hindmarsh Tiers

Hindmarsh Tiers, an area of public and private land with diverse land use, covers about 700 ha in total area and the valley floor lies at about 230 m elevation. Aquifer tests on the Tertiary limestone aquifer found high values of hydraulic conductivity ranging from 85-125 m/day which suggests that flow through the aquifer in the Hindmarsh Tiers may be controlled by solution cavities.

Economic pressures are increasing water extraction.

Groundwater in the Fleurieu Peninsula is predominantly used for agricultural irrigation and also for stock and domestic use. The available yield is dependent on location with the underlying geology often determining the yieldable volume and quality of the groundwater. The fractured rock aquifers, in the Barossa Complex, Kanmantoo Group and the Adelaidean System, have limited production potential. The sedimentary aquifers are much more productive and the most intensive use occurs from the Tertiary Limestone in the Myponga and Hindmarsh Tiers catchments; the extensive Permian Sands sedimentary aquifer has variable characteristics across the area (Barnett and Rix 2006; Figure 46 and 47).

The Quaternary sediments or alluvium have been deposited at the lowest point of catchments adjacent to drainage lines. They generally consist of silts and clays with high organic content and some reworked Permian Sands. In some places peat has significant thicknesses (Barnett and Rix 2006).

The Tertiary Limestone comprises the Murray Group Limestone and the aquifer is the most productive in the Southern Fleurieu Peninsula. It can provide major groundwater supplies where it is confined by the Quaternary sediments and exists predominantly in the Myponga and Hindmarsh Tiers catchments (Figure 46 and 47).

The Permian Sand consists of unconsolidated sands, silts and clays with occasional gravel beds together known as the Cape Jervis Formation (Barnett and Rix 2006). As an aquifer, the Permian Sand generally provides good yields with low salinity but it is variable due to the higher clay content in some areas. These sediments are easily eroded and form low rounded hills contrasting with the steeper and more rugged basement rocks. The Permian Sands were predominantly laid down in the Myponga, Hindmarsh and Inman valleys (Barnett and Rix 2006).

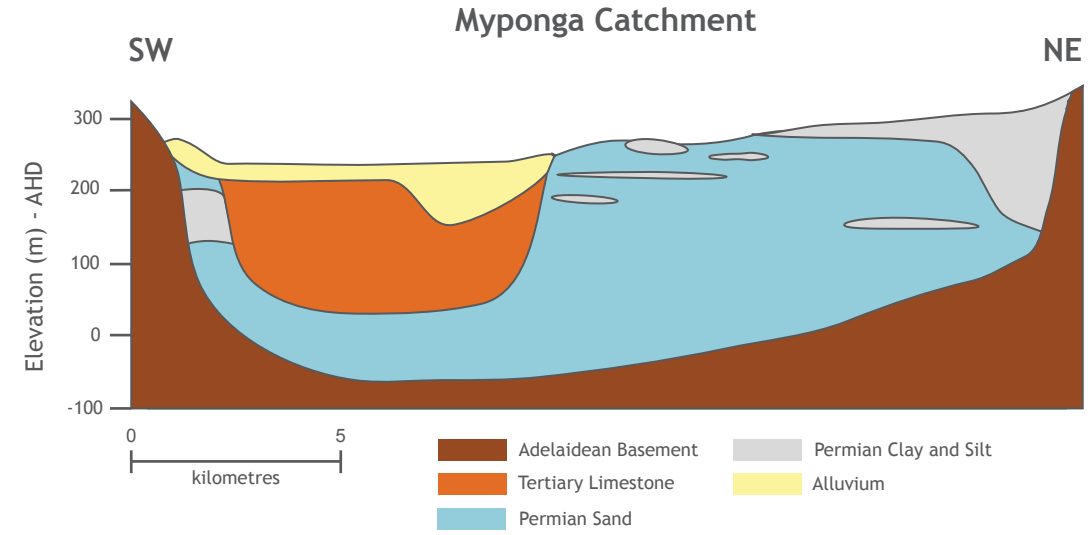


Figure 46: Southwest-northeast cross section of the Myponga catchment

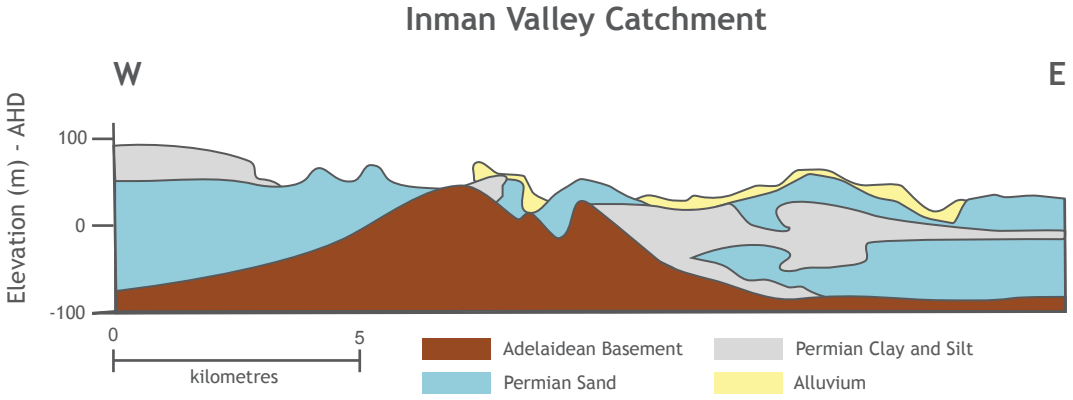


Figure 47: East-west cross section across the Inman Valley catchment

The Kanmantoo Group of rocks - schist, gneiss and feldspathic sandstone - are generally considered poor aquifers with tight fractures and joints containing poor quality water with high salinity levels exacerbated by lower rainfall in this area reducing recharge and flushing. These rocks underlie the southern two-thirds of the area (Barnett and Rix 2006).

The Adelaidean System rocks comprise mainly siltstone, shale and slate with minor beds of sandstone and quartzite. Generally joints and fractures are open and permeable and thus yields are relatively high with variable water quality (Barnett and Rix 2006). The Adelaidean sediments underlie only a small portion of the area in the northwest and are not widely accessed.

The Barossa Complex rocks are the oldest in the area and consist of schists, gneisses and pegmatites. They have been exposed by erosion to form the central core of the Southern Fleurieu Peninsula (Barnett and Rix 2006), east of Yankalilla centred on Myponga Hill. In general rocks of the Barossa Complex are tight and impermeable with few open systems of fractures and joints for storage and transmission of groundwater (Barnett and Rix 2006).

Groundwater dependent ecosystems

The groundwater dependent ecosystem (GDE) types found in the Fleurieu are predominantly aquifer spring discharge and baseflow, and the Southern Fleurieu wetlands. They have been characterised according to their hydrogeological setting, which controls the water source and water availability for ecosystems.

Fractured rock spring discharge and baseflow occur throughout the area where the saturated fractures outcrop and support persistent pools, wetlands and riparian vegetation. Wetlands are found across the area near the top, bottom and transitional areas of the Southern Fleurieu catchments (Barnett and Rix 2006).

A second class of GDEs rely on the availability of groundwater below the surface but within the rooting depth of the vegetation. These terrestrial GDEs include riparian forests that require a supply of groundwater within the root zone. The response of vegetation to reduced availability of groundwater in the soil is incremental. Plant recruitment decreases and plant death increases and new species invade the system; the new structure and function of the ecosystem does not necessarily provide the services required by the environment or the community (Eamus 2009). Identifying GDEs reliant on subsurface availability of groundwater requires evidenced based methodologies to determine if a system meets the requirements of such a classification (Eamus 2009).

Climate change could reduce the frequency and timing of surface water inflows, and bring hotter, drier conditions and changing rainfall patterns (Barron et al. 2011). This could change the recharge of the shallow aquifers and have a wide range of impacts on GDEs such as the Fleurieu Swamps.

In areas of outcrop, urban development often reduces natural surfaces able to receive direct rainfall recharge.

Fleurieu swamps

The Fleurieu Swamps extend from Parawa to Victor Harbor and Myponga and are listed as a Critically Endangered Ecological Community under the *Environment Protection and Biodiversity Conservation Act 1999*. The wetlands characteristically support multiple vegetation associations that merge into one another at a fine scale. The vegetation structure is typically dense with species of variable abundances. They occur on waterlogged soils with moisture available all year round in drainage lines and in broad depressions in valley floors. Geology controls the moisture availability. This unique system contains important biodiversity and is used for primary production purposes (mainly grazing and forestry). Water resource management and impacts on the swamps are complicated, and because swamps differ, difficult to predict. Impacts on water balances of swamps have included changes to flow as a result of vegetation clearance, extraction of water for agricultural purposes, and increasing forestry in the area which has an impact through both direct extraction of groundwater resources, and interception of surface water flow. Common vegetation in swamps includes ferns, rushes, reeds and sedges and shrubs such as Prickly Teatree (*Leptospermum continentale*), Swamp Heath (*Sprengelia incarnata*) and Silky Teatree (*Leptospermum lanigerum*). It has been estimated that the swamps cover an area of approximately 4000 hectares (including those in the South Australian Murray-Darling Basin NRM region) (T Vale pers. comm.).

The community is concerned about the condition of the Fleurieu Swamps as it values this ecological community and its contribution to the region.

Threats such as over grazing, erosion, weeds and nutrients all impact on the condition of the swamps ecosystem.

Recent increases in forestry in the region have also caused some concern as its impact on water resources is unknown.

Threatened species ecologists are finding that fire has an important role to play in maintaining the biodiversity of Fleurieu Peninsula Swamps and maintaining habitat suitability for the Mount Lofty Ranges Southern Emu-wren. However, further work is still required to clarify the fire regimes required by this species and habitat. It critically important in these habitats to achieve the vegetation response required by managing the extent, season and intensity of prescribed burning. There are also challenges to overcome in introducing and managing fire in these habitats as they contain very dense vegetation and are often either very small patches (for swamps), or large, inaccessible patches.

The wetlands have been categorised on the basis of their position in the landscape and their underlying geology. These categories should be considered as a broad classification only as the hydrology and hydrogeology of swamps is complicated. Categories are:

- perched
- fractured rock
- Permian sands.

Perched wetlands

Wetlands are considered perched when they occur in drainage lines over clayey weathered basement, which can attain a thickness of up to 30 metres. Water is not lost vertically and the wetlands at the surface are not effectively connected to the fractured rock aquifer beneath the clay (Figure 48). Thus the deeper regional groundwater in the fractured rock aquifer can't contribute to the wetlands, which depend on rainfall runoff or lateral subflow from the soil profile above the clay. Water also flows slowly down the catchment in wetland sediments. Perched wetlands are generally found near the top of catchments (in first or second order streams with steep gradients). Most are located to the south on the Parawa plateau, with some also found on the high plateau south of Myponga. They often have stringybark vegetation associations bordering the swamps. This type of wetland constitutes approximately 77% of Fleurieu Swamps.

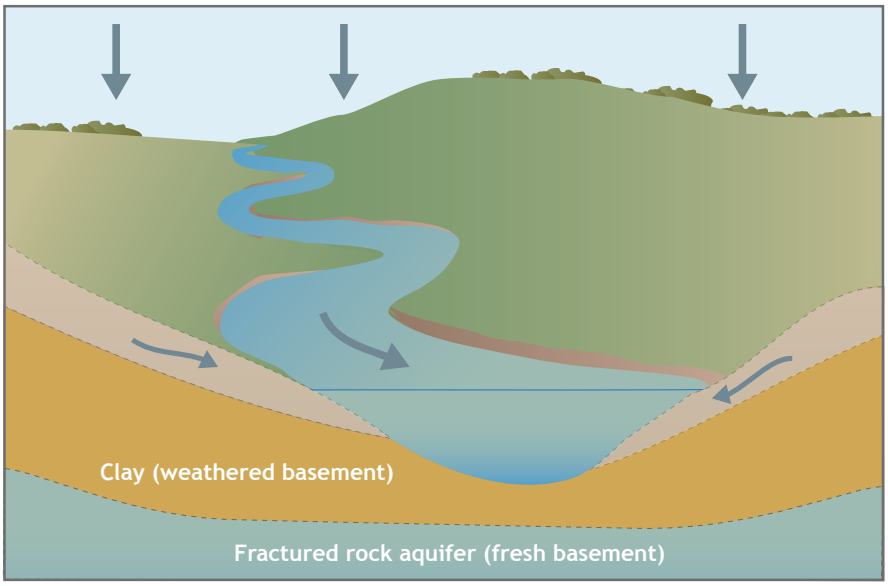


Figure 48: Perched wetlands structure in the Fleurieu Swamps (Adelaide and Mount Lofty Ranges NRM Board 2007b)

Fractured rock wetlands

Toward the bottom of the catchments, the weathered basement has been mostly eroded away and wetlands may be in direct contact with the regional fractured rock aquifer (Figure 49). Groundwater discharge may therefore make a significant contribution to wetland water requirements, particularly

during the summer months. These wetlands are found on the lower flanks of high plateaus and toward the south coast in mostly fourth order streams where stream gradients are relatively low. Exposures of fresh bedrock would be commonly visible. It is estimated that approximately 2% of Fleurieu Swamps are this type of wetland.

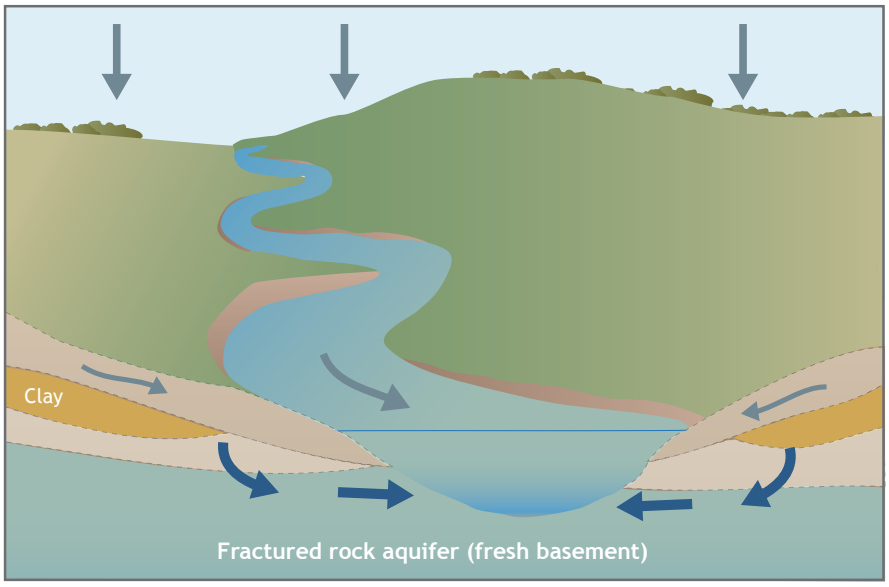


Figure 49: **Structure of fractured rock wetlands in the Fleurieu Swamps (Adelaide and Mount Lofty Ranges NRM Board 2007b)**

Permian sands wetlands

Wetlands underlain by Permian Sands usually occur in the lowest parts of the landscape in valleys and depressions where they are in direct contact with the regional watertable aquifer (Figure 50). Because of the sandy soils, there is very little surface runoff and groundwater provides almost all wetland water requirements. If the watertable is not too low for plant uptake, there are no constraints on the amount of water available. Often Permian sands wetlands have stringybark vegetation associations fringing the swamps. It has been estimated that this type of wetland forms approximately 19% Fleurieu Swamps.

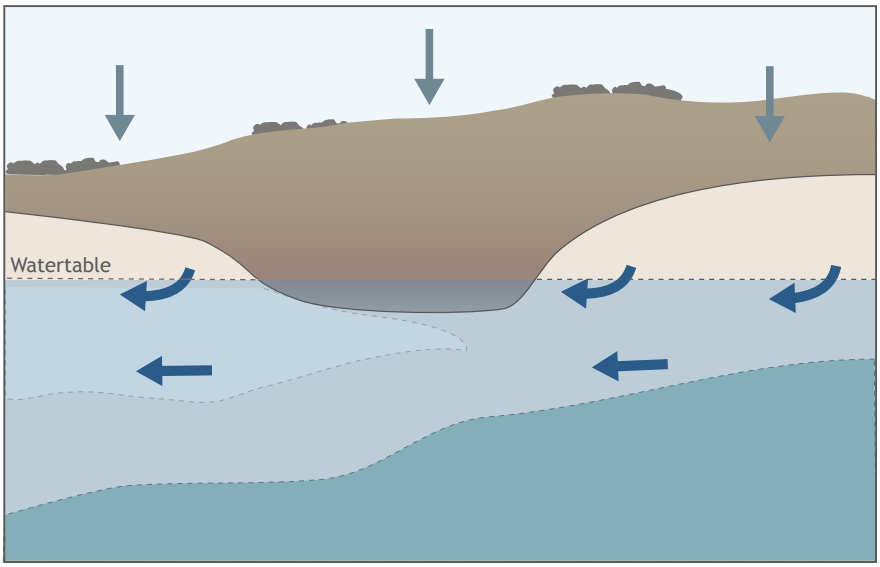


Figure 50: **Structure of Permian sands wetlands in the Fleurieu Swamps (Adelaide and Mount Lofty Ranges NRM Board 2007b)**

Water resources for the swamps have declined with increased land use for production. Now, small islands of natural habitat sit between other land uses.

The swamps are perceived to have declining water availability and quality due to surrounding land use and historic drainage of the land for production. Areas of over-grazing lead to disturbance of the swamps and erosion allowing weeds to infiltrate, while nutrient in-flow from surrounding pasture also contributes to weed and algal proliferation. Impacts of forestry on water levels are unknown as are the water regimes in the swamps.

Thresholds suggested for maintaining the swamps include abundance of weed species, drying of wetlands for extended periods of time (water extraction (including forestry), drainage and climate change) and pressures of grazing.

Woody weed and pest animals are significant threats, as are aggressive native species more suited to low water availability situations. Water quality needs protection from nutrient inflow and erosion from cleared land. Swamps are highly variable which makes it difficult to make generalised management decisions. Further research is needed to better understand these communities.

Livelihoods

Fleurieu Peninsula production is based mainly on high value grazing (including dairy, beef and prime lamb). The industry is supported by a combination of suitable soils, access to water, a favourable climate, and access to labour, transport and support industries.

The soils of the Fleurieu form a mosaic in the landscape with many soil types such as:

- shallow soils on calcrete or limestone
- deep loamy texture contrast soils with brown or dark subsoil
- calcareous soils
- hard red brown texture contrast soils with alkaline subsoil
- deep sands and highly leached sands.

Average annual rainfall

Myponga	758 mm
Parawa	946 mm

Primary production is heavily dependent on the natural resources of the subregion, in particular healthy soils, healthy water and minimal agricultural pests. Healthy soils, while linked to intrinsic soil properties, are also heavily influenced by management of soils and production. A soil cover survey assessed the risk of soil erosion in the Fleurieu three times from December 2011 to June 2012. Land surveyed in the Fleurieu Peninsula was used mainly for livestock grazing (Young 2012). The surveys indicated a decrease in the number of sites at low risk of erosion from December (94%) to June (86%) in combined data from the Willunga Basin and Fleurieu. The greatest risk to pasture paddocks in the Fleurieu is heavy grazing but data suggests that this is not generally a problem in the area. The highest erosion risk rating in the Fleurieu was for paddocks sown to cereal or cultivated fallow. Further monitoring of soil cover and erosion risk will provide firmer trends in land management practices to prevent erosion.

Recent population growth and urban development has increased the complexity of managing primary production activities in the Fleurieu Peninsula. Land considered valuable for primary production activities now and into the future is being identified and protected. Figure 51 identifies priority primary production areas in the Fleurieu Peninsula including the key considerations that supported each area being included as valuable to primary production. The categorisation and description of these areas draws on provisional mapping and analysis from PIRSA's Primary Production Priority Areas project (PIRSA 2011a,h,i,j,k).

Bungala – Yankalilla and Inman & Back Valleys

Key considerations

- favourable soil and climate conditions for cropping and grazing on the western part of the unit and high rainfall grazing on the eastern end
- presence of several large properties and producers
- small areas have potential for horticulture

Notes

Some soils prone to mass movement and require management (minor elements of the landscape); cool climate conditions provide good scope for climate change adaptation

Central Plateau

Key considerations

- favourable soil and climate conditions for grazing
- the presence of several large properties and producers
- small areas having potential for horticulture

Notes

Cool climate conditions and elevation provide scope for climate change adaptation. Area would also suit forestry

Wattle Flat

Key considerations

- favourable soil and climate conditions for agriculture
- presence of several large properties and producers
- small areas having potential for horticulture
- good quality surface and groundwater

Notes

Some soils become waterlogged over winter but have good potential for summer irrigation

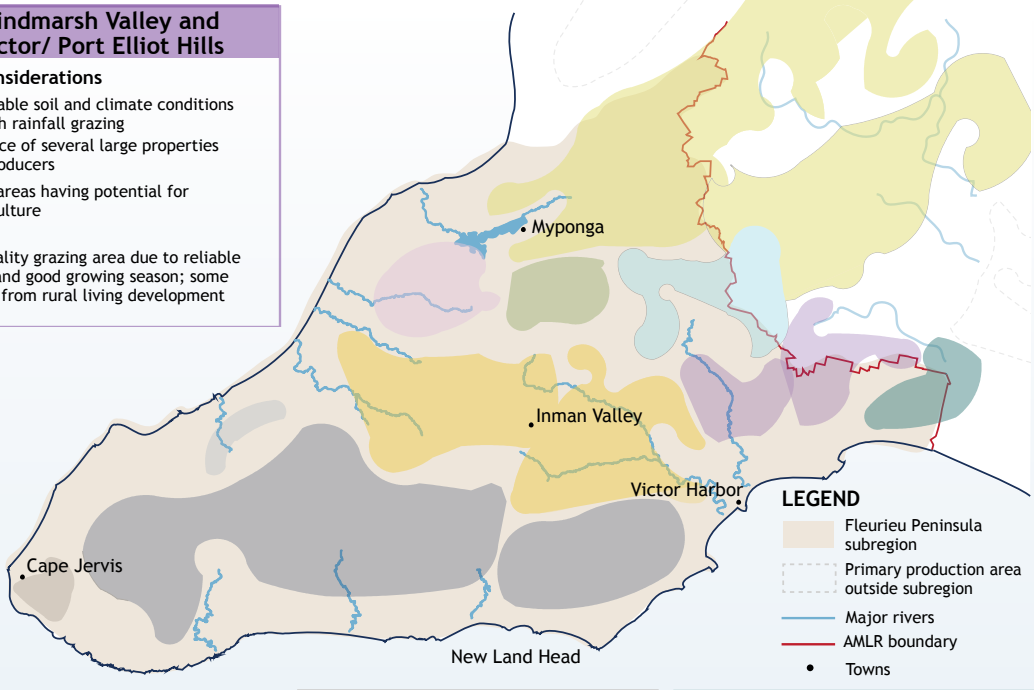
Hindmarsh Valley and Victor/ Port Elliot Hills

Key considerations

- favourable soil and climate conditions for high rainfall grazing
- presence of several large properties and producers
- small areas having potential for horticulture

Notes

Good quality grazing area due to reliable rainfall and good growing season; some pressure from rural living development



Wirrina East

Key considerations

- favourable soil and water conditions for grazing

Notes

A relatively small area surrounded by less suitable grazing land, used in a similar but less intensive manner

Cape Jervis

Key considerations

- favourable soil, water and climate conditions for cropping

Notes

Likely to come under considerable development pressure due to coastal location

Goolwa Plains

Key considerations

- favourable soil and climate conditions for dryland cropping

Notes

The remoteness from other cropping areas, fragmented nature of the unit and local development pressures will pose a challenge to the future of this unit

Myponga Valley

Key considerations

- favourable soil and climate conditions for grazing
- presence of several large properties and producers
- good quality underground water supply

Notes

Cool climate conditions and elevation provide scope for climate change adaptation; some soils waterlogged over winter but have good potential for summer irrigation (Myponga)

Parawa Plateau and Waitpinga Catchment

Key considerations

- favourable soil and climate conditions for grazing
- presence of several large properties and producers
- small areas having potential for horticulture

Notes

Reliable rainfall and good growing season; cool climate conditions provide scope for climate change adaptation; large parcels and holdings allow farming at a large scale than in Central Mt Lofty Ranges

Hindmarsh Tiers

Key considerations

- favourable soil and climate conditions for grazing
- presence of several large properties and producers
- areas of forestry
- good quality underground water supply
- some potential for cool climate horticulture

Notes

Some of the soils waterlogged over winter have good potential for summer irrigation; cool climate conditions also provide good scope for climate change adaptation

Figure 51: Priority primary production areas in the Fleurieu Peninsula (PIRSA 2011a,h,i,j,k)

Grazing and dairy

Agriculture in the Fleurieu Peninsula is predominantly a high rainfall pasture system that supports dairy and beef cattle industries, as well as prime lamb production. The gross value of production in the Fleurieu Peninsula is $60 million (Australian Bureau of Statistics 2012c) with dairy and livestock the main contributors. There are also small amounts of viticulture, horticulture and cropping in the subregion.

The many areas in the Fleurieu considered good quality for grazing, include Waitpinga, Parawa, the Central Plateau, Bungala and Yankalilla Creek catchments, Wattle Flat, Myponga and Hindmarsh Tiers. Reliable rainfall, good soils and a long growing season are characteristics that contribute to the suitability of these areas for grazing. These attributes are also suited to forestry and there is some conflict between grazing and forestry land use particularly around water availability.

The Bungala River and Lower Myponga catchments also include, as a minor element in the landscape, some soils used for agriculture that are prone to mass movement and require management (Blake et al. 2004).

Woody weeds continue to be a threat to both productive and natural ecosystems; soil acidification due to land management practices is an emerging threat and low commodity prices and the general global outlook are impacting on the viability of properties. The increase in the value of land has made it more difficult for people to buy existing farms or to expand the size of a farm. Fewer farms in an area can prompt loss of services in townships as the critical mass of population is not available to sustain local businesses.

Climate change impacts on the grazing industry are likely to result in more intensive management of stocking rates as variations in temperature and rainfall will have increased impacts on pasture growth. Winters will be warmer with fewer frosts and so growth rates could be higher; using nitrogen fertiliser during winter may become more effective. Summers will be hotter, beginning earlier and finishing later – potentially causing heat/moisture stress over summer, while shortening the peak of spring growth and delaying the start of 'autumn'. Short rotation pasture systems and winter fodder crops may become more attractive than irrigating pasture over summer. Grazing management is also likely to require better prediction tools and models of rainfall in particular to guide suitable stock management that ensures soil cover and natural resources are not degraded. Changes to species used for pastures (including using native grasses), the timing of mating and new breeds and cross-breeds will also need to be considered (Rebbeck et al. 2007).

For the dairy industry the grazing impacts and adaptation responses also require consideration and management of climate impacts on cows. Cows have evolved a range of mechanisms to off-load heat, but problems can occur if temperatures and humidity remain high. Response to heat also differs between breeds. Temperatures above 25°C reduce the ability for cows to produce milk and get in calf. Provision of shade, minimising the distances walked, and active cooling by sprays are important heat stress management tools (Howden et al. 2008).

Climate change projections predict lower and more variable rainfall, higher evaporation, changes in seasonal patterns and more frequent/longer droughts. These factors generally cause runoff to be reduced at more than double the rate of rainfall reduction and thus less water is available for farm supplies. Businesses that rely on surface runoff for irrigation could face severe water shortages. However, runoff estimates are not always reliable because runoff depends on timing and intensity of rainfall

The community values the productive agricultural land in the Fleurieu and is concerned about the pressures impacting on a farmer's ability to stay viable.

While some of these pressures are outside the scope of this strategic plan, issues of land management, development policy and water management are all opportunities for partnerships with the community.

as well as rainfall amount. Reductions in the reliability of supply will vary but are likely to be greatest where surface water extraction is already high, and where climate change is predicted to have the largest impact on water availability.

Forestry

The Adelaide and Mount Lofty Ranges NRM region contains around 11,600 hectares of plantation forestry, of which about 9,700 hectares is softwood owned or managed by ForestrySA and about 1,900 hectares is privately owned hardwood including farm forestry. Further information about the commercial forestry industry in the region can be found in the Northern Hills subregion section.

Farm forestry is a relatively new industry in the Fleurieu Peninsula. It provides a means of integrating smaller scale plantations with other primary production to diversify income through timber, fire wood production or potentially carbon sequestration, while delivering natural resources management benefits such mitigating soil erosion and salinity, and providing biodiversity habitat and connectivity.

There are some concerns about the impact of forestry on groundwater dependent ecosystems, surface runoff and direct extraction from shallow groundwater resources (within about 7 m of the ground surface), particularly for Fleurieu Swamps.

One of the risks associated with forestry plantations is that they can occur in woodland and grassland areas that are not traditionally used for agriculture and therefore have significant biodiversity value. Forestry plantations are typically of limited habitat value for species in decline and can instead provide resources for already abundant species in the landscape that can compete with those in decline (e.g. Rainbow Lorikeet (*Trichoglossus haematodus*)).

Climate change impacts on forestry include productivity declines with decreases in water availability, as both growth rate and length of the growth season are reduced. Extreme heat events can also result in damage and mortality to plantation forests. The changes may also affect the quality of the wood produced from the plantations. There may also be increased risk from pests and fire with climate change (Pinkard and Bruce 2011).

Adaptation opportunities include plantation management through numbers of trees, selection of better genetics or alternative species, or potentially different sites for planting. More intensive management of plantations is also likely to be required to adapt to the impacts of pests, weeds and disease (Pinkard and Bruce 2011).

Tourism

The natural beauty, coastal assets and recreational opportunities are strong drawcards for this subregion, and it has a significant tourism industry in overnight stays and day trips. It is supported by significant urban centres with the facilities to cater for tourist needs. There is a large seaside rental industry and generally excellent support services for tourists.

As a transient population, tourists present both threats and opportunities to this subregion. Many tourist activities rely on natural resources, including whale watching and penguin tours. Knowledge of the value of the natural assets can be built with tourists, but their transient nature needs specifically designed programs.

Different types of tourism could be linked with this subregion's natural assets, for example the arts community being able to make use of the natural beauty and landscapes of the area. Cape Jervis is also the contact point for tourists travelling to and from Kangaroo Island (in the Kangaroo Island NRM region).

Marine

In summary

The 41% of the Adelaide and Mount Lofty Ranges NRM region that is Marine Environment supports marine flora and fauna in intertidal habitats, marine reefs, extensive seagrass meadows in various states of health, soft bottom systems and deep water habitats. It also supports commercial and recreational fishing, the state's major port and its attendant activities, and tourism.

The subregion lies in both Gulf St Vincent and the more exposed waters of Backstairs Passage.

Marine – Priorities for the future

This set of priorities for the future for the Marine Environment subregion has been developed based on the information contained in this section:

- Protect Southern Fleurieu seagrass communities from land based impacts
- Restore and protect metropolitan coast seagrass communities
- Determine priority catchments for works to minimise land based impacts on the marine environment
- Continue research into understanding the links between land-based pollution and marine system health
- Work with fishing industry groups to support sustainable resource use
- Manage habitats to reduce or halt population declines of at-risk species (including threatened species and communities) and build resilience into the system
- Facilitate integrated climate change adaptation of people reliant on the marine environment
- Protect the islands to ensure their value as seabird breeding sites is maintained
- Take action to address historic impacts, manage current threats, and facilitate population increases to reverse species and ecological community declines
- Monitor for, and control, pests that have not yet become established in the region or in the Marine subregion

Introduction

The waters of the Marine Environment subregion's make up 41% of the total Adelaide and Mount Lofty Ranges Natural Resources Management region. The subregion's marine boundary takes in the sheltered waters of eastern Gulf St Vincent, from the northern boundary of Mallala Council to the more exposed coastline of the southern Fleurieu Peninsula at Middleton Beach. The seaward boundary runs out to the middle of the gulf and Backstairs Passage, and includes the eastern side of Investigator Strait. Gulf St Vincent has a maximum depth of 40 metres.

Near-shore islands in this subregion include sand islands in Port River and granitic islands off the southern coast of the Fleurieu Peninsula. Extensive mangrove forest, samphire marshes and mudflats dominate the north. Seagrass communities provide valuable habitat in inshore waters and rocky reefs are habitat for marine plants and animals. This subregion intersects the traditional waters of the Ngarrindjeri and Kaurna people.

It is bordered by the Northern Coast, Metropolitan Adelaide and Southern Coast subregions; as well as the Northern and Yorke, Kangaroo Island and SA Murray-Darling Basin NRM regions.

Protecting the Leafy Sea Dragon

The Leafy Sea Dragon (*Phycodurus eques*) is one of two species of sea dragon found in Australia's southern waters and nowhere else in the world, the other being the Weedy Sea Dragon. Despite its fearsome name, it is incredibly beautiful in shape and colouring and its camouflaging appendages give it a fragile appearance. It is a relative of the seahorse and belongs to the pipefish family Sygnathidae

The species has been an iconic part of the Reef Watch program undertaken by the Conservation Council of SA and is South Australia's marine emblem.

The species strategy is to blend in with the algal communities growing around the Fleurieu Coast and under pressure from land based impacts on the marine environment.

Lifestyles

A significant part of this subregion falls within Gulf St Vincent, which is currently divided by three NRM region boundaries: Northern and Yorke, Kangaroo Island, and Adelaide and Mount Lofty Ranges.

In recognition of the importance of treating the whole of Gulf St Vincent as one system (requiring a coordinated planning and management approach), the three boards have signed a memorandum of understanding (MoU). The MoU identifies the gulf as a producing aquatic system essential to all marine industries, as well as having significant cultural and heritage values. It also means that important species and areas of habitat are managed in a coordinated way across jurisdictional boundaries, as well as reducing the opportunity for conflicting actions.

The MoU also enables engagement of the community across the whole gulf, which is particularly relevant as many users of the marine environment use all parts of the gulf without recognising NRM boundaries.

This subregion has many key threats identified:

- **Land-based impacts** (discussed throughout this section)
- **Resource use** (discussed throughout this section)
- Marine biosecurity

- **Hormone disrupting chemicals** in the environment and potential impacts on marine habitats and species (societal use has introduced pharmaceuticals and cosmetics in the environment and potential impacts are unknown)
- **Marine pollution** including marine litter (or debris) which tends to impact on specific species rather than being a threat to the habitat as a whole (Bryars 2013), and is a key threat to the marine environment (the debris comes from lifestyle choices that are mainly catchment based, e.g. changes in packaging – plastic vs waxed paper straws)
- **Climate change** which may increase ocean temperatures and raise sea levels along the coast (Poloczanska et al. 2012): Increased ocean temperatures impact on ecosystems and species will decline when they reach their upper temperature boundaries; many temperate species may have little opportunity to migrate south to more suitable habitats as they are not available; the spread and extent of species will change and the impacts of pests will increase as they spread to new areas; and rising sea levels will impact on coastlines and increase erosion and impact on coastal vegetation.

Climate change will also change the chemical features of the ocean. Acidity will increase as more carbon dioxide is dissolved, with possible impacts on a range of calcium carbonate based beaches in our region, which could dissolve with increased acidity of the water. The major issue for managing marine environments with climate change is the lack of information available about the impacts.

The marine environment may adapt autonomously through natural physical and biological processes, or through human intervention. Both adaptation responses can be supported by active management such as protecting a network of areas to support species redistribution, and protecting and restoring habitats essential for important life stages. Some significant risks of unintended or unanticipated consequences of direct action make it a highly uncertain adaptation strategy.

The region has two marine parks administered under the *Marine Parks Act 2007* (Upper Gulf St Vincent and Encounter Marine Park). Management plans for the marine parks have been developed and outline policies about zoning for activities in the parks. The five aquatic reserves administered under the *Fisheries Management Act 2007* do not have management plans but fisheries legislation has provisions for preparing plans.

Aquatic reserves and marine parks are established to protect the habitat, ecosystems and communities of marine and estuarine waters. The relevant parks and reserves are:

- **Adelaide Dolphin Sanctuary** protects mangroves, seagrass, saltmarsh, tidal flats, tidal creeks and estuarine rivers that provide habitat and food for 30 resident and up to 300 visiting dolphins
- **Barker Inlet Aquatic Reserve** and adjoining **St Kilda-Chapman Creek Aquatic Reserve** were established to conserve mangrove and seagrass communities, and to protect nursery areas of several important commercial and recreational species including Western King Prawn, King George whiting, Yellow Fin Whiting and Blue Swimmer Crabs
- **West Island Aquatic Reserve**
- **Encounter Marine Park**
- **Upper Gulf St Vincent Marine Park.**

Seascapes

Adelaide's metropolitan nearshore environment has had considerable impacts. This is demonstrated by broad-scale loss of vital habitat-forming seagrasses and degradation of nearshore rocky reefs. Research suggests that this poor condition is driven by the discharge of nutrients from large metropolitan wastewater treatment plants and industrial plants located on the Port River, as well as the flow of suspended solids and dissolved organic matter from catchment sources in stormwater runoff (Fox et al. 2007).

Hydrodynamic modelling for the Adelaide Coastal Waters Study has shown that pollution in the near-shore waters generally moves along the shore in a north–south direction rather than flushing into deeper waters. The numerous discharges of nutrients and sediment into the coastal waters, and higher residence time in shallower waters, is likely to result in poorer than expected water quality in the shallower area and drive impacts on seagrasses and rocky reef systems. Seagrass and reef systems farther away from Adelaide's metropolitan centre are in better condition but are showing some symptoms of excess nutrients or sediment. The main pressures on systems away from the metropolitan coast include coastal development and agricultural runoff (Fox et al. 2007).

Intertidal habitats

Intertidal habitats are those at the edge of land and sea. They are regularly inundated by the tides, creating a range of niches for plants and animals which can tolerate these often extreme conditions (wetting, drying, salinity, temperature and exposure to sun and submersion). These habitats include rocky reefs, sandy beaches, estuarine sand and mudflats (Adelaide and Mount Lofty Ranges NRM Board 2008).

Intertidal habitats vary according to the type of substrate and wave energy, and are zoned:

- **Upper (or high)** – submerged only during the highest (spring) tides of the year and contain relatively few, but highly-specialised organisms such as periwinkles, barnacles and some encrusting algae
- **Middle and low** – usually have abundant algal growth and a high diversity of fauna including molluscs, crustaceans (barnacles, crabs, amphipods and shrimp), echinoderms (urchins, sea stars, brittle stars, sea cucumbers), anemones, sponges, ascidians (sea squirts), polychaetes (bristle worms) and nemerteans (ribbon worms) (Benkendorff et al. 2007).

Temperate reefs

Temperate reefs are related to the underlying coastal geology and are sanctuaries for many marine species. This subregion has many natural reefs, most notably around Hallett Cove, Port Stanvac, Christies Beach, Port Noarlunga, Moana and the southern Fleurieu Peninsula. Artificial reefs off the metropolitan coastline include a scuttled dredge, barge and concrete blocks, a tyre reef, shipwrecks, ex-HMAS Hobart and illegally dumped rubbish such as whitegoods and car bodies to create snapper drops for fishing.

The metropolitan reefs are generally low profile limestone and typical of subtidal reefs in the state. Dominated by large seaweeds (macroalgae) and abundant invertebrate life, they are known to have high levels of diversity and species uniqueness. The community structure of reefs can vary annually due to

Granite Island and Port Elliot

Condition: Fair

Source: Turner et al. 2007

Carrickalinga, Second Valley, Cape Jervis, West Island and the Bluff

Condition: Good

Source: Turner et al. 2007

seasonal growth. They may also vary between years with changes in dominant species (Adelaide and Mount Lofty Ranges NRM Board 2008).

The condition of metropolitan temperate reefs is threatened by:

- recreational activities (boating anchors, inappropriate diving)
- nutrients from wastewater and stormwater
- over-fishing by the recreational fishing industry
- decreasing biodiversity
- increasing sediment from rivers and cliffs resulting from increased development (both residential and industrial)
- changes to natural flows from urban rivers and creeks.

Hallett Cove Reef

Condition: Fair

Source: Westphalen 2011

Noarlunga Reefs

Condition: Fair

Source: Westphalen 2011

The reefs increasingly degrade from south to north in this subregion which correlates with the area of seagrass decline in the metropolitan coast, as well as the level of urbanisation (Connell et al. 2008).

The community is concerned about the protection and condition of marine reefs.

The Reefwatch program has recorded a decline in biodiversity and loss of key species.

Land based impacts from urban areas in the Fleurieu such as increased stormwater contribute to marine reef decline.

Marine Park Sanctuary zones will increase protection of reefs.

The reefs along the southern Fleurieu Peninsula coast are steeply sloping granite or gneiss. Intertidal calcareous rock platforms, or sandy beaches, commonly occur between the granitic headlands. Southern Fleurieu Peninsula reef systems are also exposed to stronger wave action than those in gulf waters. These reefs appear to be healthy and in good condition, and support a high diversity of animal and algal life. Nutrient and sediment loads from Inman and Hindmarsh rivers, at Victor Harbor, might influence the local reef ecosystem. Minimising land based impacts on the marine environment is critical to maintaining the health of these reefs. Much sediment in the general area was laid down by historical flows of the Murray River (Westphalen 2011).

Seagrass

Seagrasses are flowering plants that live in the coastal waters of most of the world's continents. They provide habitat for many smaller marine animals, some of which, like prawns and fish, are commercially important, and a nursery habitat for juveniles. They also absorb nutrients from coastal runoff and stabilise sediment, helping to keep the water clear. Seagrass meadows support around 40 times more animals than the adjacent bare sand and are a protective buffer from waves for beaches and the shoreline. The seabed and beaches can be readily eroded by waves and currents if stabilising seagrasses are lost (Adelaide and Mount Lofty Ranges NRM Board 2008). Figure 52 identifies the process of seagrass decline as water quality conditions (particularly increases in nutrients) deteriorate.

Seagrasses are also vulnerable to impacts from nutrients and sediments in stormwater and industrial discharge, dredging and trawling activities. The outcome of seagrass loss – sediment re-suspension – leads to more seagrass loss (cyclical feedback loop). There is little understanding of the ability of seagrass to recolonise an area once the contributing factors for its loss have been removed, particularly on a large scale. Land-based native vegetation can easily and naturally regenerate in rural areas once grazing pressures have been removed. However, limited seagrass has regenerated near Port Adelaide sludge outfall off Semaphore since it was decommissioned in 1993. Seagrass recovery and restoration contribute to carbon sequestration activities as seagrasses can sequester more carbon than terrestrial plants (Moore and Westphalen 2007).

Sea-level rise and increased storminess from climate change have the potential to cause a decline in seagrass abundance and extent. Warming temperatures may also increase the risk of decline (Poloczanska et al. 2012). Seagrass will also be impacted by land based consequences of climate change such as impacts from increased runoff from more intense storm events. As well as higher levels of sedimentation from rural landscapes, where less rainfall translates into lower soil cover and therefore more soil erosion.

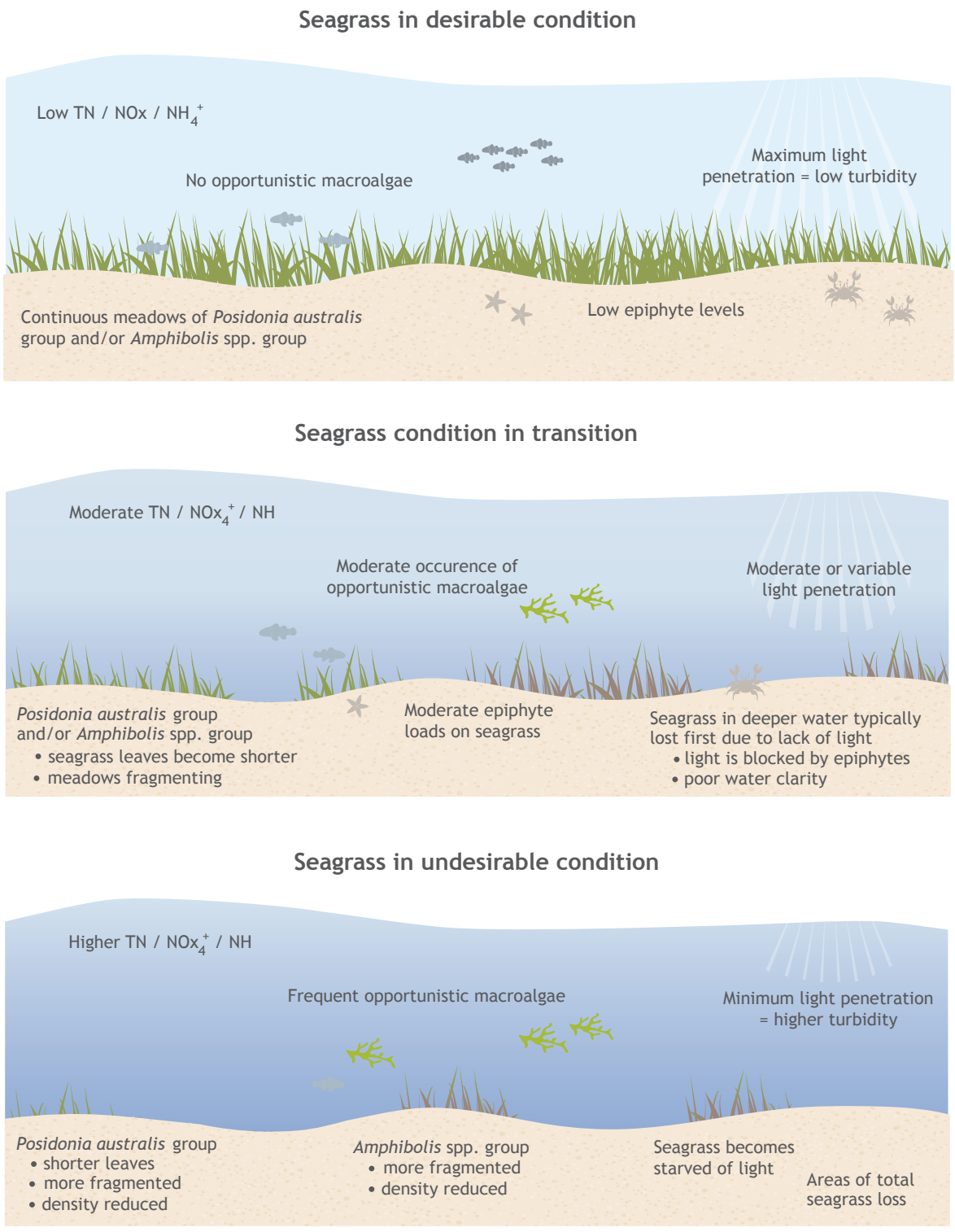


Figure 52: State and transition model of seagrass condition for Gulf St Vincent waters (Gaylard et al. 2013)

Seagrass meadows are extensive along the coast, but detailed studies have found substantial meadow loss in the metropolitan area. Long-term aerial photography suggests some 5,200 hectares of seagrass has gone from metropolitan Adelaide since 1935, mostly at Holdfast Bay. The Adelaide Coastal Waters Study (Fox et al. 2007) identified near-shore seagrass meadows, and southern offshore parts of Holdfast Bay, as fragmented but limited sampling offshore (5 metre and 10 metre depths) suggests generally healthy meadows.

Metropolitan seagrass

Condition: Variable

Source: Tanner et al. 2012

Yankalilla Bay seagrass

Condition: Good

Source: Tanner et al. 2012

This loss of seagrass is still of concern but implementation of the Adelaide Coastal Water Quality Improvement Plan may improve conditions for seagrass rehabilitation. Anecdotal evidence indicates some improvement in seagrass condition since the water quality improvement plan was implemented. Further monitoring and evaluation of seagrass condition along the coast is required and published evidence of change will be included in this document once available.

The extensive seagrass meadow at Yankalilla Bay appears healthy and in good condition. Monitoring results to date indicate a slight increase in epiphytes near river mouths but overall, no consistent impact at either Bungala or Yankalilla River was observed on seagrass recruitment or growth (Tanner et al. 2012). However, observations from more recent investigations of some Carrickalinga and Normanville reefs in shallower water show they appear devoid of macroalgae and have a high cover of mussels and turfing algae. Some blowouts were also observed that may be related to seagrass loss. This loss is attributed to impacts from catchment processes such as increased discharge of polluted water. The impact of urbanisation on seagrass (through increased discharge of polluted water along the metropolitan coast) must be taken as a lesson for the Fleurieu Peninsula. It is critical that appropriate management of this discharge to the marine environment is enforced to protect the seagrass systems in this area.

Another significant area of healthy continuous and extensively dense coastal seagrass meadows occurs in Encounter Bay on southern Fleurieu Peninsula. Mapping of the bay found eight species of seagrass, and monitoring off the Inman River indicates very good seagrass meadows structure in the region overall. Areas identified as continuous seagrass appeared to be in good condition. A low number of sites had high epiphyte cover, directly offshore from the mouth of the Inman River. River discharges may be causing seagrass loss but historical interpretation of aerial photography and changes in habitat distribution complicate precise analysis. Most change appears to have occurred between 2000 and 2004 (Tanner et al. 2012).This seagrass is under similar threats to that at Yankalilla Bay as a result of the planned increase in population and development at Victor Harbor.

The community is concerned about the protection and condition of Yankalilla seagrass.

Community perception is that seagrasses are at a point where action is required to prevent further degradation from more urban development.

There is also concern that loss of seagrass leads to a domino effect on the tourism and fishing industries as well as other ecosystems.

Soft bottom systems

Despite their 'barren' appearance, sandy and soft-sediment seabeds are complex and diverse habitats. Many animals in these habitats are cryptic (not easily distinguishable as separate species), burrowing and often nocturnal. As well as the larger invertebrates and fish species found in these habitats, a diverse and little studied range of plants and animals live within the 'gaps' between the sand grains.

Knowledge of subtidal soft-sediment habitats has been enhanced by several major studies on the soft-sediment communities of metropolitan Adelaide and Boston Bay, Port Lincoln (Cheshire et al. 1998a,b). Some examined the ecological effects and environmental impacts of sand dredging (Cheshire and Kildea 1993; Cheshire et al. 2002; Edyvane 1999b) and the effects of wastewater discharges on benthic communities at Christies Beach (Loo 2001).

Studies in Australia and overseas have demonstrated that bottom trawling activities (such as prawn trawling) modify or destroy habitat significantly, with resultant changes in the structure or composition of benthic communities (Edyvane 1999b; Tanner 2005). Further research is required on productivity, ecological processes and the role of soft-sediment communities in nearshore coastal ecology and dynamics (i.e. position in the food chain and species interdependencies) (Edyvane 1999b).

Benthic communities definition

The group of organisms inhabiting the region on the bottom of a body of water, such as an ocean

Deep water habitats

The distribution of deeper water habitats or communities is influenced by the bottom type, depth, light and physical water conditions. As water depth increases and available sunlight reduces, habitats are dominated by animal communities rather than marine plants. Gulf St Vincent has a maximum depth of 40 metres with Backstairs Passage having areas with depths of 50–60 metres.

Large areas of deeper water seagrass (20–40 metres depth) and marine fauna communities of Gulf St Vincent appear to have been lost, or extensively modified in the last 30 years, particularly in areas of prawn trawling. The deep tidal race waters of Backstairs Passage host a range of deep water sponge gardens and other invertebrate communities (Adelaide and Mount Lofty Ranges NRM Board 2008).

Marine algae

A large number of macroalgae species (748) are recorded in this subregion, which is likely to reflect the larger sampling effort during earlier decades of the twentieth century rather than a truly smaller species richness in other NRM regions. However, the biodiversity of canopy-forming brown algal species is one of the highest across the state (~40 species) and contributes to a high overall macroalgal biodiversity in this subregion (Adelaide and Mount Lofty Ranges NRM Board 2008).

A possible 21 macroalgae species may qualify for some formal conservation status listing in South Australia and/or nationally. Several macroalgae are recorded in our region that have not been seen in other parts of South Australia. Some are found nowhere else on the planet.

'Regional hot spots' of possibly rare species (including South Australian endemics) are concentrated in the most frequently, or most intensively, sampled areas, such as Port Noarlunga area, Aldinga and Encounter Bay (where there are aquatic reserves). Four potentially rare species have been recorded from the Outer Harbor area, which is a highly modified and industrialised area next to a major port facility. The report also identifies a range of species of possible 'cryptogenic origin' (i.e. broadly distributed), and it is not known whether they are native to South Australia, or were introduced during the 1800s or 1900s.

Warming of the ocean due to climate change reduces the resilience of macroalgae to other stresses such as pollution. Extreme events, such as storms, will increase in frequency and magnitude and impact on the distribution of species, essentially resulting in erosion of the sea floor (similar to that observed on land when soil cover is disturbed or reduced).

Marine fauna

Marine fauna are a significant but less studied component of overall biodiversity. The conservation status of most marine fauna in South Australia is not well known. Vertebrate species (such as marine mammals, shore birds and seabirds, and a number of commercial and recreational fish species) have been the focus of research or management. As such, information is available to determine condition and trends of some populations. However, assessments at a regional level are usually lacking.

Current knowledge of marine invertebrates and zooplankton is more limited. A review of 17 major marine invertebrate taxonomic groups (of potential conservation concern) assessed taxonomy, distribution, habitat, depth range, relative abundance and apparent conservation status. Members of 16 of the groups (with the apparent exception of Aplacophora, a small group of shell-less worm-like molluscs) have representatives in the region that may be considered of conservation concern.

At least 143 marine invertebrate species from 16 taxonomic groups may meet criteria for consideration as rare, threatened or vulnerable species; or there is insufficient data and further information (and a precautionary approach) is needed.

With the exception of marine mammals and seabirds, marine species have received little formal protection or conservation. The exploitation of fish, and some invertebrates, is managed under the Fisheries Management Act and some species are protected under this legislation. All syngnathid fish (seahorses, pipefishes, and the weedy and leafy sea dragons) in South Australia are listed as protected under the Fisheries Management Act.

Basic species inventories exist for many marine species but there is little baseline population data for species other than the commercially exploited, those visible at the sea surface or those that come ashore to breed (seals, birds, marine reptiles).

Little penguins and fur seals

Recent monitoring of populations of Little Penguins and fur seals has indentified that populations of Little Penguins on Granite Island have declined by 23% each year since 2001. At West Island a similar decline in penguin populations has been observed since 1992 (Wiebkin 2011)

Penguins are susceptible to numerous threats including disturbance by people and pets, noise and light, entanglement in fishing lines and nets, depletion of food sources, predation by native animals, domestic pets and feral animals, loss of habitat, pollution and degradation of coastal and marine systems. Protection and management of penguins is important not only for environmental reasons, but also for their contribution to the economy through tourism.

New Zealand Fur Seal population surveys have indicated that the population seems to be recovering rapidly over the last 30 years as a result of the halt of sealing. There are some concerns about managing fur seal populations to reduce their possible impact on penguin numbers; however, further work on the interactions between fur seals and penguins and also penguins and other threats is required. Many other management options could minimise the impact of other threats on penguin populations (Wiebken 2011).

The impacts of climate change are likely to manifest in all populations of fauna, with warmer water temperatures likely to have a profound influence on the distribution of marine mammals. A range of species will be influenced by changes in the food chain. Evidence suggests that sea surface temperatures

influence the reproductive success of marine mammals. For seabirds, warming will affect the timing and success of breeding, and changes to food chain species will impact on their range and foraging ability. Species will, where possible, adapt through moving with the changing climate regime and changes to ecosystems (Poloczanska et al. 2012).

Offshore islands

The larger or more significant offshore islands in the subregion are listed below:

- **Torrens Island and Garden Island** are sandy islands in the Adelaide Dolphin sanctuary. Both have mangrove stands on the eastern and southern sides and show central areas of samphire and cyanobacterial mud (covered by dumped urban waste on Garden Island).
- Torrens Island is a Conservation Park and home to the Torrens Island Power Station which takes in cooling water from the Port River and discharges thermal effluent to Angas Inlet.
- Garden Island has been used extensively as a garbage dump, and is now used for methane retrieval. A yacht marina and fisherman's boardwalk fringe the island.
- Controlling weeds and maintaining the condition and extent of the existing native vegetation are high priorities on the islands
- **Section Bank (Bird Island)** at Outer Harbor supports significant breeding populations of seabirds, particularly Australian Pelican, and roosting and feeding habitat for migratory shorebirds and oystercatchers. Coastal action planning identifies the need to facilitate management of the Section Bank through clarification of its conservation status.
- **Granite Island and West Island** are granitic islands in the Fleurieu Peninsula.
- Granite Island is a Recreation Park characterised by huge granite boulders tinged with orange lichen and its Little Penguin colony. Its proximity and connection to Victor Harbor across a wooden causeway make it one of the most visited parks in South Australia.
- West Island is a Conservation Park and included in the West Island Aquatic Reserve and a haul out site for New Zealand Fur Seals. The 10 hectares of the island is mainly granite rock with a significant amount of soil on the top of the island. There are no beaches making landing difficult. Vegetation is mainly salt tolerant groundcovers; on the sheltered eastern slopes Drooping Sheoak (*Allocasuarina verticillata*) and Coastal Teatree are found.
- Both these islands support other penguin predators including: native water rats, non-native black rats and White-Bellied Sea-eagles. The introduced population of (native) Brush-Tailed Possums on Granite Island may also be predators. West Island also has infestations of Kikuyu grass which is known to entangle and kill penguins and block burrow entrances.

Protecting seabird breeding sites

Significant colonies of Fairy Terns (*Sternula nereis*), Pelicans (*Pelecanus conspicillatus*) and Black-faced Cormorants (*Phalacrocorax fuscescens*) use the Section Bank as breeding site. This is currently the only breeding site for these species within the AMLR region. The relative isolation from land based predators has protected these species from impacts of foxes, dogs and cats. The island also has a diversity of suitable breeding habitats. Recent incursion of foxes onto the island has resulted in up to 85% mortality of pelican nests in some years (Greg Johnston pers. comm.).

Livelihoods

Fishing

Commercial fisheries contribute $7.6 million in Gross Regional Product. The main fisheries are:

- **Gulf St Vincent Prawn Trawl Fishery** for Western King Prawn, and by-product catches of Slipper Lobster and Calamari
- **Marine Scalefish Fishery** for a number of invertebrate species such as Calamari, Cuttlefish, Sand Crab, Blue Crab, Goolwa and Mud Cockles
- **Australian Sardine Fishery** taking a range of small pelagic fish, including Sardine (Pilchard), Anchovy, Sprat and Round Herring in Gulf St Vincent waters.

Charter boats, although not classified in commercial fishery activities, are run by commercial operators relying on fisheries and fisheries management for their livelihoods. The main species of fish retained by charter boats in the Gulf St Vincent–Kangaroo Island region are Bight Redfish, King George Whiting and Snapper (Knight and Vainickis 2011).

Recreational fisheries are important socially and economically. The Adelaide area contains the highest number of recreational fishers in South Australia (20% of all Adelaide residents or 65% of the state total). A large percentage of the state's recreational fishing effort (33%) occurs in Gulf St Vincent, most of it less than 5 km from shore. Of the 38,000 recreational vessels in SA, 18,300 (47%) are owned by residents in the Adelaide area (Adelaide and Mount Lofty Ranges NRM Board 2008). The impact of recreational fishing on fish stocks and the environment is less monitored and managed than that of commercial fishing – a significant gap in the knowledge of marine fish populations and habitat condition.

Further community awareness and education of all marine users is needed. A key activity related to the establishment of marine parks is to work with recreational fishing groups to inform and educate fishers about marine parks and encourage stewardship across the community for marine environments. Management and regulation of marine fish species is limited to a number of primary and secondary species with few or no commercial or recreational fishing restrictions for a range of other fish species (rays, stingrays, stingarees and skates, Gurnard Perches and Scorpionfishes, Leatherjackets, Estuary Catfish, Harlequin Fish, Rock Ling, Boarfishes, Luderick, Knifejaw, Dusky Morwong, Black-Banded Sea Perch and recreational catches of Blue-throated and other wrasses, Smooth Hammerhead Dogfishes and Wobbegong Sharks) (Baker 2007).

There is a need for continuing support to understand and monitor some reef fish and other species that may have strong site fidelity of small home ranges (Blue Devil and Harlequin Fish). These characteristics, as well as long life span and limited recruitment, may make some species vulnerable to localised depletions and threats (Bryars 2010, 2011; Bryars et al. 2012). As well as current marine park sanctuary zoning, investigation into regulation of take on some species of conservation concern is warranted.

The limited marine aquaculture in the region includes an onshore commercial hatchery licensed for Barramundi, Murray Cod, Silver Perch, Yellowtail Kingfish and Golden Perch (at West Beach) and the SARDI research facility licensed for Pacific Oyster.

Climate change impacts from increased temperatures on temperate and pelagic fish will cause changes to habitats and increased pressure from pests and disease. With increased ocean temperatures, tropical species are expanding south displacing pelagic species vital to fisheries. Temperate fish dependent on estuarine environments will also be affected by reduced freshwater flows into these environments, with water flow management becoming important.

Tourism

Marine based tourism adds significantly to local economies and includes ecotourism, fishing, surfing, diving, boating and marine wildlife viewing. The cultural and artistic opportunities around the marine environment, while difficult to measure, contribute to the value of the marine system.

Examples of tourism activities, and the relevant component of the marine system, include:

- recreational dive industry; rocky reefs and marine wildlife
- cruises and dolphin swims; Indo-Pacific Bottlenose Dolphins
- whale watching; Southern Right Whales
- bird watching; coastal systems including saltfields.

Marine tourism requires careful management to minimise impacts on the very thing being observed. For example, whale and dolphin watchers must maintain a certain distance from the animals to ensure they are not disturbed or endangered by boats. Recreational activities in the marine environment can also impact on the coastal environment as the access points to the ocean become more heavily used. The potential for degradation of coastal habitats, introduction of pests and pollution threats increases as use increases.

Management of the marine system ensures tourism opportunities are maintained and improved, and contributions to the local economy continue. Commercial tourism activities are easier to regulate and manage than the same activities conducted privately by individuals. The impacts of these individuals could be much greater than the commercial activity if they are unaware of the rules. Their impacts may also be much greater than thought because their numbers are not considered in the regulation of commercial activities.

Shipping and port facilities

Port Adelaide is the main service point for shipping in South Australia. During 2011–12, 15.67 million tonnes of cargo was moved through the port and 2.4 million tonnes of petroleum was imported (Flinders Ports South Australia 2013). As a significant contributor to the economy of the state, the port and marine environment surrounding it are important infrastructure. Potential threats to the marine system from this activity, particularly risks from oil spills and spread of marine pests from ballast water, need to be considered and managed.

Mining

The gulf has been explored for petroleum. There are no current exploration licences/tenements but some areas are under consideration (www.petroleum.pir.sa.gov.au/__data/assets/pdf_file/0003/28551/p01.pdf). In the 1990s, exploration was marred by the collapse of the mobile offshore drilling unit, Maersk Victory rig in western Gulf St Vincent in 1996 offshore of Edithburgh. The footings of the rig were left in a prawn fishing area, hindering prawn trawling activities (SECITARC 2000).

PLANNING AND IMPROVEMENT

Natural resources management policy, planning and delivery occur in a dynamic environment that will change throughout the life of this strategic plan. The *Natural Resources Management Act 2004* requires the plan to be reviewed within ten years of adoption, and two additional activities influence the requirement to change, modify or update this plan:

- new evidence that changes our understanding of how the systems in our region operate
- unplanned changes, shocks and drivers.

To ensure a rapid and reasonable reaction to these sources of change, this plan needs to have a rigorous continuous improvement process supporting it that includes:

- sound evidence base and evidence plan management
- implementation of a monitoring, evaluation, reporting and improvement (MERI) plan
- an adaptive management approach.

Evidence plan

The understanding about systems and their dynamics in this plan has been developed using the best available evidence. Knowledge gaps remain due to the complexity of natural resources management in the region, but building the evidence base underpinning the plan gives a more robust approach to investment and works decisions. The evidence base is initially available as a reference list for each section of the plan (see Reference list).

Some assumptions about the dynamics of systems have been made in this plan. They, and their potential impacts, are managed through a risk assessment framework. Assumptions that have low impact on the content and outcomes of a system dynamic are tagged as low risk; assumptions that have the potential to completely change the understanding of a critical aspect of a system dynamic are tagged as high risk. This process requires an assessment of the confidence in the quality of the evidence available to support the understanding of a system dynamic.

High confidence in the evidence or a low risk attached to the assumptions made about systems requires ongoing surveillance monitoring to ensure a system is retained in a desired state. Low confidence in the evidence or a high risk attached to the assumptions made about a system requires specific research, investigations and monitoring to build confidence in the evidence base and minimise risks associated with assumptions (Figure 53).

Adaptive management

Adaptive management is a structured, iterative process of robust decision making in the face of uncertainty. It integrates project/program design, management and monitoring to systematically test assumptions in order to adapt, learn and improve. In its simplest form adaptive management is a plan-do-learn cycle, which is very powerful when an evidence based approach is incorporated. The adaptive management strategy relies on a planned process that identifies new and emerging social (including cultural), environmental and economic changes, and evidence used to test the assumptions made in developing the understanding of the systems in the region (Figure 53). The testing of assumptions with the new evidence may generate changes to the understanding of the systems of the region. The strategic plan is then adapted by linking the new evidence to the understanding of the systems. Specifically it identifies whether new ideas or modifications to existing delivery approaches need to be considered in light of the new evidence. Ongoing monitoring and evaluation of the impacts of interventions also feed back into the planning cycle.

Because adaptive management is based on a learning process, it improves management outcomes. The challenge in using the adaptive management approach lies in finding the correct balance between gaining knowledge to improve management in the future and achieving the best short-term outcome based on current knowledge.

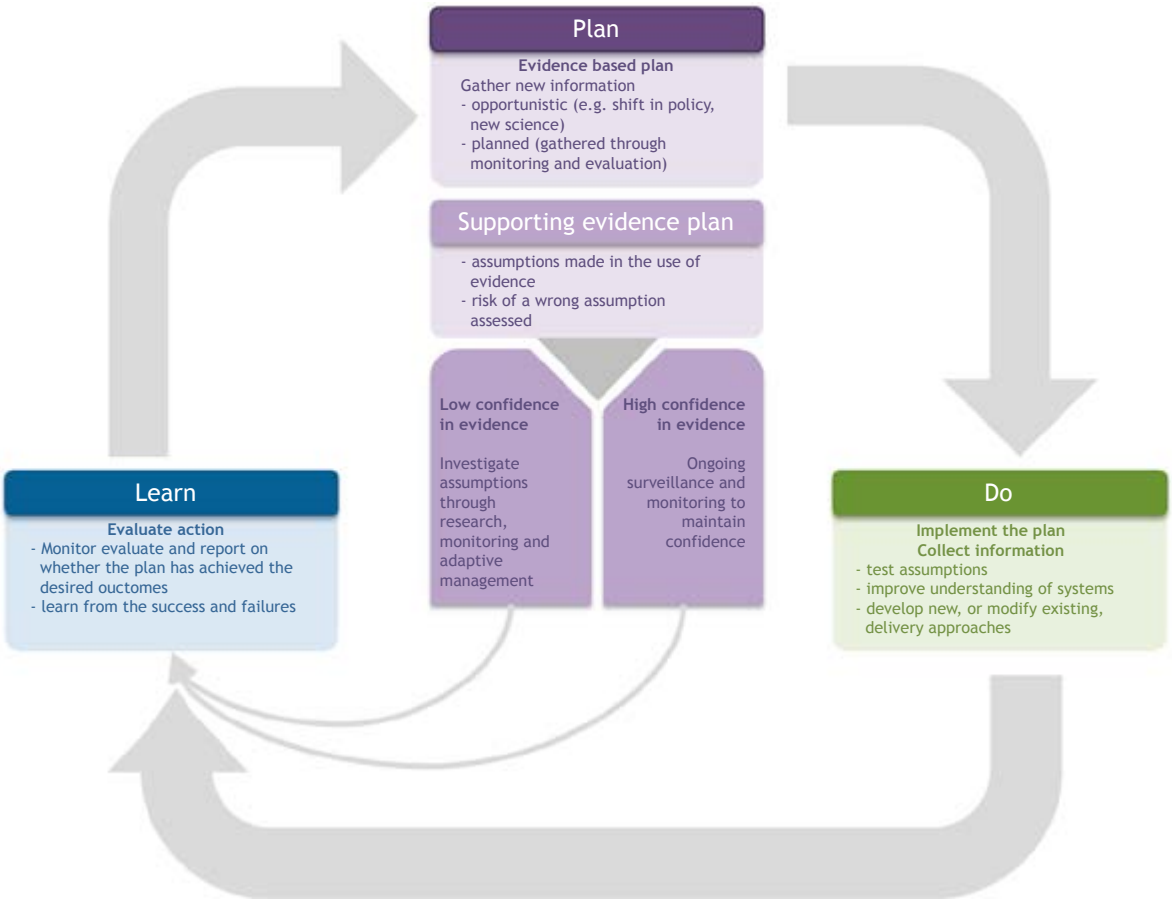


Figure 53: Continuous improvement approach to support adaptive management and evidenced based natural resources management planning.

Monitoring, Evaluation, Reporting and Improvement (MERI) Plan

Monitoring, evaluation, reporting and improvement is critical to the successful implementation of the regional plan. Monitoring and evaluation ensures outcomes of investment, and new information and research, are incorporated into the understanding of how systems operate in the AMLR, and provides information on the achievement of targets and goals. Reporting to stakeholders on the outcomes of investment is critical to building an understanding of the value of NRM and investing in NRM. Reporting takes many forms and needs to cover all scales of activity from individual project outcomes to reporting achievement against goals and targets. Improvement is integral to ensuring investment and activity achieve the goals and targets set. Evidence based planning and adaptive management are integral components of an improvement process which ensures that information and knowledge is fed back into the planning cycle in a meaningful way that achieves change as required.

The full MERI Plan includes both strategic and operation approaches. The MERI Plan will be a 'living' and supporting document to the Regional Plan, it will be reviewed regularly to reflect key changes and learnings. A MERI Plan that sets out the approach required to help achieve the AMLR strategic plan is summarised here.

Development and implementation of the MERI Plan is guided by the following principles:

- Monitoring should build on existing data, providing baselines
- Monitoring should provide information to test assumptions about regional plan system dynamics
- Evaluation is planned and implemented using sound project management processes and all project participants should participate in evaluation actions
- Evaluation is designed to meet a range of needs, is fit for purpose and may involve external assessment
- Reporting is designed to communicate the outcomes of investment in NRM and will do so through a number of different reporting forms to suit the needs of individual audiences (where practicable)
- Improvement in knowledge and practice results from evidence gathered through monitoring of investment programs and external sources
- Improvement through adaptive management is a fundamental pillar of the Regional Plan
- Lack of knowledge should not hinder decision making and action to protect natural resources and should be managed by adopting sound risk management approaches
- MERI is integrated into all programs and projects and is not an end point but a key part of adaptive management
- Long-term outcomes are monitored as a priority rather than short-term outputs
- Multiple lines and layers of evidence are used to evaluate and inform decisions.

Implementation of the MERI Plan should also trigger review and amendment processes of the Strategic Plan outside of the legislative review requirements when new information results in a fundamental change in the understanding of the dynamics of regional and subregional systems. Major changes in the understanding of regional and subregional systems will prompt amendment of the Strategic Plan to ensure it contains the most up to date evidence. This evidence supports decision making about where resources are best applied to achieve the desired outcomes for natural resources. Community values may also influence investment decisions and should be considered along with the evidence base. Applying the principles of the Strategic Plan (detailed in section 1.2) to the decision making processes will support achieving the desired natural resource outcomes for all stakeholders.

ABBREVIATIONS AND REFERENCES

Abbreviations

AMLR	Adelaide and Mount Lofty Ranges
AMLR NRMB	Adelaide and Mount Lofty Ranges Natural Resources Management Board
BIL	Barossa Infrastructure Limited
CBD	central business district
CP	conservation park
CRP	current recommended practice
DENR	Department of Environment and Natural Resources
DEWNR	Department of Environment, Water and Natural Resources
DMITRE	Department for Manufacturing, Innovation and Trade
DPTI	Department of Planning, Transport and Infrastructure
EPA	Environment Protection Authority, South Australia
GDE	groundwater dependent ecosystem
KNYA	Kungun Ngarrindjeri Yunnan Agreement
MAR	managed aquifer recharge
MERI	monitoring, evaluation, reporting and improvement
MoU	memorandum of understanding
NAP	Northern Adelaide Plains
NGO	non-government organisation
NPW SA	National Parks and Wildlife South Australia
NRM	natural resources management
PIRSA	Primary Industries and Resources, South Australia
PWA	prescribed wells area
PWRA	prescribed water resources area
T1, T2	tertiary aquifers
WAP	water allocation plan

References

The following references are cited in the text of this document. Further evidence to support the development of the regional conceptual models and the case studies for each model can be found in the Zotero catalogue. Instructions for accessing the catalogue can be found at

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APPENDIX A: POLICY CONTEXT FOR THE PLAN

This plan is part of an extensive framework of national, state and regional policies and plans. Some key policies and plans of relevance are highlighted in this appendix.

Natural resources management planning in South Australia

Natural resource management in South Australia is guided by the *Natural Resources Management Act 2004* (the Act). The Act sets out the natural resources planning hierarchy, which includes the state and regional natural resources management plans. It also describes the roles of the Natural Resources Management Council and the eight regional natural resources management boards.

South Australia's Strategic Plan

South Australia's Strategic Plan (SASP) is intended to provide direction to government, business and community organisations on the future of South Australia. The SASP was revised in 2011, and contains 100 measurable targets that reflect the priorities of the state. A number of these targets are of relevance for natural resources management, and therefore, the plan. The SASP guides the State NRM Plan and Regional NRM Plans. Key targets of the SASP that are relevant to the plan are:

- **62.** Climate change adaptation: Develop regional climate change adaptation plans in all State Government regions by 2016
- **68.** Urban development: By 2036, 70% of all new housing in metropolitan Adelaide will be being built in established areas
- **69.** Lose no species: Lose no native species as a result of human impacts
- **70**. Sustainable land management: By 2020, achieve a 25% increase in the protection of agricultural cropping land from soil erosion and a 25% improvement in the condition of pastoral land
- **71.** Marine biodiversity: Maintain the health and diversity of South Australia's unique marine environments
- **72.** Nature conservation: Increase participation in nature conservation activities by 25% by 2015
- **73.** Recycled stormwater: South Australia has the system capacity to harvest up to 35 GL of stormwater per annum by 2025
- **74.** Recycled wastewater: South Australia has the system capacity to recycle up to 50 GL of wastewater per annum by 2025
- **75.** Sustainable water use: South Australia's water resources are managed within sustainable limits by 2018.

State Natural Resources Management Plan (2012–2017)

The State Natural Resources Management Plan, *Our Place, Our Future*, sets the strategic blueprint for natural resources management in South Australia. The State Plan aims to integrate the management of natural resources more closely with regional development and primary production, and provide an efficient and relevant management system. It also takes a 'landscape-scale' approach to natural resource management across public and private land.

Regional natural resources management plans (such as this one) are required to be consistent with the State Plan under the Act. The State NRM Plan provides guidance through vision and goals, guiding targets (Table A1), high level indicators and representative measures. This plan is consistent with the broad intent of the State Plan, as described through its vision, goals and targets.

Table A1: State NRM Plan goals and guiding targets

VISION: *WE CARE FOR THE LAND, WATER, AIR AND SEA THAT SUSTAIN US*	
Goals	**Guiding targets**
Goal 1: People taking responsibility for natural resources and making informed decisions	1. Ensure people are better informed and improve capacity in NRM decision making
	2. Involve more people in the sustainable management of natural resources
	3. Improve institutional and organisational capacity to support people to manage natural resources
	4. Improve capacity of individuals and community to respond to climate change *(pressure target)*
Goal 2: Sustainable management and productive use of land, water, air and sea	5. All NRM planning and investment decisions take into account ecological, social and production considerations
	6. Maintain the productive capacity of our natural resources
Goal 3: Improved condition and resilience of natural systems	7. Improve soil and land condition
	8. Increase extent and improve condition of native vegetation
	9. Improve condition of terrestrial aquatic ecosystems
	10. Improve condition of coastal and marine ecosystems
	11. Increase understanding of the condition of landscapes (geological and culturally important features. *(knowledge gap target)*
	12. Improve the conservation status of species and ecological communities
	13. Limit the establishment of pests and diseases and reduce the impacts

Climate change

Climate change is described a change in the average pattern of weather over a long period of time. There is clear evidence that the climate is changing. The Fourth Assessment Report, produced by the Intergovernmental Panel on Climate Change (IPCC) in 2007, states that global warming is:

- 'unequivocal'
- 'most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in greenhouse gas concentrations'.

The fifth assessment report released by the IPCC in 2013 indicates that the understanding of the climate system has only continued to strengthen since the 4th assessment report and it is more certain than ever that increasing global temperatures since 1950 have been caused primarily by human activities

Climate change science considers the climate system as a whole - the atmosphere, the oceans and the cryosphere (ice, snow and frozen ground). The IPPC report indicates that the climate system is continuing to warm, including increasing land temperatures and warming oceans. Climate change is not just about global warming; the science indicates that the climate will also be altered in many other ways.

For example, there will be changes in:

- rainfall patterns
- ocean currents
- the intensity and frequency of extreme events (such as storms, droughts and floods)
- rising global sea level
- ocean acidification.

Securing a clean energy future

The Australian Government is responding to climate change through a wide range of measures as documented in the Australian Government's Climate Change Plan *Securing a clean energy future* (the CCP).

The CCP plan includes:

- introducing a carbon price
- promoting innovation and investment in renewable energy
- encouraging energy efficiency
- creating opportunities in the land sector to cut pollution.

The section of the CCP related to creating opportunities in the land sector is particularly relevant to natural resources management, and therefore the plan. The Carbon Farming Initiative (CFI) is a key program that will provide economic rewards for land managers who take steps to reduce carbon pollution. It will do this by creating credits for each tonne of carbon pollution which can be stored or reduced on the land. CFI projects may include activities such as:

- reforestation
- forest management and native forest protection
- landfill gas recovery
- manure management
- management of methane from livestock and storage of carbon in soils and biochar.

In addition, the Australian Government has established the Biodiversity Fund to provide incentives for carbon farming projects that deliver biodiversity benefits. The Biodiversity Fund will invest around $946 million, over six years, to help land managers:

- store carbon
- enhance biodiversity
- build greater environmental resilience across the Australian landscape, including restoring, managing and better protecting biodiversity on public and private land.

Both the CFI and the Biodiversity Fund provide opportunities for the funding of actions with a carbon benefit in the region.

Adapting to climate change in Australia

It is important that Australia reduce its carbon pollution to minimise the severity of climate change. However, because some greenhouse gases stay in the atmosphere for significant time periods (100 years), some changes cannot be avoided due to past and future global emissions.

The Australian Government's position paper, *Adapting to Climate Change in Australia*, sets out the government's vision for adapting to the impacts of climate change and proposes practical steps to realise that vision. It outlines the Australian Government's role in adaptation which includes:

- building community resilience and establishing the right conditions for people to adapt
- taking climate change into account in the management of Commonwealth assets and programs
- providing sound scientific information
- leading national reform.

The position paper identifies six national priority areas for action: water, coasts, infrastructure, natural ecosystems, natural disaster management, and agriculture.

The plan also considers requirements for adaptation in the region, and takes into account the national priorities outlined in *Adapting to Climate Change in Australia*.

A climate change adaptation framework for South Australia (August 2012)

The climate change adaptation framework *Prospering in a Changing Climate* is the South Australian Government's climate change adaptation strategy. It sets the foundation for South Australians to develop well informed and timely actions, to be better prepared for the impacts of climate change.

This framework will guide actions taken by business, the community, non government organisations, the research sector, local governments and state government agencies to develop well informed and timely adaptation responses. Therefore the framework needs to be considered in the development and implementation of the plan.

Implementation of the framework will be guided by principles that describe how adaptation responses will be prioritised, developed and delivered. The principles of this framework are consistent with the principles for adaptation described in section 3.2.7 of this plan.

The framework recognises that climate change and its economic, social and environmental impacts will vary across South Australia and therefore, provides for the development of locally relevant adaptation responses. These are being developed based on existing State Government regions. The following regions are within the Adelaide and Mount Lofty Ranges NRM region:

- Barossa
- Northern Adelaide
- Eastern Adelaide
- Western Adelaide
- Adelaide Hills
- Southern Adelaide
- Fleurieu and Kangaroo Island.

Preparing for climate change will require local organisations and State Government agencies to work with communities to assess climate change risks and opportunities, determine priorities and develop adaptation action plans. The first stage is the development of 'regional integrated vulnerability assessments' to understand the sectors and systems that are most at risk.

Water resources

The Adelaide and Mount Lofty Ranges region has significant surface and groundwater resources. The water resources of our region support industry and agriculture, as well as being a significant contributor to the water supply for metropolitan Adelaide. The use and management of water resources is governed by a number of national and state policies, which are outlined below.

National Water Initiative

The Council of Australian Government's principle water policy agreement is the *National Water Initiative* (NWI). The agreement sets out the blueprint for water reform across Australia. Through it, governments across Australia have agreed to actions that achieve a more cohesive national approach to the way Australia manages, measures, plans for, prices and trades water.

Under the NWI, governments (including the South Australian government) have made commitments to:

- prepare water plans with provision for the environment
- deal with over-allocated or stressed water systems
- introduce registers of water rights and standards for water accounting
- expand the trade in water
- improve pricing for water storage and delivery
- meet and manage urban water demands.

This agreement will, in part, be met by a number of actions in our plan.

Water for Good

To ensure the state's water future to 2050 and beyond, the South Australian Government developed South Australia's water security plan, *Water for Good* (WfG).

Released in June 2009, WfG outlines 94 actions aimed at ensuring that water supplies are secure, safe, diverse, reliable and able to sustain a growing population, as well as a growing economy in a changing climate.

Water for Good is presented under a number of headings, with key outcomes identified for each heading. Some of the key outcomes of relevance to this our plan are outlined below. Further information on the actions to support these outcomes is documented in WfG. Key outcomes include:

- The challenges of demand and supply:

  Outcome: regional water demand and supply plans are regularly and robustly reviewed and updated.

- Managing our water future (rain, rivers, reservoir and aquifers):

  Outcome: All of South Australia's natural water resources – surface, ground and watercourses – are managed within sustainable limits.

  Outcome: Drinking water catchments are adequately protected.

  Outcome: Through actions undertaken to secure future water supplies, any further expansion of storage capacity within the Mount Lofty Ranges (MLR) will not be needed until at least 2050. However, our adaptive planning framework will review this option by 2025.

- Stormwater recycling:

  Outcome: In 2013, Government and private sector partnerships are capable of harvesting 20 GL/yr of stormwater in Greater Adelaide, for non-drinking purposes more than doubling our current harvesting capacity.

  Outcome: Target up to 35 GL/yr of stormwater to be harvested in South Australia, for non-drinking purposes, by 2025. This will be achieved in partnership with other governments and the private sector, where verifiable geological data has identified suitable locations, and where cost-effective projects can be undertaken.

  Outcome: Target up to 60 GL/yr of stormwater to be harvested in Adelaide, and up to 15 GL/yr in regional South Australia, by 2050. This will be achieved in partnership with other governments and the private sector, where verifiable geological data has identified suitable locations, and where cost effective projects can be undertaken.

- Wastewater recycling

  Outcome: Capability to recycle 45% of urban wastewater by 2013.

  Outcome: Capacity to recycle 50 GL/yr of wastewater in South Australia, for nondrinking purposes, by 2025.

  Outcome: Capability to recycle a minimum of 75 GL/yr of wastewater recycled in South Australia, for non-drinking purposes, by 2050.

- Using and saving water:

  Outcome: All householders use water wisely following the lifting of water restrictions. Greater Adelaide has a target to use 50 GL/yr less water in 2050 than would have been the case without the actions in this Plan.

Outcome: All water users, including industry and agriculture, applying best practice water use and management approaches.

Outcome: The South Australian community has an enhanced level of awareness of water issues and has taken actions to address water issues and save water, such that we are known internationally as a water sensitive state.

- Planning:

  Outcome: Adaptable, efficient and enduring water supply and management options are delivered within an environmentally sustainable framework that is supporting economic prosperity, population growth, and an enhanced quality of life for all South Australians.

  Outcome: Mandatory water-sensitive urban design for new residential and commercial urban development dovetails with the Plan for Greater Adelaide.

Biodiversity

Biodiversity, or biological diversity, is the variety of all life forms. There are three levels of biodiversity:

- genetic diversity — the variety of genetic information contained in individual plants, animals and micro-organisms
- species diversity — the variety of species
- ecosystem diversity — the variety of habitats, ecological communities and ecological processes.

Biodiversity occurs in all environments on Earth - terrestrial, aquatic and marine. Biodiversity is not static; it is constantly changing. It can be increased by genetic change and evolutionary processes, and it can be reduced by threats which lead to population decline and extinction. Biodiversity, in Australia, is currently declining because of the impacts of a range of threats.

Conserving biodiversity is an essential part of safeguarding the biological life support systems on Earth. All living creatures, including humans, depend on these life support systems for the necessities of life. For example, we need oxygen to breathe, clean water to drink, fertile soil for food production and physical materials for shelter and fuel. These necessities can be described collectively as ecosystem services. They are fundamental to our physical, social, cultural and economic wellbeing.

Australia's Biodiversity Conservation Strategy (2010–2030)

Australia's Biodiversity Conservation Strategy 2010-2030 is a guiding framework for conserving Australia's biodiversity over the coming decades. It replaces the 1996 *National Strategy for the Conservation of Australia's Biological Diversity,* which was developed to fulfil Australia's obligations under the 1993 *United Nations Convention Biological Diversity*. The strategy is designed to provide a roadmap for all Australians to become involved in biodiversity conservation. It also ensures that implementation is a shared responsibility across all levels of government, the community and the private sector. It is, therefore, relevant to consider in the development and implementation of this plan.

The strategy highlights three priorities for action to help stop the decline in Australia's biodiversity:

- Engaging all Australians through: mainstreaming biodiversity; increasing indigenous engagement; and enhancing strategic investments and partnerships.

- Building ecosystem resilience in a changing climate by: protecting biodiversity; maintaining and re-establishing ecosystem functions; and reducing threats to biodiversity.
- Getting measurable results through: improving and sharing knowledge; delivering conservation initiatives efficiently; and implementing robust national monitoring, reporting and evaluation.

The strategy is also underpinned by the following set of principles:

- We share the Earth with many other life forms that have intrinsic value and warrant our respect, whether or not they are of benefit to us.
- Biodiversity is best conserved by protecting existing natural habitats.
- Effective conservation of biodiversity operates at the landscape and seascape scale across public and private tenures.
- Natural ecosystems are dynamic but have a finite capacity to recover from external threats, impacts and pressures.
- Building resilience recognises the critical links between ecological and social systems.
- All Australians benefit from biodiversity; all Australians can and should contribute to its well-being.
- Our efforts to conserve biodiversity must acknowledge and respect the culture, values, innovations, practices and knowledge of Indigenous peoples.
- Knowing that our knowledge is limited, we should apply the precautionary principle while employing adaptive management approaches using new science and practical experience.

Both the priorities and the principles have been considered in the development of this plan.

Environment Protection and Biodiversity Conservation Act

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's key piece of environmental legislation which commenced 16 July 2000.

The EPBC Act enables the Australian Government to join with the states and territories in providing a truly national scheme of environment and heritage protection and biodiversity conservation. The EPBC Act focuses Australian Government interests on the protection of matters of national environmental significance, with the states and territories having responsibility for matters of state and local significance.

The objectives of the EPBC Act are to:

- provide for the protection of the environment, especially matters of national environmental significance
- conserve Australian biodiversity
- provide a streamlined national environmental assessment and approvals process
- enhance the protection and management of important natural and cultural places
- control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources

National Wildlife Corridors Plan

The *National Wildlife Corridors Plan* is an Australian Government initiative to support landscape connectivity. It recognises that connectivity is a fundamental requirement of healthy, productive landscapes.

Wildlife corridors are connections across the landscape that link up areas of habitat, while supporting multiple land uses such as; conservation, farming and forestry. Corridors can be of different sizes; ranging from small corridors created by local communities to large corridors that stretch across many different landscapes.

The Corridors Plan lays the foundation for a new, collaborative, whole-of-landscape approach to conserving Australia's biodiversity. It will help Australians reconnect with the environment, and make our landscapes healthier through a long-lasting network of wildlife corridors.

The Corridors Plan builds on *Australia's Biodiversity Conservation Strategy*, the National Reserve System (including Indigenous Protected Areas), climate change policies, and other public and private sector initiatives. It will guide and support individuals, private land managers, community groups, policy makers, planners and natural resource managers to develop and manage corridor initiatives.

An example of a small wildlife corridor might be a revegetated area along a creek that links two patches of forest. This allows wildlife to move between these patches to find food and shelter, as well as to support breeding.

Large-scale corridors might span tens or hundreds of kilometres, across multiple landscape types and jurisdictions. These typically require collaboration between a wide range of groups working in partnership to manage them. Many smaller wildlife corridor projects may be undertaken as part of a larger corridor initiative, each making an important contribution to connecting the landscape.

The corridor plan outlines the following five point plan of action:

- developing and supporting corridor initiatives
- establishing enduring institutional arrangements
- promoting strategic investment in corridors
- working with key stakeholders and supporting regional natural resource management (NRM) planning
- monitoring, evaluating and reporting.

The corridor plan is underpinned by the following guiding principles:

- Building wildlife corridors across Australian landscapes is a cooperative endeavour
- Corridors should be designed and implemented in ways that benefit local communities
- Healthy, functioning landscapes require connectivity at a variety of scales
- Effective corridors connect the landscape across a mosaic of land tenures and land uses without affecting property rights
- The design and location of corridors should be based on the best available information derived from scientific research, traditional Indigenous knowledge and practitioner experience
- Corridors should be designed to assist native species' adaptation to the impacts of climate change
- Corridor design recognises and manages for potential risks such as those posed by invasive species and fire

The corridor plan has been considered in the development of our plan.

No Species Loss: A Nature Conservation Strategy for South Australia (2007-2017)

The aim of the *No Species Loss Strategy* is to avoid the loss of further species in South Australia. The strategy defines what is required, within 10 years of its publication, to protect the State's species and ecosystems. The strategy also recognises that some of the damage we have done to our native ecosystems may take hundreds of years to repair, if this is possible at all.

This strategy seeks to inspire partnerships among community, industry and government groups to value nature; realising that people cannot flourish without the benefits and services for a healthy natural environment.

This strategy outlines five goals that must be achieved if we are to protect the state's native species from extinction. These are:

- conservation of South Australia's biodiversity
- community ownership and stewardship for biodiversity
- ecological knowledge that can influence decision making
- adjustment to the impacts of climate change
- active and integrated natural resources management partnerships.

Conserving Nature (2012-2020)

Conserving Nature: A strategy for establishing a system of protected areas in South Australia provides strategic direction for creating the state's terrestrial and inland aquatic protected area system. The purpose of the protected area system is the conservation of nature on public, private and Aboriginal land. It guides and assists decision-making by the State Government, non-government organisations and others, about where to establish new protected areas(or add to existing protected areas) so they achieve the best conservation and community outcomes. This strategy is of relevance to this plan, and in particular, to the protection of land, through a variety of mechanisms. Marine parks are not covered by this strategy.

This strategy has three main objectives:

- conserve the full range of ecosystems
- build the capacity of natural systems to adapt to climate change and other stressors
- protect places of special meaning for people.

This strategy also contains the following guiding principles for establishing protected areas:

- The protected area system should be comprehensive, adequate and representative of the full range of South Australia's biodiversity.
- Protected areas should be established to secure the long-term protection of South Australia's biodiversity and the natural systems and processes that are essential for clean air, water and soil.
- Protected areas should also be established to protect places and sites of special value to people, including sites of scientific, cultural and spiritual value.
- Large protected areas are more effective for conserving biodiversity than small ones, however a range of protected area sizes may be necessary to adequately represent the full range of South Australia's ecosystems.

- Resilience of protected areas to climate change and other stressors will be enhanced by connectivity tools such as ecological corridors between protected areas and adjacent landscapes of conservation value.
- The reserve management category assigned to a protected area should reflect the protected area's purpose and the values that are being protected.
- Protected areas should be managed to maintain and enhance their values, and be managed as an integral part of the broader socio-economic and cultural landscape.

NatureLinks

NatureLinks is a practical approach to conserving the State's native flora and fauna by managing and restoring large areas of habitat across the state. These areas of habitat, within broad 'biodiversity corridors', will enable native species to adapt and survive to environmental change.

NatureLinks recognises that a healthy and diverse environment is crucial to the State's social and economic well-being. It works with conservation organisations, land managers and local communities, to restore and manage stretches of land and sea across the breadth of each corridor. This includes existing conservation areas on public and private land, as well as seeking to expand these conservation areas.

There are five NatureLinks corridors connecting public and private lands across the state; the Cape Borda to Barossa NatureLink encompasses:

- the whole of Kangaroo Island
- Adelaide and Mount Lofty Ranges region
- the western portion of the South Australian Murray Darling Basin region.

NatureLinks promotes the following fundamental ecological principles to ensure the best long-term outcomes for healthy ecosystems:

- biodiversity conservation activities should be planned at landscape scale
- habitat restoration should be undertaken at large spatial scales
- species in fragmented landscapes should be managed as metapopulations (populations linked by the exchange of individuals)
- an ecological community approach to biodiversity conservation should be encouraged
- ecological restoration should be planned over long time scales
- biodiversity conservation activities should be underpinned by sound ecological knowledge.

NatureLinks also links to the National Wildlife Corridors Plan.

Marine Parks and planning

The *Marine Parks Act 2007,* proclaimed on 22 May 2008, paved the way for the establishment of a representative system of marine parks in South Australian waters to protect the marine environment from the increasing pressure that it is under.

A series of marine parks have now been established since the formation of this Act. The Encounter Marine Park and Upper Gulf St Vincent Marine Park are within our region.

Marine parks have management plans that assign zones in park for various purposes:

- *General Managed Use Zones:* allow ecological sustainable development and use.
- *Habitat Protection Zones:* allow activities and uses that do not harm habitats or the functioning of ecosystems. Buffer sanctuary zones.
- *Sanctuary Zones:* prohibit the removal or harm of native plants, animals or marine products to provide a high level of conservation.
- *Restricted Access Zones:* limit access to an area allowing a very high level of conservation and providing scientific reference sites.
- *Special Purpose Areas:* allow specified activities that would otherwise be prohibited in a particular zone.

Living with wildlife

Wildlife management is often thought of in terms of protecting and nurturing wildlife populations and the habitat they live in. However, wildlife management can also include managing conflict between wildlife and human interests. Changing land use and the increasing spread of suburbia means that wildlife is sometimes in conflict with humans when they compete for food, water, refuge and space.

For example, wildlife activity can have the following impacts:

- Animal behaviour threatening human safety: birds swooping to defend their young in the nest; hazard to aircraft safety from flocking birds congregating on or near runways; aggressive animals.
- Damage to the built environment or assets: chewing external timbers of buildings; digging up turf on sports ovals; fouling manufactured products, goods or fencing.
- Damage to the natural environment: overgrazing at newly planted sites; pruning and chewing branches of mature trees.
- Damage to crops, produce and horticulture: eating germinating cereal and/or grain crops; trampling crops; eating stock feed; eating fruit, vegetables and flowers.

The Department for Environment, Water and Natural Resources (DEWNR) has adopted the following principles for managing wildlife:

- wildlife and conservation are not confined to reserves proclaimed under the *National Parks and Wildlife Act 1972* (NPW Act)
- wildlife management must be based on sound ecological, environmental, social and economic factors such as:
  - **ecological factors** - species ecology, species conservation status, potential effects of management actions on a species and potential effects of climate change on species
  - **environmental factors** - the extent of damage/impact on the environment caused by wildlife
  - **social factors** - animal welfare, community sensitivities, values and expectations, needs of land managers, land managers and industry
  - **economic factors** - the extent of damage/impact being caused by wildlife
- the welfare of all native wildlife is intrinsically important
- land managers, land and resource managers, community and industry have a need to control the impact caused by wildlife to acceptable levels to protect their livelihoods, safety and biodiversity assets, where it is consistent with the objectives of the NPW Act.

Biosecurity

Biosecurity is the protection of the economy, environment, social amenity and public health from the negative impacts of pests and diseases.

Biosecurity management is complex, and any system will need to respond to increasing challenges that are changing its risk profile:

- a changing climate altering the range, habitat and spread of pests and diseases and increasing the potential for severe weather events to assist spread
- globalisation increasing the volume and range of products traded internationally, passenger movements and the subsequent risk of pests and diseases entering and establishing in Australia
- population spread, shifting demographics and changing land uses increasing the interface between urban and rural areas and the natural environment, making pest and disease management more complicated to deal with and increasing the risk of zoonoses impacting on human health.

Weeds and vertebrate pests jeopardise agricultural production and conservation values in many ways. They can:

- eat or compete with crops, pasture, livestock and native flora and fauna
- contaminate crops and seeds
- harbour and spread disease
- degrade the resource base on which production depends
- reduce the value of the conservation estate
- may be toxic to people, livestock or native animals.

The *Natural Resources Management Act 2004* contains a range of requirements for the control of pest animals and plants, therefore, biosecurity and the impacts of weeds and vertebrate pests on agricultural production and conservation is an important component of our plan.

Intergovernmental Agreement on Biosecurity (2012)

The goal of a national biosecurity system, as documented in the *Intergovernmental Agreement on Biosecurity,* is to minimise the impact of pests and diseases on Australia's economy, environment and community. It does this with specific resources targeted to manage risk effectively, while facilitating trade and the movement of animals, plants, people, goods, vectors and vessels to, from and within Australia.

The objectives of the national biosecurity system are to provide arrangements, structures and frameworks that:

- reduce the likelihood of exotic pests and diseases, which have the potential to cause significant harm to the economy, the environment, and the community (including people, animals and plants), from entering, becoming established, or spreading in Australia
- prepare and allow for effective responses to, and management of, exotic and emerging pests and diseases that enter, establish, or spread in Australia
- ensure that, where appropriate, significant pests and diseases already in Australia are contained, suppressed or otherwise managed.

The following principles underpin the national biosecurity system:

- Biosecurity is a shared responsibility between all government, industry, natural resource managers, custodians or users, and the community.
- In practical terms zero biosecurity risk is unattainable.
- The pre-border, border and post-border elements of the biosecurity continuum are managed to minimise the likelihood of biosecurity incidents and mitigate their impacts.
- The biosecurity continuum is managed through a nationally integrated system that recognises and defines the roles and responsibilities of all sectors and sets out cooperative activities.
- Activity is undertaken and investment is allocated according to a cost effective, science based and risk-management approach, prioritising the allocation of resources to the areas of greatest return.
- Relevant parties contribute to the cost of biosecurity activities.
- Governments, industry and other relevant parties are involved in decision making, according to their roles, responsibilities and contributions.
- Australia's biosecurity arrangements comply with its international rights and obligations.

Australian Weeds Strategy (2007)

The *Australian Weeds Strategy 2007* provides a framework to establish consistent guidance for all parties, and identifies priorities for weed management across the nation. It aims to minimise the impact of weeds on Australia's environmental, economic and social assets.

This strategy has three goals:

- prevent new weed problems
- reduce the impact of existing priority weed problems
- enhance Australia's capacity and commitment to solve weed problems.

This strategy is underpinned by the following principles:

- Weed management is an essential and integral part of the sustainable management of natural resources for the benefit of the economy, the environment, human health and amenity.
- Combating weed problems is a shared responsibility that requires all parties to have a clear understanding of their roles.
- Good science underpins the effective development, monitoring and review of weed management strategies.
- Prioritisation of and investment in weed management must be informed by a risk management approach.
- Prevention and early intervention are the most cost effective techniques for managing weeds.
- Weed management requires coordination among all levels of government in partnership with industry, land and water managers and the community, regardless of tenure.
- Building capacity across government, industry, land and water managers and the community is fundamental to effective weed management.

Australian Pest Animals Strategy (2007)

The focus of the *Australian Pest Animal Strategy 2007* is to address the undesirable impacts caused by exotic vertebrate animals (mammals, birds, reptiles, amphibians and fish) that have become pests in Australia, and to prevent the establishment of new exotic vertebrate pests.

The Australian Pest Animal Strategy is based on 12 key principles:

- Pest animal management is an integral part of the sustainable management of natural resources for the benefit of the economy, the environment, human health and amenity.
- Combating pest animal problems is a shared responsibility that requires all parties to have clear understanding of their roles and responsibilities.
- The development, monitoring and review of integrated pest animal management strategies need to be underpinned by good science.
- Setting priorities for, and investment in, pest animal management must be informed by a risk management approach.
- Prevention and early intervention are the most cost effective techniques for managing pest animals.
- Pest animal management requires coordination among all levels of government in partnership with industry, land and water managers and the community, regardless of land tenure.
- Effective pest animal management requires capacity building across government, industry, land and water managers and the community.
- Management of established pests should aim to address actual rather than perceived problems, and to reduce impacts rather than simply pest animal numbers.
- Management should be strategic in terms of determining where management should occur, timing of management, being proactive and using appropriate techniques.
- Where there is a choice of methods, there needs to be a balance between efficacy, humaneness, community perception, feasibility and emergency needs.
- The benefits of management should exceed the costs of implementing control.
- As part of an integrated pest animal management program, commercial harvesting may offset management costs.

Food and agriculture

National Food Plan (in development)

The Australian Government is developing Australia's first national food plan to help ensure that the government's policy settings are right for Australia over the short, medium and long-term.

The aim of the national food plan is to foster a sustainable, globally competitive, resilient food supply that supports access to nutritious and affordable food. To achieve this outcome the government proposes to focus on the following objectives, helping the government better integrate what it already does, and help identify if, and where, a better approach might be needed:

- Identify and mitigate potential risks to Australia's food security.
- Contribute to global food security.

- Reduce barriers to a safe and nutritious food supply that responds to the evolving preferences and needs of all Australians and supports population health.
- Maintain and improve the natural resource base underpinning food production in Australia.
- Support the global competitiveness and productivity growth of the food supply chain, including through research, science and innovation.
- Reduce barriers faced by food businesses to access international and domestic markets.
- Contribute to economic prosperity, employment and community wellbeing in regional Australia.

South Australian Food Strategy (2010-2015)

The gross revenue raised from food has been growing at an average of 5% per year over the past decade and reached a record high of $12.4 billion in 2008-09.

To remain internationally competitive, the industry must continue to meet consumer expectations by being sustainable, well managed and consumer driven. *The South Australian Food Strategy 2010-2015* is applicable to the whole food value chain – starting from the consumer and working back through retail, distribution and processing to the producer.

Six priorities have been developed by industry and government for this strategy:

- Consumer insight and market development – understanding the consumer and having the ability to capture opportunities in a wide variety of markets will be vital.
- Enhancing knowledge, collaboration and leadership – having the capability, skills and knowledge to work in a changing environment will be critical. Underpinning this will be the need to collaborate.
- Enhancing capacity and productivity – improving productivity and having a business environment that encourages investment is essential in ensuring the ability to compete.
- Optimising environmental sustainability – managing the limited natural resources (water, land, marine and biodiversity) is fundamental in moving forward.
- Leading in product integrity – Providing safe and wholesome food to enhance consumer confidence and satisfy market expectations is essential in maintaining and growing markets.
- Fostering regional and sector development – South Australia has a number of unique regional and sector attributes that can drive growth.

Of these, 'optimising environmental sustainability', is particularly relevant to the development and implementation of our plan.

Land use planning and development

Land use planning and development (approval) can potentially impact on natural resources, and therefore is important to consider in relation to a natural resources management plan. The key documents that guide the planning system in South Australia are also important for our plan.

Interactions between NRM boards, local councils and the State Government land use planning system are formally structured through the following legislation:

- *Natural Resources Management Act 2004*
- *Local Government Act 1999*
- *Development Act 1993*.

The state's planning system operates under three tiers (as established by the *Development Act 1993)*. *The Planning Strategy* provides direction on land use and development in the state over the medium term (a period of 10-15 years). This strategy is implemented at the local level through council development plans.

In considering the interaction between the planning system and natural resources management, it is important to remember that the planning system applies to 'development', which is defined in Section 4 of the *Development Act 1993,* as:

- a change in the use of land or buildings
- the creation of new allotments through land division and building work
- cutting, damaging or felling of significant trees, specific work in relation to state and local heritage places
- prescribed mining operations (amongst other things).

All development requires development approval by the relevant authority (usually a council or, in some instances, the Development Assessment Commission). Development applications are assessed against the relevant development plan, which contain the policies (or 'rules') governing what can and can't be done on any piece of land.

The 30-year Plan for Greater Adelaide

The 30-year Plan for Greater Adelaide was launched on 17 February 2010. It sets out the land-use policies to manage the growth and change forecast for our region. The region covered by the 30-year plan is greater than our region. It also includes all of the Mount Barker and Alexandrina local government areas.

During the lifetime of the 30-year plan, the state is planning for:

- steady population growth of 560,000 people
- the construction of 258,000 additional homes
- economic growth of $127.7 billion
- the creation of 282,000 additional jobs.

The plan will:

- locate the majority of new housing in current urban lands, particularly around transport corridors
- focus on creating mixed-use precincts that bring together housing, jobs, transport services, recreation and leisure
- set aside a net land supply of 10,650 hectares to create new growth areas which will be based on the principles of mixed-use development, higher densities and a greater mixture of housing, and wherever possible will be located next to transport corridors
- through its implementation, generate $11.1 billion of gross state product (GSP) over the 30 years
- create 14 new transit-oriented developments and more than 20 sites that incorporate transit-oriented development principles and design characteristics
- contribute to keeping housing and living affordable in South Australia
- provide for housing choice for our ageing population, families, professional and young people

- develop suburbs and neighbourhoods which are connected and represent the world's best practice in sustainability and urban design
- strategically expand larger townships with infrastructure and services, while constraining growth in smaller townships to preserve their heritage and character
- protect at least 115,000 hectares of environmentally significant land and up to 375,000 hectares of primary production land
- support the important growth of the mining and defence industries, which will be important to South Australia's future
- create a network of greenways and open-space precincts, including designating green buffers that define the area between the town of Gawler, the northern suburbs and new growth areas
- significantly reduce the rate of water and energy consumption in all new dwellings
- support our national leadership position in the renewable energy sector and position South Australia to export green energy to other states and territories

Managing fire in the landscape

Fire has played an integral part in shaping the ecology of the Australian landscape for millions of years and will continue to do so. As such, fires will continue to be an economic, social and environmental challenge for land managers and communities (DEWNR 2012).

Australian plants and animals have evolved and adapted to survive particular fire regimes. Fire regimes with the frequency, intensity and season that species in the habitat are adapted to will stimulate the regeneration and renewal of the ecosystem. However, if fires occur outside of the conditions to which the plants and animals have adapted, extinction of populations can occur. A fire regime is characterised by fires that occur at a range of intervals, with different intensities, at various times of year and in different fuel types

Unfortunately, comprehensive knowledge about how species respond to different fire regimes is unavailable. Information is also lacking about how best to implement appropriate fire regimes in habitats that are fragmented, isolated from one another and degraded by weeds, feral animals and other threats. As this knowledge improves, so does our capacity to use fire as an effective biodiversity management tool.

National Bushfire Management Policy

The Australian Government and state/territory governments have developed the *National Bushfire Management Policy* and supporting strategies to guide the evolution of effective and ecologically sustainable fire regimes in Australia.

The Bushfire Policy focuses on the management of fire in forests and rangelands. While it largely covers public lands, the general issues and principles apply more widely. The Bushfire Policy places priority on the protection of life. It also identifies the need for consideration regarding the benefits for all Australians (now and in the future) for the provision of ecosystem services such as:

- conserving biodiversity, heritage and carbon
- producing water and timber
- hosting recreation and tourism opportunities.

The vision inspiring the Bushfire Policy is that:

Fire regimes are effectively managed to maintain and enhance the protection of human life and property, and the health, biodiversity, tourism, recreation and production benefits derived from Australia's forests and rangelands.

Fourteen national goals have been developed to support the implementation of the Bushfire Policy:

- maintain appropriate fire regimes in Australia's forests and rangelands
- balance the environmental impacts of fire
- promote indigenous Australians' use of fire
- community engagement
- public awareness and education
- integrated and coordinated decision making and management
- employment, workforce education and training
- bushfire risk mitigation
- bushfire response
- safety in fire operations
- bushfire recovery
- international responsibilities
- risk management
- investing in and managing knowledge.

Ecological fire management guidelines

Fire management for biodiversity conservation is all about minimising the risk of extinctions resulting from inappropriate fire regimes. Ecological fire management guidelines have been developed for all fire-prone vegetation types in agricultural areas of the state. These guidelines outline the role of fire, and the approaches that are available to manage fire for maintaining and enhancing biodiversity. These guidelines should not be used as prescriptions; instead they define a window of 'acceptable' fire regime suitable for the conservation of most species.

An important part of fire management is understanding the tolerances different plants and animals have to the components of a fire regime (fire interval, frequency, spatial, intensity and season) based on their biology. Ecological fire management guidelines use this information to identify how the fire regime should be managed for each vegetation type. The species with the most demanding or sensitive requirements in relation to fire frequency, intensity, season and extent are used to define the minimum (or maximum) fire regime for the habitat they occur in.

Vital to this whole process is an understanding of the longevity, shelter, food, and breeding/recolonisation requirements of these species. Currently, due to the limited data available for some species, expert opinion is also required to identify appropriate fire regimes. Further data will be required to review and refine the ecological fire management guidelines to improve our ability to use fire as a biodiversity management tool.

Fire on public land

The primary purpose of prescribed burning on DEWNR land is to manage fuels to minimise the risk that bushfires pose to human life and property as well as to populations of plants and animals. Fire management planning on DEWNR owned land is based on the following fire management zones:

- A zones – Asset protection zones
- B zones – Bushfire buffer zones
- C zones – Conservation-land management zones

The objectives for prescribed burns within A and B zones are to keep fuels below specific levels in order to reduce bushfire risks to life and property. In C zones (which cover the majority of each park), prescribed burning can be conducted either to protect areas of contiguous native vegetation burning in a single fire event or to achieve ecological objectives. Environmental assessments are conducted for all planned burns containing native vegetation and for C zones must be undertaken in accordance with the ecological fire management guidelines as described above

Prescribed burning is used for ecological purposes either to reinstate a natural fire regime or to assist in managing weed infestations. For example, prescribed burning can be used to:

- regenerate plants that rely on fire (or other disturbance) to germinate
- modify the habitat structure (temporarily) to benefit threatened communities or species
- burn weedy plants and dead plant material to help prepare a site for revegetation
- burn pest plants to improve access to an area for future weed treatment
- kill weeds and cause the majority of weed seeds in the soil to germinate so they can then be controlled before they set seed (either by another burn, mechanical removal or chemical treatment) to break the weed cycle.

When prescribed burns are conducted for ecological purposes careful consideration is given to ensuring the timing and intensity of the burn is appropriate to achieve the desired ecological objectives. In modified environments this includes allocating sufficient resources to the post-fire weed control as failure to do this can cause the habitat to deteriorate rather than improve.

APPENDIX B:
STRATEGIC DIRECTIONS LINKS

Tables B1-4 show the strategic directions and their links to the regional conceptual models and subregional priorities.

Table B1: Strategic directions and links for climate change driver

	Strategic Direction	
C-A	**Participate in opportunities for low carbon futures**	
	Links to regional conceptual models adapting to climate change sustainable primary production terrestrial landscape health marine health	***Links to subregional systems*** Northern Coast and Plains (carbon plantings) Northern Hills (carbon plantings) Central Hills (carbon plantings) Willunga Basin (carbon plantings) Fleurieu Peninsula (carbon plantings) Marine (seagrass protection and enhancement)
C-B	**Build the adaptive capacity of communities**	
	Links to regional conceptual models adapting to climate change building capacity of natural resources managers community support for natural resources management	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
C-C	**Build the understanding and knowledge of future climate change impacts**	
	Links to regional conceptual models adapting to climate change building capacity of natural resources managers community support for natural resources management sustainable primary production terrestrial landscape health marine health aquatic health	***Links to subregional systems*** Northern Coast and Plains (sea level rise, agricultural production, ecosystem adaption and water availability) Northern Hills (agricultural production, ecosystem adaption and water availability) Central Hills (agricultural production, ecosystem adaption and water availability) Willunga Basin (agricultural production, ecosystem adaption and water availability) Fleurieu Peninsula (sea level rise, agricultural production, ecosystem adaption and water availability) Metropolitan Adelaide Marine
C-D	**Provide opportunities for landscapes to adapt to climate change**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health adapting to climate change	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Marine
C-E	**Provide opportunities for production systems to adapt to climate change**	
	Links to regional conceptual models sustainable primary production adapting to climate change aquatic health marine health	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Marine

Table B2: Strategic directions and links for land management and change driver

	Strategic direction	
L-A	**Identify and resolve land use planning conflicts to minimise impacts on natural resources**	
	Links to regional conceptual models terrestrial landscape health aquatic health sustainable primary production	***Links to subregional systems*** Northern Coast and Plains (urban expansion) Central Hills (urban expansion and changing land use) Fleurieu Peninsula (urban expansion)
L-B	**Reinstate ecosystems in priority locations to stem biodiversity declines**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health adapting to climate change building capacity of natural resources managers	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Marine
L-C	**Improve the condition of priority biodiversity areas**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health adapting to climate change building capacity of natural resources managers	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Marine
L-D	**Improve the long-term prospects of threatened * and declining species and communities**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health adapting to climate change building capacity of natural resources managers	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
L-E	**Maintain high value primary production areas for primary production**	
	Links to regional conceptual models sustainable primary production	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula
L-F	**Reduce land based impacts on aquatic and marine health through appropriate land management and management of runoff**	
	Links to regional conceptual models aquatic health marine health building capacity of natural resource managers sustainable primary production	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine

	Strategic direction	
L-G	**Provide suitable water regimes to maintain and improve the condition of aquatic (freshwater) and marine ecosystems**	
	Links to regional conceptual models aquatic health marine health	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine

*** threatened includes non listed species**

Table B3: Strategic directions and links for economic impact driver

	Strategic direction	
E-A	**Support and encourage sustainable primary production**	
	Links to regional conceptual models sustainable primary production adapting to climate change aquatic health terrestrial landscape health	***Links to subregional systems*** Northern Coast and Plains (horticulture and broadacre) Northern Hills (viticulture, grazing and broadacre) Central Hills (viticulture, horticulture and grazing) Willunga Basin (viticulture) Fleurieu Peninsula (grazing, dairy)
E-B	**Support and encourage sustainable marine industries**	
	Links to regional conceptual models marine health adapting to climate change	***Links to subregional systems*** Northern coast (recreational fishing) Southern coast (recreational fishing) Marine (commercial fishing)
E-C	**Support and encourage sustainability in other industries reliant on natural resources**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health adapting to climate change sustainable primary production	***Links to subregional systems*** Northern Coast and Plains (tourism) Fleurieu Peninsula (tourism) Metropolitan Adelaide (industry dependent on groundwater)
E-D	**Maximise the use of stormwater and treated wastewater**	
	Links to regional conceptual models marine health aquatic health sustainable primary production	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide
E-E	**Recognise the intrinsic economic value of biodiversity**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health community support for natural resources management building capacity of natural resources managers sustainable primary production	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine

Table B4: Strategic directions and links for knowledge and capacity driver

	Strategic direction	
K-A	**Build capacity of Aboriginal and non Aboriginal communities in Aboriginal culture**	
	Links to regional conceptual models community support for natural resources management building capacity of natural resources managers	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
K-B	**Increase the connection that people have with the environment and food production and the link to natural resources**	
	Links to regional conceptual models community support for natural resources management sustainable primary production terrestrial landscape health aquatic health marine health	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
K-C	**Encourage sustainable living and engagement with nature**	
	Links to regional conceptual models community support for natural resources management	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
K-D	**Increase and diversify the participation in natural resources management activities**	
	Links to regional conceptual models community support for natural resources management	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
K-E	**Support all land managers to achieve good natural resources outcomes**	
	Links to regional conceptual models sustainable primary production building capacity of natural resources managers	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula
K-F	**Support land managers to increase areas under environmental stewardship**	
	Links to regional conceptual models sustainable primary production building capacity of natural resources managers terrestrial landscape health	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula

	Strategic direction	
K-G	**Support innovation and knowledge sharing**	
	Links to regional conceptual models terrestrial landscape health marine health aquatic health community support for natural resources management building capacity of natural resources managers sustainable primary production adapting to climate change	***Links to subregional systems*** Northern Coast and Plains Northern Hills Central Hills Willunga Basin Fleurieu Peninsula Metropolitan Adelaide Marine
K-H	**Encourage urban planning to consider the inclusion of nature in an urban context (link to place making, community health and wellbeing, amenity and urban cooling)**	
	Links to regional conceptual models community support for natural resources adapting to climate change	***Links to subregional systems*** Metropolitan Adelaide Willunga Basin Northern Coast and Plains

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