4 Threatening Processes

Digital maps have been assembled to give a spatial representation of threat level for 20 variables that threaten conservation value; see Chapter 2 above for detailed description of the provenance of the threatening processes layers. Selected threat layers (maps) are discussed below, to clarify their regional distribution and impact:

Recreation/ Visitation Impacts
- Campsites – formal and informal
- Off Road Vehicle Tracks

Development Impacts
- Development Zoning
- Land Ownership
- Viewshed Analysis (increased threat due to sea views)
- Viewscape Analysis (increased threat due to the aesthetics of the coastal zone)
- Existing development

Land Use Impacts
- Land use
- Mining activities
- Waste water treatment plants/ Rubbish dumps/ Tailings/ Evaporation pans

Threats to Habitat Integrity
- Vegetation Isolation (lack of connectivity between vegetation patches)
- Vegetation degradation (proportion of exotic plant species)
- Vegetation patch shape (perimeter length to area ratio)
- Vegetation patch size
- Distribution of known environmental weeds

Hazards
- Dune Instability
- Cliff Instability
- Potential Acid Sulfate Soils
- Feral Species – Deer
- Feral Species - Rabbits

[Climate change is included at the end of this chapter; this was not suitable for the GIS based analysis, but local climate scenarios for the years 2030 and 2070 from IPCC and CSIRO projections are described at the end of this chapter. Local potential impacts of projected changes were placed in cell descriptions, in Section 6.3].

Those threat layers, which were included in the GIS analysis, but for which there is little to add to the data description (Chapter 2) are not discussed below; they include: Land Ownership, and vegetation block metrics (isolation, degradation, shape, and size).

4.1 Development, Land Ownership and Land Use

Development zoning, land ownership and land use were used in the analysis of threatening processes because they have the potential to lower conservation priority values through development, land use change and/or other activities.

All land proclaimed under the *National Parks and Wildlife Act 1972* (including all Parks and Reserves) has been given low threat values for development, land ownership and land use, because they are specifically set aside for preserving and managing conservation. Land use and/or activities allowed within these areas are restricted under the Act and only minor works, such as toilets, showers or campsite development, are likely.

Where development zoning allowed urban development, high threat scores were allocated; where zoning principles and objectives sought to conserve, low threat scores were given. Mean values for cells are high where a large proportion of the cell is zoned to allow urban or industrial development.

Existing development was included as a separate layer, to address the potential threatening activity surrounding existing dwellings and to adjacent land. Outside of settlements, where built up areas are well defined, individual dwellings were pin pointed and an area of activity associated with each.

Most cells had medium to high totals for planning impacts, land use and development. Cells SE15-17 (the Coorong) and Cell SE6 Canunda consistently had low totals for each layer, where most zoning points to conservation and development impacts are also limited by the size of the parks and the presence of extensive water bodies or sand dunes.

4.2 Coastal Viewscape and Viewshed Analysis

In 2004/5 a South Australian analysis of the scenic value of coastal lands was undertaken for the Department of Environment and Heritage, (Lothian 2005); this was termed a viewscape survey. Where coastal areas had a high score for visual amenity, this was regarded as a pressure for urban development, and hence given a high threat score. The mean threat values for cells in the analysis are shown in the graph below. Scenic amenity scores are moderate to high throughout the region, indicating that there is no regional pattern visual aesthetics that emerges from this.

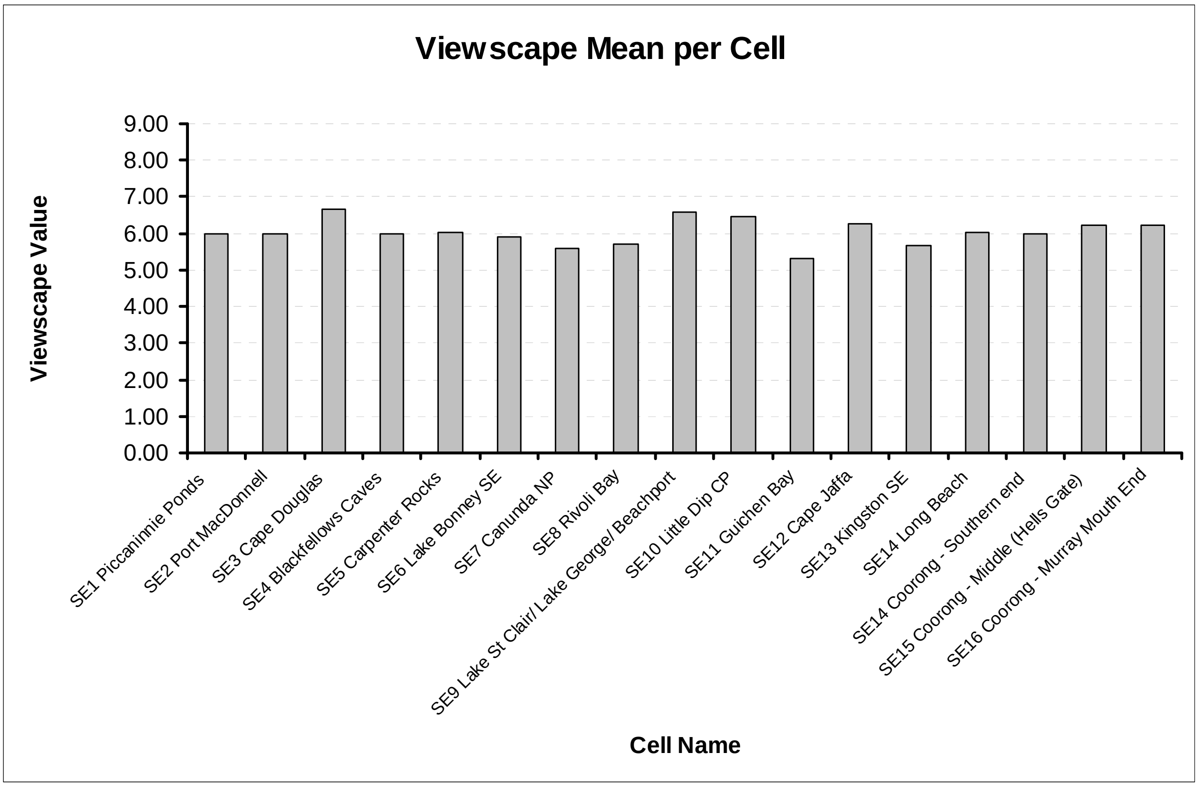

Figure 4.1. Mean Viewscape values by cell.

Viewshed scores are a representation of the development threat of a sea view: areas within the coastal boundary are allotted values according to the quality of sea view (from Lothian, 2005), on the assumption that a sea view will increase the pressure for development. The mean viewshed threat values for cells in the analysis are presented in the graph below, the value in each case represents the proportion by area of places with a view of the sea. Scores are moderate to high in the southern parts of the region (Cells SE1-5) and the cells in the southern end of Lacepede Bay (Cells SE12-14).

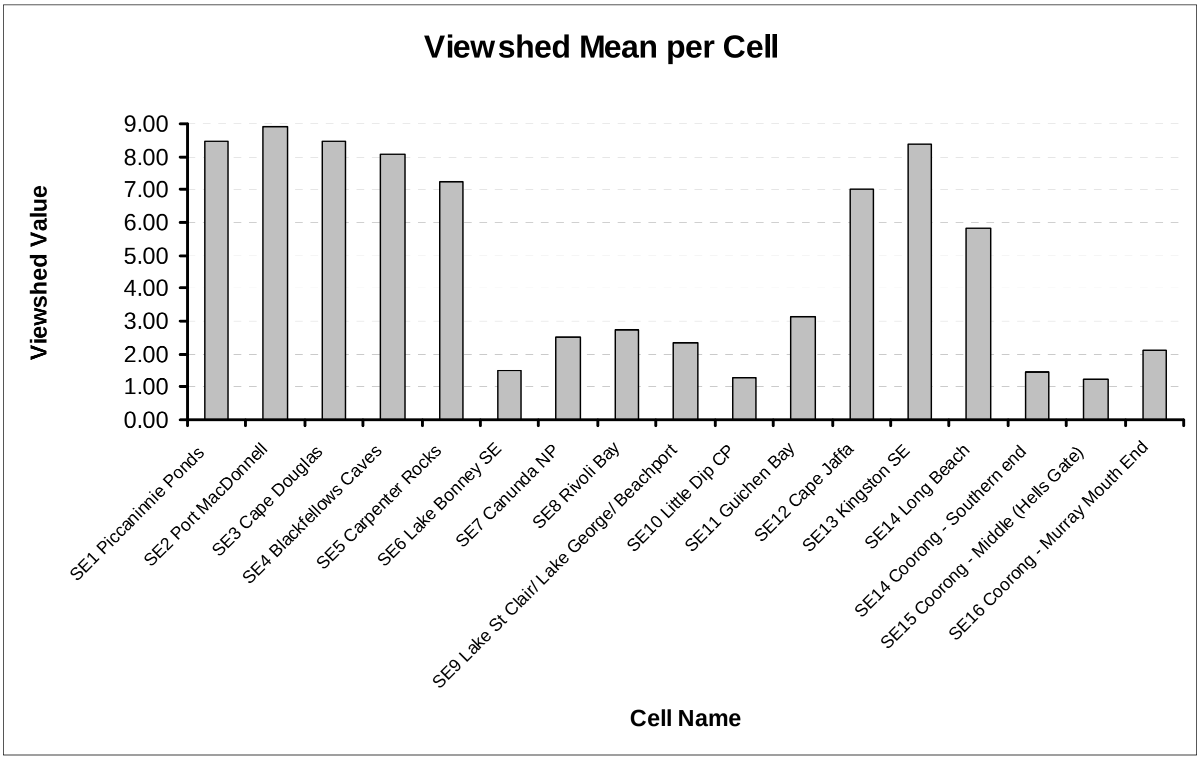

Figure 4.2. Mean Viewshed values by cell.

4.3 Off Road Vehicles

The South East coast attracts recreation and conservation enthusiasts locally and from afar. The Limestone Coast and Coorong is a popular destination for fishing, surfing, camping and particularly for off road vehicle (ORV) driving, the focus of this section. The coast is now a major destination for off-road vehicles, with increasing numbers of people visiting the region every year. While in some areas access is controlled, particularly in NPWSA reserves, in others it remains unregulated, with severe impacts on the coastal landscape.

Number 2 Rocks, Canunda NP. Photograph Coast Protection Board 2008.

The coast has highly sensitive vegetation and soil and tends to have slow recovery times, and is thus highly susceptible to damage by ORVs. Damage is often exacerbated by the harsh conditions that frequently affect the coast. The impacts of ORVs on coastal environments include:

- Wildlife disturbance, harassment, displacement and destruction – the effects of ORV noise on wildlife is reviewed in http://www.wildlandscpr.org/biblio-notes/impacts-off-road-vehicle-noise-wildlife; the effects on shorebirds, mammals and reptiles has been discussed in Section 3.1 – fauna. Beach-nesting birds are a particular issue, since seasonally they lay eggs on the beach a little above HWM. protected only by camouflage, blending in with the sand. For example the Hooded Plover (vulnerable in SA) has been reported throughout the South East region, but it is estimated that 95% of eggs are lost in Southern Australia, because of pressure of use on beaches.(See Maguire, 2008, Chap.2)

- Vegetation and wildlife habitat change, fragmentation or destruction. This includes damage not only directly by vehicles, but also through the collection of firewood, the creation of access tracks and the increased risk of fire.

- Introduction of weeds and plant diseases. This is especially evident in the spread of weeds that flourish in disturbed areas of soil such as Pyp Grass, *Euphorbia sp*., Gazania and Beach Daisy for example. Tracks and deflated dunes are often colonised first by these plants, spreading then into intact vegetation.

- Soil disturbance, compaction and degradation. Dune blowouts are obvious examples of this impact, but also the crushing and breakage of clay pans such as in the Coorong and throughout the Canunda and Little Dip dunes for example. Gilbertson & Foale report tracks in the Coorong mud remaining uncolonised by plants for over 10 years. Disturbed beach sediments are more likely to become mobile and thereby lost to the beach system.

- Beach compaction, leading to crushing of microscopic life forms within the sand. The impacts on beach meiofauna are well documented, (see e.g. Schlacher et al 2008). The consequent impacts on shorebirds and fish that rely on this food source are not well understood.
- Litter, waste (including human waste) and other pollution. Litter surveys (e.g.: Robe Long Beach litter survey) show that large volumes of rubbish and debris wash up on the beach, with consequent fauna, amenity and safety impacts. Similarly, rubbish and waste left by fisherman, campers and other visitors to the coast is a costly and harmful reminder of visitation.
- Loss of heritage and amenity values. This is particularly evident along the SE coast, where numerous Aboriginal Heritage sites are being impacted by vehicles and/or human disturbance. The scenic amenity of the coast is jeopardised by networks of tracks and damage to headlands.
- Vandalism.

In addition to these conservation threats, ORVs are seen as a threat to human safety on many beaches near to towns and cities, e.g. Waikato beaches, (Waikato Regional Council, 2010).

ORVs can be 4-wheel drives, 2- and 4-wheel motorbikes, dune buggies and conventional vehicles that are driven off designated roads. Historically little thought was given to vehicles travelling through untouched coastal areas, creating a myriad of poorly formed and located tracks through native vegetation. Over time an increase in the number of vehicles capable of travelling off road has seen a significant increase in the use of ORVs on the coast and thereby the impacts and damage caused by them. In 1980 Cullen & Bird wrote in a report for the Coast Protection Board:

"Such vehicles have long been used by fishermen and others to cross dunes and travel along beaches, but in the last few years there has been a dramatic increase in the ownership of such off-road vehicles and this is now seen as an important recreational activity".
(Cullen & Bird, p.36)

This trend has continued and in recent years there has been a further increase in 4WDs and motorbikes, together with the addition of quadbikes, and also in numbers of small boats launched from trailers on beaches.

4.3.1 Managing Off Road Vehicles

The use of ORVs in coastal areas of the SE is a complex issue, with several of the impacts referred to above, with varying management responsibilities, land tenures and conflicting demands. The challenge for managers is striking the balance between increasing human pressures and the protection of natural and cultural values, while also ensuring public safety.

Legislation permitting driving on beaches and Crown land in South Australia continues to attract interstate 4WD and motorbike users. High numbers of visitors consequently generate tourism income for local coastal townships, which have become dependent on tourism revenue.

The Limestone Coast and Coorong Coastal Management group recognises that this activity is synonymous with the SE coast, but also that this pressure is impacting upon the natural assets that draw people to the region. A recreational vehicle forum was held in 2008 that included a wide range of stakeholder organisations, to discuss sharing and managing this asset wisely. Key recommendations from the workshop included:

- Better resources for drivers, particularly visitors, including accurate track maps and markers; visitor information kits and an education campaign promoting "doing the right thing" and environmentally sustainable use;

- an audit into human impacts on environmental & cultural values along the coastal strip to assess areas requiring protection or access (mention is made of the need for a thorough review of the protection of indigenous cultural sites in Section 3.3.2. above, and in the Regional Recommendations);
- temporal, permanent and seasonal closures of high priority beaches to protect environmental and cultural values, or where conditions render a beach unsafe;
- consideration of a 'parks pass' type system and "user-pays" principles; and
- engaging local community in monitoring, management & decision making.

The Limestone Coast and Coorong Coastal Management Group has since released a publication in 2010 titled 'The Limestone Coast 4WD and Explorers Guide'. This guide to the SE coast offers tips for sensible ORV use, maps of existing tracks and routes and information to educate visitors on the sensitive natural areas that they are sharing with plants and animals.

Steps are being taken in the right direction to combat the growing problem of ORV access along the coast. However, the current impacts are clearly unsustainable, as the study results show. Impacts caused by ORV tracks, observed during field trips to the area, include vegetation destruction, landscape degradation, erosion, damage to cultural sites, the introduction and spread of weeds and evidence of refuse and other discarded debris. A safety risk was also observed along some cliff tops, with tracks and informal viewing areas close to undercut and unstable cliffs (e.g. Figure 4.3).

Figure 4.3. Vehicle track over eroding cliff tops at Errington Hole, Cell SE10. Photograph Coast Protection Board 2008.

Off-road vehicle analysis

Tracks were used in the 'threatening processes' analysis to represent ORV activity. Existing road and track databases were used, together with additional mapping undertaken by DENR utilising 2008 aerial and oblique photography. Bare sand dune areas were included as tracks as they provide little restriction to vehicle movement and are often used by vehicles, especially motorbikes. Bare dunes are often linked directly to a track network, whose presence points to an increased threat on the environment in these adjacent areas.

Within the Limestone Coast and Coorong region the GIS analysis shows ORV tracks are a high threat in 9 of the 17 cells (see Figure 4.4 below). The analysis shows that the biggest threat from ORVs is in dune areas, over headlands and on beaches. Damage impacts both private and public land throughout these cells.

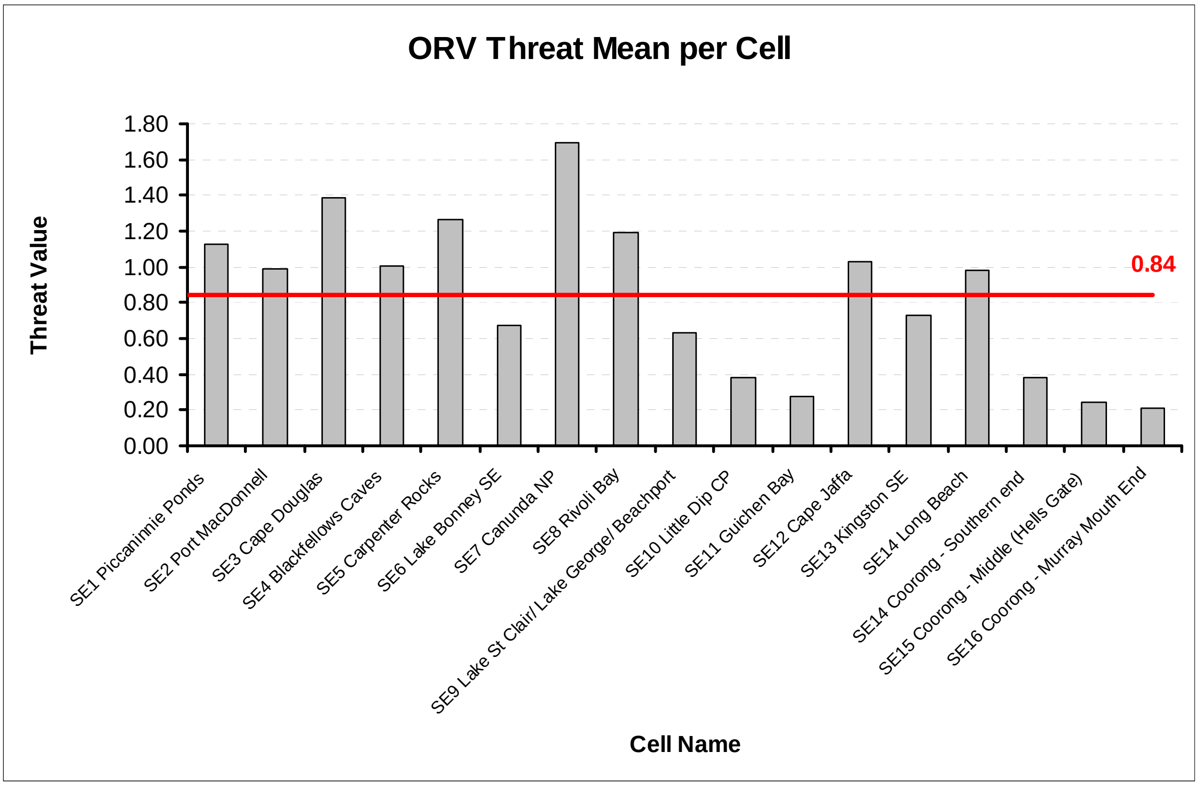

Figure 4.4. Mean ORV Threat values by cell (average value of 0.84 shown).

ORV activity is recorded on virtually all beaches across the region. In fact, beaches that vehicles do not access are rare. The seasonal closure of the Coorong beach north of Tea Tree Crossing is one of these exceptions. In other areas, ORV activity is concentrated between Finger Point, Port MacDonnell, and Cape Douglas in SE3 and SE4; adjacent to the Blackfellows Caves township in SE4; around the settlement of Carpenters Rocks in SE5; between Carpenters Rocks and Southend, encompassing all of Canunda NP in SE6 and SE7; in the southern half of Rivoli Bay, Cell SE8; from Beachport to Nora Creina in Cell SE9; the northern end of Little Dip CP Cell SE10, particularly in proximity to Robe; the bottom end of Cell SE14, nearest to Kingston; and the southern boundary of Cell SE15 to the Coorong NP boundary. Track mapping indicated that the most heavily impacted areas are in fact within or adjacent to the three major conservation parks on the SE coast: Canunda NP (see Figure 4.6), Little Dip CP and the Coorong NP. This is most likely due to the high visitation to these parks and the existence of the well known and published ORV track networks.

Broad, sweeping transgressive dune system in these areas are prone to off-track riding and driving, with compliance to control access difficult. This is in part due to the remoteness of some locations and the difficult terrain, combined with limited resources to address the problem. Controlling access requires policing of ORV activity and a rapid response to any off-track driving. Often, beach and dune conditions themselves prove to be the limiting factor to access either restricting it entirely or encouraging the creation of new tracks to circumnavigate problem areas. Access control is also made difficult by vast areas of mobile dunes with sparser vegetation often occupying these areas, making the creation of new tracks and/or driving around tracks that have been blocked off relatively easy.

The volume of ORV tracks (Figures 4.5 - 4.7) and the negative impacts observed across the region point clearly to the need for access control. Detailed mapping of existing tracks is now available and should be used as a baseline for ongoing monitoring. This mapping now enables a strategic assessment of the track network to consolidate access to the coast and remove any tracks detrimental to flora, fauna or heritage sites. A strategic approach can increase the effectiveness of access control by permitting access to the coast, but reducing the number or routes and access points. However, for success this needs to be complemented with appropriate signage, education, and resourcing for policing and the rehabilitation of closed tracks and damaged sites.

Figure 4.5. Multiple beach access points and fresh tracks evident on an actively drifting foredune. Cell SE14, south of the Coorong NP. Photograph Coast Protection Board 2008.

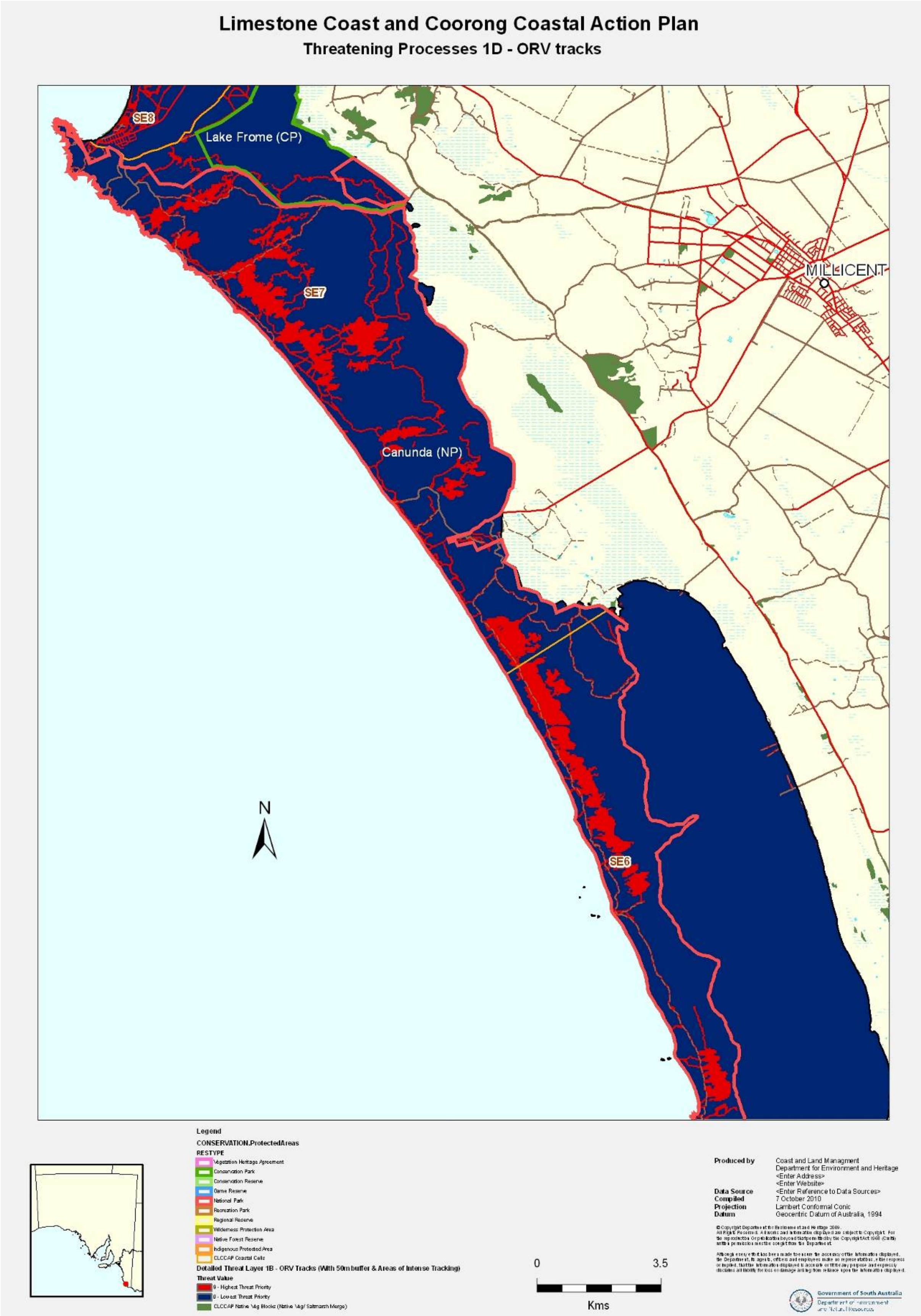

Figure 4.6. High threat areas of off road vehicle activity (indicated in red) in Cells SE6 and SE7, within Canunda NP.

Figure 4.7. A beach access point in Rivoli Bay, near Southend, causing a foredune blowout. Continued traffic combined with onshore winds leads to widening and deepening.

Local councils have by-laws prohibiting vehicles from Council land unless designated. However this does not cover vehicles on State and privately owned land. Even on Council land, controlling off-road vehicles requires Council staff or police enforcement and council's may not consider this to be a high priority or if the vehicles do not appear to be causing significant problems they may decide to ignore it. Where tracks used by ORVs have been fenced to prevent entry, historic access to the area often leads to vandalism to regain entry. In some areas there is ambiguity over Council's powers to pass and enforce by-laws affecting traffic on beaches. Within Conservation and National Parks, the extension of the park boundaries to low water mark allows the potential for control of traffic in these areas. Further to this, where marine park boundaries include beaches, access could be regulated through relevant management plans.

There are some recent good examples of the balance that can be struck between access and the protection of sensitive sites along the coast. The Coorong seasonal Hooded Plover closure during the nesting and fledging season from September to December is one. Another is the rehabilitation of the Errington Hole midden site. This involved collaboration between the SE Aboriginal Focus Group of the NRM Board, members of the Kungari Heritage Association Inc. and DENR, to construct fencing and install signs to protect two Aboriginal middens at the Errington Hole site (Cell SE10). Another recent initiative is the protection of shorebirds at Danger Point headland, near 8-Mile Creek in Cell SE2. This site is an important feeding area for internationally significant migratory shorebirds; however there are a number of conflicting uses such as driving and boat launching, which are putting the birds at risk. DENR has worked with the District Council of Grant to install signage and close unnecessary beach access tracks, encouraging vehicles to use a track behind the foredune instead of driving along the beach. Adjacent landholders were engaged and signage reminds people of the presence of nesting and feeding shorebirds and encourages beach users, particularly with dogs, to remain along the tide line to minimise disturbance.

4.4 Dumps and Wastewater Treatment Plants

Dump sites and waste water treatment plants within or adjacent to the coastal boundary were taken from the digital map, sourced from the EPA by the Science Resource Centre, DENR. High threat scores were given to the Finger Point Sewage Treatment Works adjacent to Port MacDonnell; the Carpenters Rocks rubbish dump; the Canunda rubbish dump; the Southend sewage treatment plant; the Beachport rubbish dump; Robe rubbish dump and STP; and the Kingston dump.

This layer illustrates the value and the problems of the analysis. The mapped data draws attention to the location of the sites, which may be adjacent to sensitive features. For example, the Robe rubbish dump and STP are located in the dunes behind Robe, with the latter discharging treated effluent into the dunes adjacent the beach. However, it is not possible to buffer the sites in a way that adequately represents their influence: that is to assign GIS raster point scores in a way that consistently represents their potential threat. On the other hand, the representation of the area of the site in the analysis scores does serve to flag the issue and add to the total threat profile and score.

4.5 Mining and Exploration

Mining activities were also used in the threatening processes analysis as they can decrease conservation values by vegetation clearance, track creation, soil and wildlife disturbance, weed introduction, increased fire risk, creating corridors for feral animal activity and opening areas for recreational use. High threat cells within the study area include Cells SE2, 3 and 7-11. Petroleum production and exploration licences over these cells are responsible for the high threat value.

4.6 Dune Instability

Dunes occupy a large proportion of the lands within the SE region: 46,630ha. or 37.4% of the project area; 17.2% of these dunes are unvegetated. Large quantities of Holocene sand construct massive sand barriers at the Younghusband Peninsula, Little Dip and Canunda; these mobile sands sit on top of earlier Pleistocene barriers, now lithified as calcarenite. In addition extensive low dune ridges occupy low lying land behind Guichen Bay and Rivoli Bay. Smaller dunes are found in other areas, as at Wright Bay and Piccaninnie Ponds, for example.

Data on unstable dunes was obtained from the existing layer ‘coastal hazards’, based on recent aerial photography. High values were given where dunes were de-vegetated, ‘actual drift hazard’. These areas are extensive within the region (8,024 ha.) and so this variable had a marked effect on threat totals. Medium threat values were given to other dunes or those that are vulnerable to ‘potential drift hazard’. Dune instability is a major problem in this region.

Blowouts, deflation and transgressive dunes are common in the sand dunes of the south-east coastal region. The causes of dune instability through vegetation loss are both natural and human induced. They include storm damage, fire, drought, and plant disease, off road vehicle and foot traffic impact, grazing and clearance. These causes, with regard to any one area, may be multiple and often interlinked. Also the de-vegetation of a dune may be linked to a single event, such as a fire or a storm; but the impact of such an event may be exacerbated by previous circumstances, such as years of drought, or the establishment of a track or car park within the dunes.

High tides and storm waves commonly bring damage to the foredune, and strong onshore winds may deflate the sand, thus extending the damage to develop a blowout. Primary colonising dune plants may, over time, reclaim this area resulting in a diversity of dune plant species, and habitat, within the dune complex. Diversity of dune plant species is a consideration in decisions to act or not act over dune stabilisation and also in decisions over how to act. Extensive planting of one species of dune plant, Marram grass, has in the damper parts of the Australian coast in Tasmania and Victoria resulted in areas where there is a very low diversity of plant species: in these circumstances Marram has created an apparently stable situation where other native plants have found it hard to invade.

However, if there is widespread de-stabilisation, creating an extensive transgressive dunefield, natural re-vegetation may be slow, and over time large quantities of sand may be transported by the wind and subsequently lost to the beach/dune system. Where large quantities of sand are transported landwards, damage to native vegetation, roads, buildings or farmland may occur through burial. In the case of the Holocene sand barrier of the Younghusband Peninsula, large scale dune transgression has occurred through natural causes, 19C grazing and recently ORV activity. Transgressive dunes have crossed the Peninsula and at, for example Cattle Point (see below) are spilling into the Coorong Lagoon. In other places dunes are spilling onto the plastic muds fringing the lagoon, causing local folding in the muds.

Cattle Point, northern Younghusband Peninsula. Transgressive dunes blown into the Coorong Lagoon and onto the Coorong muds. Photograph Coast Protection Board 2008.

In addition, in extreme cases, coastal recession may result from transport of sediment inland from the beach. In the case of the barriers of the SE this amounts to a recession of the whole landform. It is clear that with ongoing and accelerated sea level rise storm damage to foredunes will increase, and vegetation recovery may well be slow, increasing dune instability.

The paragraphs above refer largely to dunes with active inter-connection with the beach. Other dunes are found in the South East region, that have been blown up sand or calcarenite shoreline ramps and now isolated by on-going erosion, these are termed ‘cliff-top dunes’. Such dunes are commonly found on calcarenite headlands between Robe and Carpenters Rocks: they are usually small, often forming isolated hummocks with deflated kunkar surfaces between. The headlands have suffered the impact of centuries of historic and pre-historic visitation; damage to vegetation in these windy spots is difficult to repair and sand is quickly blown away. Since these dunes are no longer replenished from the beach, over time they decline and are lost, leaving deflated kunkar surfaces.

The destabilisation and erosion/drift of dune sands also presents a problem where Aboriginal heritage sites long buried, are uncovered and exposed to weather and human interference. In the South East, where heritage sites are widespread along the coast, this has increasingly become a problem. Particularly in terms of damage then caused by ORVs and vandalism to sites, intentional or otherwise, given the extensive areas of the coast that are now accessible.

Mobile, transgressive dune system with a broad deflation basin extending to the current foredune and beach. A more recent foredune blowout has formed (bottom left) with the depositional lobe extending towards the imbracate parabolic dunes to the rear. This may result from the vehicle access to the beach. Cell SE 9, Lake George. Photograph Coast Protection Board 2008.

4.7 Cliff Instability

Cliff instability is an issue with regard to conservation since on the land it is associated with accelerated run-off, mass movement (rock slide, slump, and rock fall), as well as loss of soil and habitat both on and adjacent to the cliffs. In the nearshore, it can increase the turbidity and nutrient load on reef and seagrass habitats. Cliff instability is also a potential hazard threatening path movement or collapse above the cliffs and rock fall below.

Cape Dombey, Erosion of the calcarenite cliffs is threatening to cause the collapse of the 19th century obelisk.

Calcarenite at Cape Dombey. Cross bedding in the dune sands is capped by a hard layer of calcrete or kunkar.

Photographs J Quinn 2009.

This variable does not attract high threat score totals because of its limited aerial extent, but may be locally very significant, demanding urgent action. As a result, most comment on this threat variable is sourced from the detailed cliff instability layer, rather than the cell statistics.

Cliffs are not found in the region north of Cape Thomas at the top of Guichen Bay. South of this point, cliffs are found in limestone headlands that occur frequently between Cape Dombey (Robe) and Number Two Rocks (Canunda National Park). This limestone is calcarenite of Late Pleistocene age, which forms the composite Robe Range. The headlands are significant topographically in the landscape and separate sandy beaches and bays; they are heavily used today as viewpoints, as they were in the past by the traditional owners. Although the headlands are visually dominant within the vast coastal plain of the South-East, they are in fact low to medium in height and few are higher than 50m. Cliff instability is a well recognised threat at Cape Dombey, where rapid collapse on a number of fronts is threatening the 19C obelisk, having consumed surrounding car parks.

All the headlands are fronted by extensive low to mid-tide shore platforms, which appear to record the rapid recession of the cliff faces in Holocene times. Gill, 1978, suggested calcarenite cliffs near Warnambool have been eroded back at a rate of 4cm/yr. since 7,000BP; Short & Hesp, 1984, propose an overall recession of 2cm/yr. along this section of coast. Markers from an 1896 land survey at Cape Dombey Robe (Fotheringham, 2009), compared with a 1987 survey, give indication of the rate of calcarenite cliff recession over 91 years. Exposed sites along the crenulate cliff line receded on average 7m (2 sites measured 19m), sheltered sites averaged a recession of 2.4m. Field examination of the character of the calcarenite, including variable occurrence of resistant kunkar and soft dune sands, made it clear that erosion rate varied with calcarenite resistance as well as exposure.

Pleistocene calcarenite is not the only formation constituting cliffs in this landscape: south of Canunda NP Tertiary Gambier Limestone is found at Nene Valley, Blackfellows Caves (SE4), Carpenter Rocks, and Cape Banks (SE5). This resistant rock forms extensive high tide shore platforms along the coast south and east of Cape Banks. Erosion of the cliffs and platforms provides flint cobbles, making up some beaches and beach ridges in the far south east of the state.

4.8 Coastal Acid Sulfate Soils

Acid sulfate soils are naturally occurring soils with significant percentages of iron sulphide. These soils commonly occur in low-lying coastal areas where the water table is at or close to the surface. They were formed during or after marine inundation, when seawater containing dissolved sulfate covered organic rich environments, such as coastal wetlands, mangroves, salt marshes or Tea-tree thickets. In fact, nearly all saturated coastal soils below 5m AHD have the potential to develop coastal acid sulfate soils. While these soils are below the water table they remain relatively stable, simply being slowly processed by anaerobic bacteria; iron present within the soil combines with sulphur from the sulfate to form iron sulfides.

However, when these soils are exposed to the air, oxidation occurs and sulfuric acid is formed. The acid may simply react with carbonates and clay within the soil, but if a build up of acidic soil water occurs or is flushed to a waterway, damage to life forms may occur. In NSW for example, fish kills have been reported following disturbance to swampy areas near estuaries and coastal lakes. In the SE soil waters are generally well supplied with carbonates and acid sulfate soils are unlikely to be an issue, except in very small, localised areas.

Coastal acid sulfate soils have been mapped by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in South Australia, (Fitzpatrick *et al.* 2003) and the results included as digital layer within the threats analysis.

Table 4.1. CSIRO acid sulfate soil map classes for South Australia

Map Legend	Class Description
(a) Actual CASS (disturbed). (b) Potential CASS (disturbed)	Actual Coastal Acid Sulfate Soils. Very high risk. Potential Coastal Acid Sulfate Soils (PCASS) in subsoil below 20cm (up to 1 metre thick) with surface monosulfidic black ooze (MBO), intertidal (mainly in samphire). Moderate risk because carbonate layers usually occur above and below.
Potential CASS (mangrove)	Thick PCASS – mangrove soil. Mainly in mangroves, with high risk
Potential CASS (tidal stream)	PCASS of tidal streams (CPASS underlying, not extensive laterally). Moderate risk.
Potential CASS (intertidal tidal)	PCASS in subsoil below 20cm (up to 1m thick) with surface monosulfidic black ooze (MBO), intertidal (mainly in samphire). Moderate risk because carbonate layers usually occur above and below.
Potential CASS (supratidal)	PCASS in subsoil below 50cm (up to 1m thick) with some surface MBO – supratidal. (Mainly in samphire, salt bush, blue bush or saltpan associated with hypersaline soils where there is less frequent tidal inundation). Moderate to low risk.
Sand	Soils of sand dunes and ridges. (No PCASS or CASS within 1 metre of the surface). Low risk of PCASS below water table.
Calcarenite/ Aeolianite	Calcareous soils and hardpans. (No PCASS, highly neutralising). No risk or very low risk.
Marine soils	Marine soils – subtidal and intertidal marine. (PCASS may be present, CASS neutralised by tides and carbonates). No or very low risk.
Other soils	Soils associated with other land uses within coastal landforms. Risk requires individual investigation; guided by adjacent mapped units.

CASS above = Coastal Acid Sulfate Soils

PCASS above = Potential Coastal Acid Sulfate Soils

The Coast Protection Board Policy on Coastal Acid Sulfate Soils (see Coast Protection Board, 2003, Coastline 33) relates to avoiding or minimizing the risk of development in high and moderate risk areas. The Board advises on development applications within coastal zones (as

defined in the Development Regulations 2008), including advice over PCASS. (It should be noted that the EPA has also developed policies on ASS).
Potential coastal acid sulfate soils development have been mapped for the Coorong and Limestone Coast region, and are available on the DENR website, 'Naturemaps', as well as the coastal atlas at www.atlas.sa.gov.au. The mapping of potential CASS in the region has been based on elevation, inundation and vegetation rather than field sampling and digging.

There are areas of potential acid sulfate soil development in the Limestone Coast and Coorong region. Risk of acid sulfate soil development has been assessed at moderate to high in small areas near the Coorong Lagoon (mainly potential CASS disturbed and potential CASS supratidal), small areas near the mouth of the Maria Creek (potential CASS disturbed and under tidal streams); in and around the southern half of Lake George (potential CASS under tidal streams).

4.9 Environmental Weeds

[This section draws heavily on Threatening Processes, Environmental Weeds Affecting the Southern Fleurieu Coast by Claire Lock from the Southern Fleurieu Coastal Action Plan and Conservation Priority Study 2007.]

There are presently close to 1,500 naturalised and potentially naturalised plants (also known as weeds) recorded in South Australia (eflora2010). It is estimated that weeds in agricultural areas cost Australian farmers around $1.5 billion a year in control activities and a further $2.5 billion a year in lost agricultural production. The cost of weeds to the environment is difficult to calculate, but it is expected that the cost would be similar to, if not greater than that estimated for agricultural industries (Weeds in Australia, 2007).

Weeds are also a major threat to our coastal vegetation. The coastal strip is particularly vulnerable and accessible to invasion and weed species continue to be an insufficiently recognised ecological problem in dune, clifftop and saltmarsh habitats. The coast supports a range of unique species that do not occur anywhere else. Populations of introduced plants are expanding and pose a threat to the values of the coast, causing major declines in native plant and animal communities.

Weed Threat

Weeds cause many impacts on the coast. Just as in any other natural environment they often grow faster than native plants and successfully compete for sunlight, water, nutrients and pollinators. They also prevent or interfere with natural regeneration. Their capacity to establish and spread leads to the invasion and displacement of native plant communities, thereby reducing biological diversity and threatening the viability of many plant communities.

Floristically and structurally diverse natural vegetation can be changed dramatically to a much-simplified state where one or several weeds may dominate. Coastal heath and native grassland which naturally hold sand dunes together are some of the plant communities which have been crowded out by weeds, contributing to destabilisation of coastal dune systems. Native fauna are also adversely affected by the loss of plants that provide shelter, food and nesting habitat, or by animals that thrive in response to the changed conditions.

Exotic plants have been introduced to the coast accidentally, often in ballast, or purposely for agricultural or ornamental use. Their spread to the coast has been generally accidental, as a result of various human activities, although spread by fauna, particularly by birds is common. The use of the coast as dumping grounds for domestic garden refuse is a common cause of weed invasion. It is the many disturbances of the coast that has accelerated the spread of exotic plants within the coastal zone.

Other potential weed problems include:
Provide habitat or a food source for feral animals,

Alteration of nutrient content of low fertility soils,
Alteration of hydrological cycles,
Altering dune sand mobility by changing the vegetation cover eg. creating a weed monoculture and increasing beach erosion,
Increasing fire risk by raising available fuel levels in fire danger periods,
Reducing visual amenity and aesthetics of natural landscapes, and
Losing representative examples of original coastal plant communities.

CSIRO are reporting weeds will thrive with the onset of climate change. It is suggested there is potential for weeds spread to change by altering the climatic limits that constrain the range of weed species. It is also possible that increasing temperatures might allow some 'sleeper' weeds to become invasive.

(Adapted from A Manual of Coastal Dune Management and Rehabilitation Techniques, NSW Department of Land and Water Conservation, 2001)

Weeds are an indication of vegetation degradation and a sign of coastal health. More than 500 weeds species have been recorded in the South Australian coastal zone which equates to over 30% of the total coastal flora recorded. The South East coastal region has a high number of exotic flora present, with 354 unique species recorded. This is not surprising given the high rainfall that the region receives.

In the analysis of 'Conservation Values' the proportion of weeds against natives was used to assess the health or condition of vegetation and to highlight areas that require conservation priority.

Weed species have also been assessed for their threatening values. The following sections identify the highest priority environmental weeds and assigns values to weed species to scale threat. The resulting information has been incorporated into the analysis of threatening processes within the Limestone Coast and Coorong coastal region.

4.9.1 Methodology for Determining Priority

Compilation of Weeds Data

The initial weed list for the study area, derived from the State Biological Survey, had very little data for environmental weeds on the SE coast. A weeds survey was therefore incorporated into the project to supplement what little information there was in the databases. A partnership was formed between DENR Coastal Management and State Herbarium staff to gather local knowledge and map weeds within the study area. This added considerable data to the assessment and is the subject of a supporting report available from DENR.

Assigning Threat Values

To determine weeds as a GIS threat layer for this study it was necessary for individual species to be allocated a threat value on a scale of between 1 and 9, with 1 being the lowest and 9 being the highest. Values developed for analysis make use of the list of common coastal species in the Nature Conservation Society Field Guide to Bushland Condition Monitoring Manual: Coastal Vegetation Communities (Croft *et al.* 2006) and matched to align with the five threat categories outlined in the guide.

Table 4.2. outlines the five invasive threat categories featured in the Bushland Condition Monitoring manual. The categories are based upon the following:

- The weed's degree of invasiveness or ability to expand into intact vegetation,
- The weed's capability to disrupt natural processes in bushland, and

- The degree of difficulty involved in preventing or controlling an infestation.

Table 4.2. NCS Bushland Condition Monitoring Manual weed threat categories.

Category	Description
5	Highly invasive in either disturbed or intact remnant bushland, spreads rapidly producing dense stands and a blanket cover. Potential to eliminate almost all understorey species. Very difficult to control without outside help.
4	Highly invasive in either disturbed or intact bushland, with the potential to spread rapidly and produce very dense stands given favourable habitat and/or vectors. High potential to reduce native species diversity and abundance. Can be controlled with sustained effort.
3	Invasive in intact bushland with moderate potential to reduce native species diversity. Rate of spread is slower than Category 4 and 5 weeds but once present will persist and threaten biodiversity. May produce dense stands over a wide area but can be controlled with sustained effort.
2	Generally only invade disturbed bushland, but may spread rapidly. However, generally only a slight potential to reduce native species diversity, unless present in high densities.
1	Generally only invade disturbed bushland. Often widespread and abundant but not considered a significant threat to biodiversity, unless present at very high densities.

The Bushland Condition weed threat categories provided the basis for assessment in this study, however some adaptation was necessary to incorporate species overlooked and the present and potential distribution of species (i.e. widespread versus limited). Potential for distribution incorporates the number of vectors a species has (greater numbers of vectors enable the species to spread more readily) and the potential area(s) a weed species may inhabit (i.e. preference for specific habitats). Table 4.3 summarises the weed value allocation system used to assign threat levels to weed species in the South East coastal region.

Table 4.3. Weed value allocation system.

Value	BCM Weed Threat Category	BCM Weed Threat Category Description	Distribution
9	5	Highly invasive in either disturbed or intact remnant bushland, spreads rapidly producing dense stands and a blanket cover. Potential to eliminate almost all understorey species. Very difficult to control without outside help.	Widespread OR Currently limited with numerous vectors
8			Limited distribution with few vectors
7	4	Highly invasive in either disturbed or intact bushland, with the potential to spread rapidly and produce very dense stands given favourable habitat and/or vectors. High potential to reduce native species diversity and abundance. Can be controlled with sustained effort.	Widespread OR Currently limited with numerous vectors
6			Limited distribution with few vectors
5	3	Invasive in intact bushland with moderate potential to reduce native species diversity. Rate of spread is slower than Category 4 and 5 weeds but once present will persist and threaten biodiversity. May produce dense stands over a wide area but can be controlled with sustained effort.	Widespread OR Currently limited with numerous vectors
4			Limited distribution with few vectors
3	2	Generally only invade disturbed bushland, but may spread rapidly. However, generally only a slight	Widespread OR Currently limited with numerous vectors

Value	BCM Weed Threat Category	BCM Weed Threat Category Description	Distribution
2		potential to reduce native species diversity, unless present in high densities.	Limited distribution with few vectors
1	1	Generally only invade disturbed bushland. Often widespread and abundant but not considered a significant threat to biodiversity, unless present at very high densities.	N/A

Utilising the above system, an internal DENR assessment identified 45 priority environmental weed species from the original list of 354. The results were analysed by DENR staff, incorporating local experience and knowledge of weed management.

4.9.2 Weeds as a Threatening Process

Assigning values to environmental weeds not only enables identification of the highest priority species, but also allows levels of threat to different coastal areas (cells) to be determined and compared.

Chapter 6 features cell-specific priority environmental weed and declared weed lists. When the values of all priority environmental weeds within each cell are averaged, it provides a nominal value that subsequently enables comparison of this threat layer between cells. These nominal weed threat values have been mapped as a GIS layer and are illustrated in Figure 4.8.

It is important to note that the presence of higher value weeds in a cell will increase the average. However, the collective presence of many lower value weeds will also have a similar influence. Some discussion occurred amongst DENR GIS and scientific staff regarding the possibility of simply presenting the threat value for red alert weeds (those with a value of 6 or greater) per cell so as not to dilute the threat value of higher priority weeds. It was decided that lower priority weeds should still be featured due to their collective impact and contribution towards the overall threat to an area of coastal vegetation.

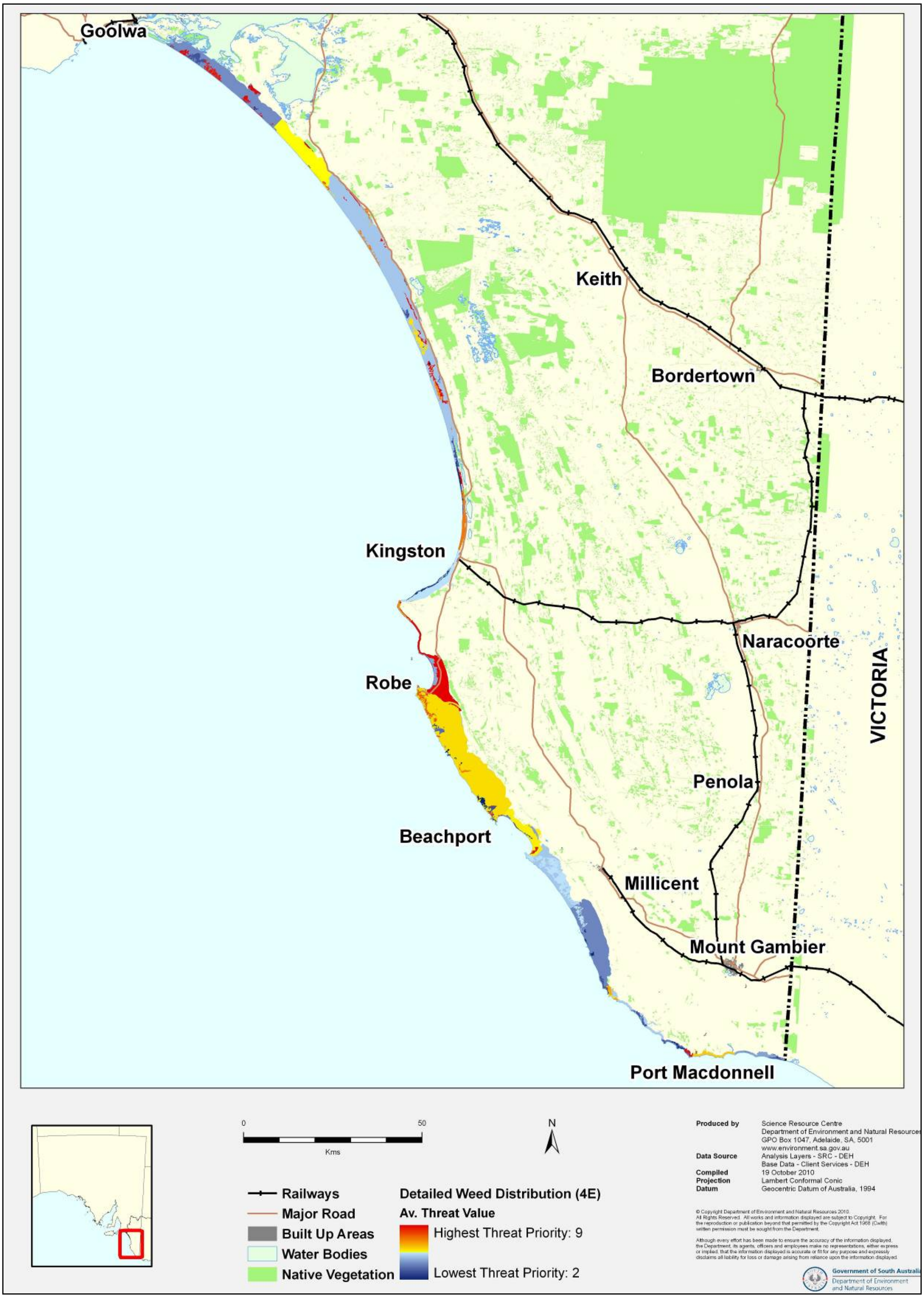

Figure 4.8. Mean weed threat values map.

The threat value allocation process identified a total of 45 priority environmental weeds for the Limestone Coast and Coorong coastal region, each featuring a weed threat value between 1 and 9. The results and distribution of species (by cell) are displayed in Table 4.4.

Table 4.4. Priority environmental weeds and associated threat values.

Species	Common Name	Threat Value	Cell Number
Acacia longifolia ssp. longifolia	Sallow Wattle	2	1,8
Acacia saligna	Golden Wreath Wattle	5	16,17
Ammophila arenaria	Marram Grass	2	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17
Arctotheca populifolia	Beach Daisy	8	4,6,7,8,9,15
Argyranthemum frutescens ssp. foeniculaceum	Teneriffe Daisy	5	2,8,9,10,12
Argyranthemum frutescens ssp. frutescens	Marguerite Daisy	5	12
Asparagus asparagoides (NC)	Bridal Creeper	9	1,9,10,12,14,15,16,17
Asparagus asparagoides f. Western Cape	Bridal Creeper	9	7
Asparagus declinatus	Bridal veil	9	
Asparagus scandens		6	8,9
Chrysanthemoides monilifera ssp. monilifera	Boneseed	6	10
Coprosma repens	New Zealand Mirror-bush	7	2,5,7,8,9,10,13
Cupressus macrocarpa	Monterey Cypress	5	8,9,10
Delairea odorata	Cape Ivy	5	10
Dipogon lignosus	Lavatory creeper	9	2,3,9,10,11,12,15
Ehrharta villosa var. maxima	Pyp Grass	8	8,9,10,15,16,17
Euphorbia paralias	Sea Spurge	4	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17
Euphorbia terracina	False Caper	4	1,4,6,7,8,9,10,11,13,15,16,17
Festuca arundinacea	Tall Meadow Fescue	5	1,4,7,8,9
Freezia cultivar	Freesia	5	17
Gazania sp.	Gazania	8	10
Juncus acutus	Sharp Rush	8	6,9,13,14,15
Leptospermum laevigatum	Coast Tea-tree	7	1,2,3,4,8,9,10,13,14
Limonium companyonis	Sea-lavender	4	3,6,10,13,14,15,16
Limonium hyblaeum		4	12,15
Limonium sp.	Sea-lavender	4	6,10,14,15
Lycium ferocissimum	African Boxthorn	9	1,2,5,8,9,10,11,14,15,16,17
Mesembryanthemum crystallinum	Common Iceplant	3	3,15,16
Olea europaea ssp. europaea	Olive	4	10
Pennisetum clandestinum	Kikuyu	5	4,10
Pinus halepensis	Aleppo Pine	3	15
Pinus radiate	Radiata Pine	3	1
Polygala myrtifolia	Myrtle-leaf Milkwort	9	3,7,9,10,12,15
Polygala virgata		7	13
Rhamnus alaternus	Blowfly Bush	9	7,8,10,11,15
Rosa canina	Dog Rose	2	10

Species	Common Name	Threat Value	Cell Number
Rubus sp.	Blackberry	2	3
Senecio angulatus	Cape Ivy	3	12
Senecio elegans	Purple Groundsel	3	1,2,3,4,5,6,7,8,910,11,12,13,14,15,17
Sparaxis bulbifera	Sparaxis	5	10
Sporobolus africanus	Rat-tail Grass	3	3,13
Tamarix aphylla (NC)	Athel Pine	3	10
Thinopyrum junceiforme	Sea Wheat-grass	8	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17
Vinca major	Blue Periwinkle	6	9,10
Zantedeschia aethiopica	White Arum Lily	2	10

The cells that recorded the highest weed apparent threat included, SE11 Guichen Bay, SE12 Cape Jaffa, SE14 Long Beach and SE2 Port MacDonnell. The spread of weeds in these cells is likely to be influenced by adjoining agriculture and urban land uses. These high values could be a combination of the presence of the higher value weeds in a cell or the collective presence of many lower value weeds which also has a similar influence. The large majority (all but one, Cell SE2) recorded very high numbers of exotic species versus native species which was also a scored degradation value. SE12 and SE14 had the highest proportion of weeds present.

4.9.3 Priority Weeds

Red Alert

Part of the process for assessing weeds as a threat within the Bushland Condition Monitoring Manual is identification of 'Red Alert Weeds'. Red Alert weeds are species that are already presenting a major threat to bushland or have the potential to become major threats (i.e. the highest priority weeds). NCS gives weeds with a threat category of 3, 4 or 5 a classification as Red Alert Weeds as they have the capacity to spread quickly, even in intact vegetation and are difficult to control (Croft et al, 2006). The higher the number of Red Alert species present in bushland, the greater the threat of weed invasion in the future. Any category 4 or 5 species should receive immediate attention. In the context of the weed value allocation process, Red Alert Weeds are those with values from 4 to 9 (refer to Table 4.4 and individual cell descriptions in Section 6.3). A total of 33 Red Alert weeds have been identified in the Limestone Coast and Coorong coastal region through this methodology.

The following provides a brief threat analysis for NCS category 4 and 5 weed species (weeds with values in the GIS analysis from 6 to 9) that represent the highest level threat. They are listed in alphabetical order and described in more detail.

Arctotheca populifolia - Beach Daisy

Beachport. Photograph R Sandercock.

Study threat rating: 8
Regional distribution: Common
Local density: Common

Beach daisy is a low spreading thickset hairy perennial *herb* to shin high. Fleshy, semi-succulent prostrate *stems* are covered with hairs. *Leaves* also matted with hair are oval-shaped, pale grey-green in colour and are on short stalks. Flowers a yellow daisy, the ray florets are bright yellow and widely spaced and the central flowers are greenish yellow from winter to early summer. Produced on long stalks in the axils of leaves, extending beyond the leaf structure. *Fruit* is 5 mm long with a white woolly cover, remains closed when ripe.

A coastal species, it grows in deep sand and is a pioneer of beaches and foredunes. It is capable of rapid regeneration in extreme conditions. It is short lived but persistent and an invasive environmental weed and is more strongly sand-binding than the natives which it replaces, resulting in more mounded dune shapes. Seed spread by wind and being highly viable also travel by tidal currents. Found on open ocean coasts often on western facing beaches and possibly spread on the Leeuwin current with seed sources out of Western Australia, where it is found from Perth to Esperance.

Asparagus asparagoides - Bridal Creeper

Photograph R Sandercock.

Study threat rating: 9
Regional distribution: Common
Local density: Common

Bridal Creeper is a rhizomatous and tuberous cool season low growing *vine*, growing on supporting vegetation to over head high. Short-lived above ground stems and long-lived tubers that are produced on creeping underground stems. Wiry *stems* and glossy, bright-green flat alternately arranged *leaves* with fine veins. Short tubular scented *flowers* are white with 6 petals on slender drooping stalks in leaf axil along the stem, singularly or pairs. Flowers late winter and spring. Stamens prominently protruding from the flower. *Fruits* when mature are round fleshy red berries.

A *Weed of National Significance*, Bridal Creeper is a serious environmental weed of high impact and is regarded as one of the worst weeds in Australia because of its invasiveness and environmental impacts. Bridal creeper was originally introduced as a garden plant and now poses a significant threat to biodiversity throughout the temperate regions. It is a climber that smothers native vegetation and competes for space, light, water and nutrients. It is also able to survive hot summers due to underground tubers that retain moisture. The seeds do not need disturbed soil to germinate and establish. This means that Bridal Creeper is able to invade bush that is in good condition and can be widely dispersed. Formerly known as *Myrsiphyllum asparagoides.*

Asparagus asparagoides forma. Western Cape – Western Cape Bridal Creeper

Canunda NP. Photograph R Sandercock.

Study threat rating: 9
Regional distribution: Localised
Local density: Occasional

There is also a second form of bridal creeper (*Asparagus asparagoides*) found in south eastern Australia known as the 'Western Cape form'. It is slightly larger in stature has bluish-green leaves and its fruit have three indistinct lobes. Its tubers are relatively large (4-7.5 cm long) and are found near the soil surface along short rhizomes.

Asparagus scandens - Asparagus fern

Climbing asparagus fern. Photograph Victorian Department of Primary Industries.

Study threat rating: 6
Regional distribution: Isolated
Local density: Occasional

Asparagus fern is a perennial *vine* with aerial parts growing on supporting vegetation to over head high. Long-lived above ground stems and long-lived tubers that are infrequently arranged along the length of the root system. *Stems* wiry and twisting with shiny, linear to spear-shaped deep green *leaves*, unequal in length and in groups of three. Male and female *flowers* live on separate plants. Small, white to pinkish flowers with 6 petals, borne singly. Fleshy, globular *berries* change from a green colour when first produced to an orange-red when mature. Flowering and fruiting during late winter and early spring.

This species has been widely grown as a garden ornamental. It is a shade tolerant plant preferring moist sites and competes with native plants for nutrients, light and space. It has escaped cultivation and invaded urban bushland and coastal environs. Potentially a serious environmental weed in southern Australia. Formerly known as *Myrsiphyllum scandens.*

Chrysanthemoides monilifera - Boneseed


Photograph R Sandercock.

Study threat rating: 6
Regional distribution: Localised
Local density: Occasional

Boneseed is an evergreen erect woody *shrub* forming a dense canopy to head high. Woody *stems* are heavily branched and often purple tinged towards the tip. *Leaves* alternately arranged, smooth, paddle shaped and coarsely toothed with downy tufts on young growth. Bright yellow daisy like *flowers* with 5 to 8 petals in short stalked clusters on the tips of branches. *Berries* are firm and green, ripening to black and contain a single smooth bone-coloured long-lived seed.

A *Weed of National Significance*, a heavy seeder and rapid spreader and is an invasive environmental weed of headlands and dunes. Don't confuse with the coastal boobialla *Myoporum insulare*. Spread by birds, it is a prolific seeder and has a long-lived seed bank with the ability to establish in disturbed and undisturbed native vegetation. It can form dense thickets several metres high which exclude most native understorey species and prevent their regeneration. This aggressive species has spread rapidly and is replacing entire ecosystems and invading conservation areas in southern Australia. Its weediness is largely due to its vigorous growth and its ability to regenerate quickly and out-compete other species after fire.

Dipogon lignosus - Lavatory Creeper


Port MacDonnell. Photograph R Sandercock.


Beachport. Photograph J Quinn.

Study threat rating: 9
Regional distribution: Common
Local density: Widespread

Lavatory creeper is a wiry twining, vigorous perennial *vine* that becomes woody at the base. *Stems* grow up to 3 m long and are moderately hairy with ovate bright green *leaves* alternately arranged with 3 broad leaflets and are more or less hairless. Short sprays of abundant white, pink or purple pea-shaped *flowers* are arranged in elongated clusters. Hairless *pods,* narrow at the ends, turn from green to brown as they mature. *Seeds* are brown or black with a conspicuous white spot.

Spread by seed by birds, it invades disturbed sites and is of particular concern in coastal habitats. It fixes nitrogen which leads to an increase in soil fertility. This supports other weedy species. Seed has prolonged dormancy and plant possesses rapid growth and forms dense canopies and is a high weed risk "sleeper".

Ehrharta villosa var *maxima* - Pyp Grass

Photograph R Sandercock.

Study threat rating: 8
Regional distribution: Common
Local density: Common

Pyp grass is a robust perennial *grass* with long creeping deep rhizomes, erect tall, spindly single or small tufts to waist high. *Leaf* blades are bluish green, smooth, rolled gradually and tapering at the tip. *Spikelets* often 1 sided, slightly hairy and straw coloured. Flowering occurs sporadically.

Pyp grass has a varied growth habit but can be a rampant coloniser of disturbed areas with thick suffocating thatches through which limited native seedlings can penetrate. First collected in Australia in 1912 it was generally introduced as a dune stabiliser. Can be very difficult to remove. Its mat-forming habit also compromises rehabilitation projects and can have an impact on the structure and dynamics of coastal dunes.

Gazania spp. - Gazania


Photograph R Sandercock.

Study threat rating: 8
Regional distribution: Widespread
Local density: Widespread

Gazania linearis: Gazania is a many-branched creeping perennial *herb* to shin high. *Leaves* variable but generally lobed and fleshy have a leathery green surface with white hairs, and a vein on the underside. *Flowers* daisy-like with many petals on long stems. The disk floret is orange to yellow in colour, changing to a deep yellow or black marking near the base of each petal. It is distinctive, not easily mistaken with native species.

Gazania rigens: Coastal gazania is a clump forming perennial *herb* growing to shin high. *Leaves* are small, linear and dark green with a white under surface. Solitary daisy-like *flowers* are produced on long stems.

Both Gazania species flower most of the year. Seeds spread rapidly by water, wind and in dumped garden waste. Many hybrids have been developed for cultivation, which makes identification difficult. Withstands salt-laden winds and grows well in sandy soils. They can severely alter the vegetation structure in plant communities by replacing and suppressing native plants possibly from a high moisture demand.

Juncus acutus - Sharp Rush


Photograph R Sandercock.

Study threat rating: 8
Regional distribution: Isolated
Local density: Common

Sharp rush is a robust long-lived, grass like tufted *sedge*, to chest high. Erect, cylindrical dark green *leaves* are smooth, rigid and taper into a very sharp spine. Below their tips, in branched dense clusters, is a green floret turning red-brown. *Fruit* is an ovoid, 3-angled capsule, pointed, red-brown and glossy.

It is salt tolerant and grows in coastal saline environs and is an invasive environmental weed. Its rhizomes spread underground forming new tufts and ultimately extensive clonal patches. It is easily mistaken for native *Juncus sp*., but can be distinguished by the extremely pointed tips and is more robust i.e. bigger tussocks and wider individual stems.

Leptospermum laevigatum - Coast Tea-tree

Photograph R Sandercock.

Study threat rating: 7
Regional distribution: Common
Local density: Common

Victorian coastal tea-tree is a large and broad woody *shrub* to overhead high, with fibrous *bark* (on older trunks). Small leathery *leaves* are broad flat blue-green and hairless arranged alternately and in clusters. White *flowers* are usually arranged in pairs in the upper leaf forks and are cup shaped at the base with 5 rounded petals and have numerous stamens that are borne on the top of a swollen base. *Fruit* an olive green woody capsule with a flat top on a swollen base containing small, brown *seeds*.

Widely cultivated as a garden ornamental, or for the stabilisation of sandy soils, and in rehabilitation areas where sand-mining has occurred. Fruits remain unopened until they are removed from the plant or the plant dies. An invasive environmental weed, particularly on the coast. The Flora of Victoria suggests that natural populations do not extend west of Anglesea. Do not confuse with *Leucopogon parviflorus*.

Lycium ferocissimum - African Boxthorn

Photograph R Sandercock.

Study threat rating: 9
Regional distribution: Widespread
Local density: Common

African boxthorn is a stout much branched thorny introduced woody *shrub* to over head high. Large spines are borne along the *stems* and short side stems. L*eaves* bright green, oval shaped, blunt tipped and smooth and sometimes slightly fleshy and are usually borne in groups of 5-12 clustered along stem and at the base of spines. Can be deciduous. Fragrant tubular *flowers* are pale-lilac to white in colour with 5 petals, sometimes with dark purple markings in the centre. *Fruit* a bright orange egg shaped or rounded berry when mature. Can be confused with the native boxthorn *Lycium australe*, *Nitraria billardierei, Scaevola spinescens* and *Bursaria spinosa.*

A serious environmental weed of high impact it is a *declared plant of South Australia*. It can provide habitat to pest and indigenous animals e.g. it is used as shelter by penguins. Therefore thoroughly check habitat values before removing and make alternative provisions if necessary. It has been known to interfere with sea-lion breeding.

Polygala myrtifolia - Myrtle-leaf Milkwort

Photograph R Sandercock.

Study threat rating: 9
Regional distribution: Common
Local density: Widespread

Myrtle-leaf milkwort is a densely leaved, evergreen woody *shrub* to head high. Crowded large, dark green elliptical shaped *leaves* alternately arranged along the stem and borne on very short stalks. Small drooping clusters of showy, pea-like *flowers*, are borne at the ends of branches. The flower has white with purple and green side wings streaked with darker veins. Forward pointing tuft of white bristles occur on the folded lower petal. *Fruit* a circular capsule.

Widely cultivated as a garden ornamental, particularly in the temperate regions of Australia. An invasive environmental weed in coastal environs and its status in a national context needs to be reviewed. It does not need disturbance to colonise and can germinate in heavy shade. Readily regenerates by seed and spread into coastal dunes and cliff tops by birds, water and ants. Seed remains viable for some time. Do not confuse with *Bursaria spinosa.*

Polygala virgata - Broom milkwort

Study threat rating: 7
Regional distribution: Localised
Local density: Occasional

Broom milkwort is an erect, evergreen *shrub* and grows to over head high. A single *stem* is formed at the base of the plant and slender hairless branches occur at the top. Simple *leaves* are alternately arranged on younger branches and usually drop before flowering. The leaves are narrow in shape, dark green with a velvety texture. Small drooping clusters of deep purple to pale lilac pea like *flowers* are borne at the ends of branches. The flower has 2 side wings streaked with darker veins. Forward pointing purple tuft of tiny hairs occur at the tip of the folded lower petal. The *fruit* is a two-celled capsule and the seed is small, black and oval shaped.

Broom milkwort has escaped cultivation as a garden ornamental and become naturalised in coastal dune vegetation and is an emerging environmental weed.

Rhamnus alaternus - Blowfly Bush

Photograph R Sandercock.

Study threat rating: 9
Regional distribution: Localised
Local density: Common

Blowfly bush is a large robust woody *shrub* to over-head high. *Stems* angular, hairy and usually purple when young. *Leaves* alternately arranged, shiny dark green, tough and have a glossy leathery surface and borne on short stalks. Often shallowly toothed and a pointed tip. Small yellow–green tubular *flowers* have 5 petals and are in small dense clusters in the leaf forks. *Fruits* are flesh and berry like, turn from green to red and eventually black as they mature and are prolific.

Introduced shrub or tree from the Mediterranean it is quick growing an invasive and dominating environmental weed. Long lived plants, prefers disturbed soils but can germinate in established vegetation. Prefers a climate with dry summers and particularly invasive of dry coastal vegetation but also lower light conditions in closed shrub and woodlands. Strongholds emerging and is considered a serious risk to coastal areas and will invade undisturbed vegetation. Do not confuse with *Alyxia buxifolia* or *Adriana quadripartita.*

Thinopyrum junceiforme - Sea Wheat-grass

Photograph R Sandercock.

Study threat rating: 8
Regional distribution: Widespread
Local density: Widespread

Sea wheat-grass is a perennial *grass*, to knee high, with long, creeping rigid rhizomes. *Leaf* blades are bluish–green; some with margins rolled in. Surface smooth and hairless, but slightly rough and hairy along veins. Spikelets have 3–9 *flowers* are narrow and pale wheat in colour when mature.

Introduced in 1933 from the Mediterranean it grows at the back of the beach as a grassland. Spread by seed and vegetatively. Uses ocean currents and shoreline drift to move seed and disturbed rhizomes. Not invasive where it has foredune plant competition. It has positive attributes with its ability to stabilise unstable sand but it is reported as altering beach morphology and dune habitat for shoreline dependent birds.

Vinca major – Blue periwinkle


Robe. Photograph Chris Brodie.

Study threat value: 6
Regional distribution: Localised
Local density: Occasional

Blue periwinkle is a long-lived *herb* with trailing stems. Large *leaves* are paired, glossy green or sometimes variegated yellow and green with fine hairs along their margins. Short upright flowering stems are hairless and filled with milky sap. Blue to purple tubular *flowers* are usually borne singly in the upper leaf forks. These flowers have five long and narrow sepals and five spreading petal lobes. The elongated *fruit* are often slightly curved and are usually borne in pairs.

It can grow in a wide range of habitats including dry coastal environs but prefers moist fertile soils in well shaded sites. Sometimes reproduces by seed, but more often it spreads vegetatively via its creeping underground and aboveground stems (i.e. rhizomes and stolons). These stems enable plants to spread laterally and cover large areas. Longer distance dispersal can occur when stem segments and seeds are spread by water, in contaminated soil, or in dumped garden waste.

At the next level of threat are the remainder of the Red Alert weeds with threat values from 6 down to 4. This list is also in alphabetical order.

Acacia saligna - Golden wreath wattle
Study threat value: 5

Photograph R Sandercock.

Argyranthemun frutescens -Daisy
Study threat value: 5

Photograph R Sandercock.

Cupressus macrocarpa - Monterey Cypress
Study threat value: 5


Beachport. Photograph Chris Brodie.

Delairea odorata - Cape ivy
Study threat value: 5

Euphorbia paralias -Sea spurge
Study threat value: 4


Photograph R Sandercock.

Euphorbia terracina - False caper
Study threat value: 4


Photograph R Sandercock.

Festuca arundinacea - Tall meadow festucas
Study threat value: 5

Freesia cultivar - Freesia
Study threat value: 5


Photograph R Sandercock.

Limonium ssp. - Sea lavender
Study threat value: 4

Photograph R Sandercock.

Limonium hyblaeum - Sea lavender
Study threat value: 4

Robe. Photograph Chris Brodie.

Olea europae - Olive
Study threat value: 4


Photograph R Sandercock.

Early Warning
While assessing weeds as a key threat to the South East coast, it was noted that a number of high priority environmental weeds are not currently recorded in the region. However, potentially there is a strong likelihood to become established from further a field in the future. It is imperative that land managers and communities are aware of these high priority weeds and are readily able to identify any new arrivals or outbreaks. Particular species of concern are detailed below:

Asparagus declinatus - Bridal Veil


Photograph R Sandercock.

Bridal veil is a rhizomatous and tuberous perennial, cool season vine, low growing on supporting vegetation to waist high. Short-lived above ground stems and long-lived tubers that are produced on creeping underground stems. Numerous needle likes leaves are grouped in threes along the stem. It has small white flowers with 6 petals borne singly. It has fleshy green-globular berries, appearing in October and turn pale bluish-grey or whitish as they mature.

A highly invasive environmental weed that climbs, outcompetes and smothers, kills and prevents regeneration of native vegetation. Has the potential to become a severe threat to biodiversity in heavily infested areas, its impacts appearing similar to those of Bridal Creeper. Birds spread the seeds which are able to germinate and establish in undisturbed soil. It also spreads vegetatively via its creeping underground stems. Formerly known as Asparagus crispus.

Trachyandra divaricata - Dune Onion-grass

Photograph R Sandercock.

Dune onion-grass is a tufted herb to knee high. Flat fleshy sticky leaves. Flowers white with a brown central stripe on petals. Flowers late winter–spring. Seed red–brown to black.

The flower stems detach and tumble with the wind and disperses numerous seed. It is possibly the coasts most serious potential weed threat. A probable introduction from ship ballast and limited to eastern Gulf St Vincent at present.

Retama raetam - White Weeping Broom

Photograph R Sandercock.

White weeping broom is a large woody weeping shrub to over-head high. Grey-green with slender, drooping branches. The leaves are small and narrow and are quickly dropped and the plant remains leafless for most of the year. Flowers are white and pea like appearing close to the stem in clusters. Flowers from late winter to mid spring, shedding seed pods late spring/early summer.

On the Alert List of Environmental Weeds. Thrives in alkaline soils and very adapted to arid conditions. Rapidly colonises and is emerging in coastal areas of Yorke Peninsula. Sold from nurseries. Recently recorded at Southend.

Non-rated Weeds of Importance

Several weed species were not rated as high priority environmental weeds during the threat evaluation process, although were still noted as being of importance due to other values.

Ammophila arenaria - (Marram Grass)

Photograph R Sandercock.

Marram Grass was historically introduced from western Europe to the Australian coast to aid in dune stabilisation projects. While not considered overly invasive, the grass can alter foredune shape, creating steeper dunes. It is no longer the first dune grass recommended for revegetation projects due to a preference for utilising local provenance species and advances in propagation techniques for the indigenous species Spinifex hirsutus (Rolling Spinifex). Introducing other dune species into Marram areas will promote succession and can control spread. May need containment if it is impacting on the ecology of the area e.g. shorebird nesting areas on the high tide line. It is long lived and spreads quickly via creeping underground stems.

Cakile maritima ssp. maritima - (Two-horned Sea Rocket)

Photograph R Sandercock.

Sea rocket was first recorded in South Australia in 1918, thought to be introduced from ship ballast. A widespread cosmopolitan plant that is found at the back of the beach and any extremely disturbed dune site. A niche plant co-existing contentedly, rarely invasive, a good soil and dune stabiliser and doesn't appear to be colonising any space at the expense of local indigenous species. Known food source for the critically endangered Orange Bellied Parrot.

4.9.4 Managing Weeds

Despite longstanding control measures administered by a wide range of natural resource managers, there is evidence of an increasing rate of weed encroachment towards every ecosystem of immediate conservation value within Australia (Agriculture and Resource Management Council of Australia and New Zealand Environment and Conservation Council, 1999). The public ownership and linearity of the coast make the recognition of the weed disturbance problematic. More needs to be done as weeds are having an impact on the coast and no adequate baseline data or monitoring is in place. As weed flora is constantly changing with new introductions the collection of specimens and mapping can be vitally important. More resources and developing a centralised weed database with GIS capability could reverse the lack of environmental weed mapping.

While it would be desirable to consider the control of weeds on the coast as a high priority, funds will be a limiting factor and weed management strategies should subsequently aim to reduce or eliminate physical disturbance to native vegetation. In addition, targeting the control of weeds and preventing new incursions in areas of high biodiversity value and large areas currently relatively free of weeds is vital.

4.9.5 Actions

A number of land management practices can be enacted which could decrease weed ingress, including: rationalising access tracks, restricting fire breaks to only where required, controlling introduced grazing animals, maintaining both weed-free and fertilizer-free buffer zones around native vegetation. It is also imperative that potential introductions of plants for productive or amenity purposes are thoroughly vetted in terms of invasive characteristics. At a local level, many coastal weeds are readily available for purchase from commercial plant nurseries and local produce markets. Information on the risk of garden plants that are known coastal weeds needs to be made available to those who are likely to use these species in near-coastal locations.

4.10 Feral Species

Two pest animal species, deer and rabbit, were included in the analysis. These animals are damaging to vegetation through overgrazing, burrowing, competition for food, the spread of disease and secondary impacts such as soil destabilsation and weed invasion. Threat prioritisation was based on information from the SE NRM Board that rated the impact deer and rabbit are having on areas of land (hundreds). No data was available for the study area outside of the SE NRM region, including the northern half of Cell SE16 and all of SE17. The absence of this information makes comparison across the entire study area difficult. However, the coarse data together with local observation indicates that deer are spreading south from the Coorong and that the rabbit threat is widespread across the entire study area.

4.11 Climate Change

> *"Coastal regions are vulnerable to sea level rise, increased sea surface temperature, increased storm intensity and frequency, ocean acidification and changes to rainfall, run-off, wave size and direction and ocean currents." (National Climate Change Adaptation Framework, COAG, April, 2007)*

Climate change is treated here as a threat, however, there is no detailed local data to be analysed through the GIS approach used in this report. Rather, the best available projections of change for this region are used to identify potential impacts in the coastal zone and this is compiled at the local level within the cell descriptions, Section 6.3.

The Intergovernmental Panel on Climate Change (IPCC) published its Fourth Assessment Report (AR4) on global climate change, in 2007. An update of AR4 for the December 2009 Copenhagen Climate Change Conference has been published by a large group of atmospheric scientists from published refereed work in 2007 and 2008, (Allison et al, 2009, 'The Copenhagen Diagnosis').The CSIRO has elaborated statewide projections of change (McInnes et. al. 2003 and Suppiah et al 2006) and most recently, an updated technical report and series of regional scale maps (CSIRO, 2007). Currently, the South Australian Coast Protection Board is in the process of review of the state policy on coastal flooding and erosion taking into account projected sea level rise.

Hennesey, 2006, has used projections for the years 2030 and 2070 for initial assessments of risk at a national scale and CSIRO 2007 uses these dates for maps of detailed local projections. Consequently these dates are employed in the climate change scenario (Section 4.11.5, below) which acts as the basis for the impacts and possible adaptations in the cell descriptions of Chapter 6.

Set out below is a brief summary of the most reliable accounts of climate change within the region. In Chapter 6 local impacts and adaptations within the coastal region have been placed into cell descriptions, together with possible management actions. The context (alerting decision makers to changes likely to relate to the objectives of this project) outlined in this section, and the risk identification (likely impacts of climate change on the local areas described for cells in Section 6.3) constitute the first two stages of a risk management framework; important future work on event and impact probability is beyond the scope of this study.

4.11.1 The Intergovernmental Panel on Climate Change, (IPCC).

The Intergovernmental Panel on Climate Change (IPCC) of the World Meteorological Organisation has coordinated the work of scientists on climate change since 1989. Four major reviews of global changes and modelled predictions of future changes ('Assessment Reports') have been produced, in 1991, 1996, 2001 and 2007. Each assessment includes three workshop reports: I – the Physical Science Basis; II – the Impacts of Change; III – Policy Responses. The Fourth Assessment Report of the IPCC confirms and strengthens the observations and modelling of earlier assessments.

The following quotations are extracted from the IPCC Policy Makers Summary published 2/2/07:-

5 Current Climate Change

"Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture".

"The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report, leading to very high confidence (greater than 95%) that the globally

averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m-2".
"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."

Table 4.5. Observed Rate of Sea Level Rise and Estimated Contributions from Different Sources (IPCC, 2007, p.7).

	Rate of sea level rise (mm per year)	
Source of sea level rise	**1961 – 2003**	**1993 – 2003**
Thermal expansion	0.42 +/- 0.12	1.6 +/- 0.5
Glaciers and ice caps	0.5 +/- 0.18	0.77 +/- 0.22
Greenland ice sheet	0.05 +/- 0.12	0.21 +/- 0.07
Antarctic ice sheet	0.14 +/- 0.41	0.21 +/- 0.35
Sum of individual contributions to sea level rise	1.1 +/- 0.5	2.8 +/- 0.7
Observed total sea level rise	1.8 +/- 0.5	3.1 +/- 0.7
Difference (Observed minus sum of estimated climate contributions)	0.7 +/- 0.7	0.3I +/- 1.0

At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones, as summarised in IPCC 2007.

Palaeoclimate information supports the interpretation that the warmth of the last half of the 20th century is unusual in at least the previous 1300 years. The last time the Polar Regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 metres of sea level rise.

Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely (greater than 90% probability) due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the Third Assessment Report's conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns.

Analysis of climate models together with constraints from observations enables an assessed likely range to be given for climate sensitivity for the first time and provides increased confidence in the understanding of the climate system response to radiative forcing.

Projections of future changes in climate from IPCC 2007

IPCC projections are calculated from a series of mathematical models of the behaviour of the atmosphere; they are given for a range of emissions scenarios. For the next two decades a warming of about 0.2°C per decade is projected: even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century. There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice melting.

The model based projections of global average sea level rise to 2090-2099 are close to the IPCC projections of the third assessment report; they show a sea level rise of between 18cm and 59 cm from 1990 to 2100. But, they do not include the full effects of changes in ice sheet flow, "because a basis in published literature is lacking".

Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized now.

4.11.2 CSIRO Review of Climate Change in Regions Within Australia

The most recent review by CSIRO (2007) has been assembled for the whole of Australia, but the maps contain sufficient detail to allow regional scenarios to be constructed. This updates, but does not radically alter, earlier work for South Australia by McInnes (2003) and Suppiah (2006). The 2007 work incorporates the IPCC Fourth Assessment Report (2007) and a large number of papers on climate change in the Australian region.

Observed climate trends in Australia

Australia's average temperature has risen 0.9^0 C since 1950; South Australia's average temperature has increased by 1.2ºC, slightly faster than the national trend. 2005 was the warmest year on record in SA. Spring snow depth in the Snowy Mountains has decreased markedly.
Since 1950 rainfall in SE Australia and in SW Western Australia has declined markedly. Trends in South Australian annual rainfall are generally weaker than other parts of the continent; most of the north-western part of the state has experienced an increasing rainfall trend, while southern coastal regions have experienced a slight drying trend since 1950. Trends in most extreme rainfall events are rising.

Global sea level rose 17cm from 1900 to 2,000: from 1950 to 1993 the average rise was 1.8mm/year; since 1993 the rise has been 3mm/year[1]. This rise and its acceleration correspond with the upper limit of IPCC projections. All Australian coasts show sea level rise, but with variation from place to place. Thus within the Gulf St Vincent, Port Stanvac shows recent changes close to the national average; however, Port Adelaide shows much faster sea level rise due to local sinking of the land; while the top of the Spencer Gulf is thought to show slower than average rise due to crustal isostatic re-adjustment.

Oceans show warming: the largest changes have been off the Pacific coast of Tasmania, due to the southern extension of the East Australian Current. Sea surface temperatures off South Australia have risen a smaller amount, of about half of one degree.

Along the southern coast of Australia winds and storms have declined: mid-latitude westerly winds have decreased; frequency of depressions along Australia's south coast has declined, with a

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[1] The National Tidal Centre of the Bureau of Meteorology has reported that current (2008) annual sea level rise in the Australian region is 4.5mm, (communication to the Mean Sea Level committee of the Coast Protection Board of South Australia). This is tracking a little above the IPCC projections. The trend at Port Stanvac, Adelaide, was 5.1mm in 2009, see: http://www.bom.gov.au/ntc/IDO60202/IDO60202.2009.pdf

southern shift in storm tracks in winter. The general pattern of weather systems that affect the South East0 has, on average, been displaced pole wards.

CSIRO Projections for South Australia's Climate

Average regional temperature, rainfall, rainfall intensity and potential evaporation projections, compared with the 1990 baseline, for the Coorong and Limestone Coast region.

[These projections are from the CSIRO 2007 maps, using medium emission scenarios.]

Mean annual temperatures are projected to increase to between 0.6 to 1.0°C by 2030 and 1.5 to 2.0°C by 2070 (CSIRO, 2007, Technical Report 5, pp. 67,68) and these changes are almost uniform throughout the year. Over the ocean sea surface temperature show a similar trend 1.0 to 1.5^{0}C by 2070, with a moderating effect in terms of seasonal variation.

With regard to annual rainfall, changes of -2% to -5% by 2030, and -10% to -20% by 2070 are projected for areas near the coast; greatest decrease is indicated in spring. Projections for different scenarios show a great range of values. However, McInnes et al (p.35) show a change in rainfall regime: with rare extreme rainfall events (i.e. periods of intense rainfall) occurring at all seasons but spring.

Projections of annual potential evaporation indicate increases across the region, of 0 to +8%; average annual water balance shows clear deficits. However, intense rainfall events may result in flash floods.

Projections of annual wind speeds show a slight fall: 0 to -5% for 2030 and 0 to -10 for 2070; but projections for different scenarios show a wide range of values, from increase to considerable decrease.

These values are projected to higher levels of change in the high emissions scenario: current (2009) global emissions are tracking in line with the high emission scenario.

Projections of sea level rise, coastal storms and changing wave conditions

The CSIRO 2007 review quotes the IPCC 2007 projections of sea level rise, noted above,

> *"Global sea level rise is projected by the IPCC to be 18-59 cm by 2100, with a possible additional contribution from ice sheets of 10 to 20 cm. However, further ice sheet contributions that cannot be quantified at this time and may increase the upper limit of sea level rise substantially.." (CSIRO, 2007, p.92).*

Variations around the global mean along the coast of Australia show (p.93) that South Australia is projected as changing close to the mean; variations are due to mean atmospheric pressure and varying strength of ocean currents.

Currently, storm surges of at least 0.5 to 1.5 metres occur along the South Australian coast[2]; they are caused by West to South-Westerlies following the passage of fronts and their associated low pressure systems further south, (McInnes,2003). The frequency of winter lows and therefore the frequency of surges decreases by about 20% in the vicinity of SA under enhanced greenhouse conditions, however, the largest storms show an increase in intensity. It should be remembered though that when storm frequency is combined with sea level rise, the probability of a surge at

[2] Storm event records show that surge near to 0.5m. above the forecast tide may be expected on the open Southern Ocean coast, due to combination of strong onshore winds and low atmospheric pressure.

heights within the present range, would increase.[3] The magnitude of the highest floods also increases: modelling of the combined effect of sea level rise and storm surge on parts of the Victorian coast "demonstrate the potential for significant increases in inundation due to higher mean sea level and much more intense weather systems", (CSIRO 2007, p.11).

Whilst local wave conditions depend on local winds and local storm frequency, underlying swell depends on synoptic conditions in the Southern Ocean. JL Davies (1980) has demonstrated that swell affecting the south coast of Australia is generated in the 'roaring forties'. CSIRO 2007, p.106, indicates that "The Southern Annular Mode is likely to shift towards its positive phase (weaker westerly winds over southern Australia, stronger westerly winds at higher latitudes)." This would result in some increase in the preponderance of long period swell, predominantly from the south-west; locally generated waves would become less significant. Under Greenhouse conditions littoral movement of sand that is observed currently (at eg Beachport) appears likely to continue, because of the continued energy input of the long period swell.

4.11.3 The Copenhagen Diagnosis, 2009

This summary of research, prepared for the Copenhagen Conference of December 2009, is a survey of worldwide trends. The report was prepared by 26 leading climate scientists, including a number of Intergovernmental Panel on Climate Change (IPCC) Lead Authors, and seeks to synthesise the most policy-relevant climate science published since the close-off of material for the last (2007) IPCC report. It updates the discussion above in this section.

The warming trend is confirmed by more recent observations, as summarised in Allison et al, 2009, p.17 " the IPCC gave the 25-year trend as 0.177 ± 0.052 °C per decade for the period ending 2006. Updating this by including the last two years (2007 and 2008), the trend becomes 0.187 ± 0.052 °C per decade for the period ending 2008. The recent observed climate trend is thus one of ongoing warming, in line with IPCC predictions."

This atmospheric warming trend is further supported by recent reports on current ocean warming, Allison et al 2009, p.37: "Increases in oceanic heat content in the upper ocean (0-700m) between 1963 and 2003 have been found to be 50% higher than previous estimates (Domingues et al. 2008, Bindoff et al. 2007). The higher estimates of heat content change are now consistent with observations of sea-level rise over the last 50 years, resolving a long standing scientific problem in understanding the contribution of thermal expansion to sea-level (Domingues et al. 2008). Observations also show deep-ocean warming that is much more widespread in the Atlantic and Southern Oceans (Johnson et al. 2008a, Johnson et al. 2008b) than previously appreciated."

Ocean trends towards greater acidity have been further detailed in Allison et al 2009, p. 38, "The increase in ocean CO2 has caused a direct decrease in surface ocean pH by an average of 0.1 units since 1750 and an increase in acidity by more than 30% (Orr et al. 2005: McNeil and Matear 2007; Riebesell, et al. 2009). Calcifying organisms and reefs have been shown to be particularly vulnerable to high CO2, low pH waters (Fabry et al. 2008). New in-situ evidence shows a tight dependence between calcification and atmospheric CO2, with smaller shells evident during higher CO2 conditions over the past 50,000 years (Moy et al. 2009). Furthermore, due to pre-existing conditions, the polar regions of the Arctic and Southern Oceans are expected to start dissolving certain shells once the atmospheric levels reach 450ppm (~2030 under business-as-usual scenario); McNeil and Matear 2008: Orr et al. 2009)."

[3] For example, from the tidal record held at DEH, if the current coastal flood risk curve for Port Adelaide is re-drawn 50cm higher, the present 100 year ARI (average return interval) flood level becomes the 2 year ARI flood. Port Adelaide has been chosen for this example because of its relatively long tide record.

With regard to sea level rise, the Copenhagen Diagnosis points out that the papers published since 2007 show loss of ice sheet mass from the polar regions, and, assuming this to continue in line with temperature change, would lead to a doubling of the IPCC AR4 estimate by 2100.

> *"Satellite measurements show sea-level is rising at 3 to.4 millimeters per year since these records (satellite) began in 1993. This is 80% faster than the best estimate of the IPCC Third Assessment Report for the same time period.*
> *Accounting for ice-sheet mass loss, sea-level rise until 2100 is likely to be at least twice as large as that presented by IPCC AR4, with an upper limit of ~2m based on new ice-sheet understanding."*

(Allison, 2009, p.37, summary points)

Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized now.

4.11.4 Sea Level Rise Scenarios

There is considerable uncertainty over future global sea level rise amongst published scenarios, due mainly to incomplete understanding of change of mass balance of the huge ice sheets of Greenland and Antarctica. It seems likely that future projections of sea level will change with improved knowledge of the behaviour of the continental ice sheets in the face of temperature and precipitation changes and also as measurement of speed of contemporary sea level rise continues. However, most of the uncertainty is on the side of larger rises, and it appears that future estimates are likely to rise.

In order to take a precautionary approach, and bearing in mind recent reports of accelerated speeds of movement of Greenland and Antarctic land-based ice, the top of the range of the Copenhagen Diagnosis (Figure 17, p.40) projection has been chosen for the local scenario: i.e. a 140cm rise by 2100. Values for 2030 of + 20cm and 2070 + 80cm, have been interpolated to give an indication of the order of change likely for the scenario. In view of the range of modelled projections and the uncertainty over continental ice melting, these figures are simply indicative of thinking based on current knowledge.

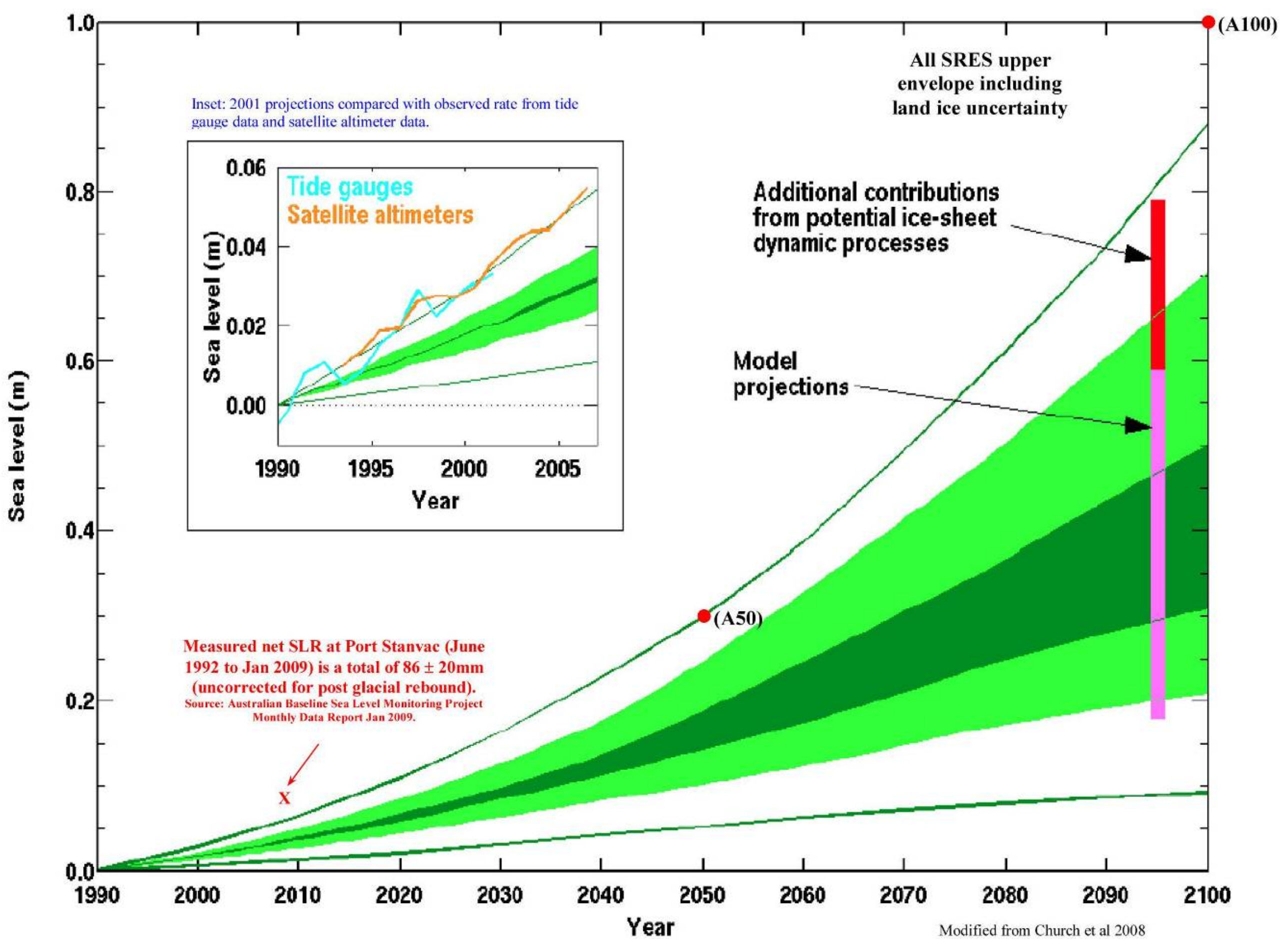
Uncertainty and mis-understanding over projected sea level rise are compounded by regional variation around global projections due to changes in winds and ocean currents, as well as local tectonic effects, but for the South East relevant research suggests sea levels is changing in line with global average figures.

[It should be noted that current SA policy on coastal flooding and erosion applying to development control in South Australia currently envisages a sea level rise of 1 metre by 2100; the Coast Protection Board is currently reviewing its policy].

A linked issue to mean sea level rise is frequency of storm and surge heights at any given location: as mean sea level rises the frequency with which maximum surge and storm elevations are reached increases rapidly. As noted by Church et al 2009 (p. 8)

"For many locations, a 0.5 m sea-level rise would result in the present one-in a-hundred-year event becoming an annual or more frequent event by the end of the 21st century".

This drastic increase in the frequency of sea flooding would not only have clear hazard potential, but in the context of this report, important implications for coastal wetlands, saltmarsh and estuaries.



Modified from Church et al 2008

4.11.5 Summary Scenario for Climate Change for use in Chapter 6

From the sections above, projected conditions in 2030 and 2070 are summarised; these dates have been chosen in order to reflect the CSIRO detailed regional projections of temperature and rainfall.

a) Sea Level Rise and Storm magnitude

The current mean sea level rise of c.4.5mm/year will accelerate. From 1992 until September 2010, measured sea level rise at Port Stanvac has averaged 4.7mm per year, and 4.1mm per year at Thevenard. While sea level rise of 4mm per year may not seem significant in itself, a general rule of thumb is that sandy coastlines will typically recede by about 50 to 100 times the amount of sea level rise. Thus, mean sea level rise of just 4mm per year (72mm in the 18 years since 1992) translates to potential coastal recession of 3.5 to 7 metres over that period. Sea levels in the region are projected to be higher in 2030 by + 20cm and in 2070 by + 80cm: these would lead to a further 10 to 20m erosion by 2030 and 40 to 80m recession in 2070.

Rare intense storms could add a surge height comparable to today's surges of + 0.5m (open ocean coast) to 1.5m. (head of Gulf). Although storm frequency may fall, flood heights considered rare to-day will become much more frequent, because of sea level rise: sea level rise exacerbates coastal flooding hazard. For example, following a 50cm sea level rise, the elevation of to-days 100 year flood at Adelaide, could become the 2 year flood. Sea level rise therefore affects not only the extent of an area that gets flooded, but greatly increases the frequency of flooding for areas already at risk of flooding.

The impact of such changes will lead to beach recession, foredune damage and loss and dune de-stabilisation; large barrier systems, such as Coorong NP and Canunda NP will continue to retreat, increased foredune damage will accelerate the existing transgression and transfer of sediment from the foreshore to the back dune[4]. Erosion of the many calcarenite cliffs will accelerate, shore platforms and reefs will be flooded; some reef habitats will be lost.

The more frequent and extensive inundation of coastal wetlands, including salt marshes, and changes to estuarine regimes, will all have terrestrial habitat implications; these changes on the land will have profound implications for the marine environment as transfer of sediment and nutrients from land to sea is altered and fish nurseries changed. Loss of saltmarsh will reduce the habitats of many birds – including migratory species - using the saltmarsh and its lakes; loss or reduction of some beaches will be a particular challenge for shorebirds. Coastal wetlands and estuaries will not only suffer more frequent storm tidal inundation, but also slow salt water intrusion through surface waterways and sub-surface seepage.

b) Increasing average temperatures and aridity

Mean annual temperatures are projected to increase to between 0.3 to 0.6°C by 2030 and 1.5 to 2.0°C by 2070.Annual rainfall: changes of -2% to -5% by 2030, and -10% to -20% by 2070 are projected for areas near the coast; greatest decrease is indicated in spring. An increase in potential evapo-transpiration of up to 8% adds to the effect of increasing aridity.

While coastal plants are already adapted to a hostile salty and windy environment, these changes will have an impact: vegetation will be slower to recover following damage, such as foredune damage from storms and this may well allow weed invasion. This is especially significant for many dune areas that will become mobilised by a reduction in stabilizing vegetation cover.

Fragmentation of habitats reduces the ability of species to adapt through migration. The response of individual plant and animal species to the whole range of changed climate conditions is uncertain. Coastal freshwater lakes will be reduced, with longer periods of lower water or desiccation.

c) Run-off regime change

Increasing aridity will be reflected in reduced run off: some seasonal streams will flow for fewer months, others will not flow at all. The intensity of rare extreme rainfall events will increase and this will be reflected in flash floods in creeks and storm drains. What are now semi arid creeks will behave more as arid land creeks.

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[4] A recent study by the Coastal Studies Unit, University of Sydney (Short & Cowell, 2009, p.1), came to the following conclusions with regard to the impact of sea level rise on the Younghusband Peninsula:

"6. Modelling of shoreline response to sea level rise in the three coastal Cells results in a remarkable uniform longshore response, with no significant difference between the three Cells.

7. Shoreline recession would be driven by the sea level rise together with sand loss to the dunes, the Murray Mouth flood tide delta and periodically to storm demand.

8. Maximum recession for a +1.5 m sea level rise along the Coorong beach (1% probability) to 2030, 2050 and 2109 is on the order of 40 m, 95 m and 250 m respectively.

9. Maximum recession for a +1.0 m and +1.5 m rise in sea level over the next 100 years (to 2109) with a probability of 1%, is on the order of 200 m and 250 m respectively, while minimum recession with a probability of 100% would be between 150 m and 200 m respectively.

10. When the full range of sea level scenarios is modelled to 2109 the recession ranges from the maximum of 250 m (1% probability) to a minimum of 40 m (99% probability).

11. As the narrowest section of barrier along the Sir Richard Peninsula is 350-400 m wide, even at the maximum rate of shoreline recession the barrier would not be breached by rising sea level by 2109."

These recession rates are higher than expected because of anticipated sand loss to the Murray Mouth flood tide delta.

The intensity of rare rainfall events may be expected to increase soil erosion, both through sheet flow and gullying: coastal slopes and soft rock cliffs may be impacted by this, although this is considerably affected by land and drainage management. Nearshore waters, coastal wetlands and lakes will receive irregular pulses of sediment from these events. The balance of sediment accretion, sediment compaction and sea level rise will determine the changes in saltmarsh (Saintilan, 2009, pp. 60-69): plentiful sediment supply (both from land and sea) may allow saltmarsh to maintain elevation with regard to sea level. A contemporary study (Saintilan & Williams 1999) demonstrates saltmarsh loss throughout SE Australia; in the balance of sediment accretion and contemporary sea level rise there appears to be an accretion deficit. Saltmarsh survival depends on planned habitat retreat in the face of sea level rise and sediment deficit.

d) Ocean waters change

Ocean waters will become more acid as carbon dioxide is absorbed into sea water. Surface ocean temperatures are projected to rise by 0.3^0 C to 0.6^0 C by 2030, and 1.0 to 1.5^0 C by 2070, although there is great variation between models for the latter date. Global changes in ocean circulation may result from movement of the climatic belts; notably this may impact on ocean upwellings.

Wind speed changes are slight; with small average falls. Weather systems over the Southern Ocean are expected to continue to supply considerable swell wave energy from the south.

The response of individual marine plant and animal species to the whole range of changed climate conditions is uncertain. In response to increasing ocean acidity marine organisms will produce smaller and thinner shells; however the timing is uncertain. Southern Ocean foraminifera have recently been reported as showing reduced calcification, (Moy, 2009). Supply of calcareous sands produced nearshore to beaches will decrease, although timescale and quantity are uncertain. Ocean warming may well result in loss of cold water species and gain in tropical species. Modification of ocean circulation has the potential to alter upwellings, in timing and occurrence. Swell wave climate under Greenhouse conditions are expected to continue to drive shoreline littoral drift sand movement in direction and strength similar to to-day within the region.

The local impact of these projections is detailed in each cell description in Chapter 6, together with possible management adaptations; the Regional Recommendations also refer to climate change.