Phillip Island Nature Parks' Coastal Process Study

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PROJECT DETAILS

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Cover Photo: Penguin Parade Viewing Stands at Summerland Beach (Photo: Christine Arrowsmith, May 14th 204)

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GLOSSARY

Aeolian	The erosion, transport and deposition of material by wind.
Australian Height Datum(AHD)	A common national plane of level corresponding approximately to mean sea level
Alluvial	Water driven sediment transport process (non-marine)
Astronomical tide	Water level variations due to the combined effects of the Earth's rotation, the Moon's orbit around the Earth and the Earth's orbit around the Sun
Backshore	The area of shore lying between the average high-tide mark and the vegetation, affected by waves only during severe storms
Coastal Hazard	A term to collectively describe physical changes and impacts to the natural environment which are significantly driven by coastal or oceanographic processes.
Colluvium	A term used to describe loose, unconsolidated sediments that have been deposited at the base of a slope or cliff.
Diurnal	A daily variation, as in day and night.
DTM	Digital Terrain Model, a three dimensional representation of the ground surface
Ebb Tide	The outgoing tidal movement of water resulting in a low tide.
Embayment	A coastal indentation which has been submerged by rising sea-level and has not been significantly infilled by sediment.
EVC	Ecological Vegetation Class. These are the basis mapping units used for biodiversity planning and conservation in Victoria. Each EVC represents one or more plant communities that occur in similar types of environments.
Estuaries	The seaward limit of a drowned valley which receives sediment from both river and marine sources and contains geomorphic and sedimentary conditions influenced by tide, wave and river processes.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto
Geomorphology	The study of the origin, characteristics and development of land forms
GIS	Geographical Information System
Holocene	The period beginning approximately 12,000 years ago. It is characterised by warming of the climate following the last glacial period and rapid increase in global sea levels to approximately present day levels.
HAT	Highest Astronomical Tide: the highest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects
LiDAR	**Li**ght **D**etection **a**nd **R**anging – also known as airborne laser scanning, is a remote sensing tool that is used to generate highly accurate 3D maps of the Earth's surface
Lithology	A description of the physical character if a rock or rock formation.
Littoral Zone	An area of the coastline in which sediment movement by wave, current and wind action is prevalent
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of water and sediments along a shoreline
MHWS	Mean High Water Springs, i.e. the mean of spring tide water levels over a long period of time.
MSL	Mean Sea Level

Nearshore	The region of land extending from the backshore to the beginning of the offshore zone.
Paludal	Sediments that have accumulated in a marshy or swampy environment.
Physiography	The study of the physical patterns and processes of the environment to understand the forces that produce and change rocks, oceans, weather, and flora and fauna patterns.
Pleistocene	The period from 2.5 million to 12,000 years before present that spans the earth's recent period of repeated glaciations and large fluctuations in global sea levels
Regolith	A layer of loose, uniform material covering solid rock.
Semi-diurnal	A twice-daily variation, eg. two high waters per day
Sea Level Rise (SLR)	A permanent increase in the mean sea level
Storm Surge	The increase in coastal water levels caused by the barometric and wind set-up effects of storms. Barometric set-up refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind set-up refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast
Storm tide	Coastal water level produced by the combination of astronomical and meteorological (storm surge) ocean water level forcing
Sub-aerial	Processes that take place on the land or at the earth's surface as opposed to underwater or underground.
Susceptibility	The sensitivity of coastal landforms to the impacts of coastal hazards such as sea-level rise and storm waves. This may include physical instability and/or inundation.
Taxa	A taxonomic category or group, such as an order, family, genus or species
Tidal Range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth
Vulnerability	Vulnerability is a function of exposure to climatic factors, sensitivity to change and the capacity to adapt to that change. In this report is means the degree to which a natural system is or is not capable of adapting or responding to the impacts of coastal hazards to which they are physically susceptible and exposed.[1]

[1] Definition taken from the Smartline Glossary http://www.ozcoasts.gov.au/coastal/smartline_terms.jsp
[2] Definition taken from the Smartline Introduction http://www.ozcoasts.gov.au/coastal/introduction.jsp

1. INTRODUCTION

1.1 Project Overview

Phillip Island Nature Parks (the Nature Park) is located on Phillip Island in Western Port approximately 120 kilometres from central Melbourne. Phillip Island is approximately 100 square kilometres in area and supports a diversity of environments and human activities. Some 90% of the island has been cleared and comprises farming and urban areas, while the remainder consists of woodlands, wetlands and beach reserves, most of which are incorporated into the Phillip Island Nature Parks.

The Nature Park was created in 1996 to integrate management of public land on Phillip Island and to facilitate innovation in wildlife management, visitor services and tourism experiences. The Nature Park consists of a number of Crown Land areas spread across the island with a total area of about 1,805 hectares.

Phillip Island now receives over 3.5 million visitors per year and is much loved by people who reside on the island. People enjoy the beautiful beaches and the magnificent ocean views, supporting activities such as surfing, fishing, beach walking, and wildlife viewing. This keen interest in the natural environment motivates many stakeholders to have input into the management of its assets. The Nature Park is charged with managing the majority of the southern coastline of the island under the Crown Land (Reserves) Act 1978, and to balance the needs of the different stakeholders.

Water Technology was engaged by the Phillip Island Nature Parks to undertake the Phillip Island Nature Parks' Coastal Processes Study. The objective of the project was to conduct an assessment of recent coastal evolution, future response of the coastline to coastal processes, and identify potential threats to natural and infrastructure assets as a result of coastal processes now and into the medium term future. The overall outcome was to determine potential management strategies to protect natural assets such as Little Penguin and Hooded Plover habitat and the park's critical infrastructure such as the viewing stands at Penguin Parade, the boardwalks at Smiths Beach, and the car park and Surf Lifesaving Club at Woolamai Beach.

The boundaries of the study area for the Phillip Island Nature Parks' Coastal Processes Study were defined as extending from Penguin Parade, Summerland Bay in the west, to Magic Lands, Cape Woolamai in the East, as displayed in Figure 1-1.

1.2 Project Team

This project was undertaken as a partnership between Water Technology (Lead Consultant and project manager) and a number of independent technical experts who provided specialist input to key aspects of the assessment.

The key team members are summarised as follows:

- Andrew McCowan and Christine Lauchlan Arrowsmith (Water Technology) – project management, hydrodynamics and physical processes, coastal engineering
- Neville Rosengren (Environmental GeoSurveys) – coastal geology and geomorphology
- Alison Oates and Doug Frood (Oates Environmental Consulting) – dune vegetation ecology

1.3 Reporting

This report is structured as follows:

- Section 1: Introduction and project scope,
- Section 2: Overview of the Study Area,

- Section 3: Coastal landforms and processes, including the natural and built environment, and future change
- Section 4: Threats to Natural and Infrastructure Assets,
- Section 5: Management and Mitigation Strategies, and
- Section 6: Recommendations.

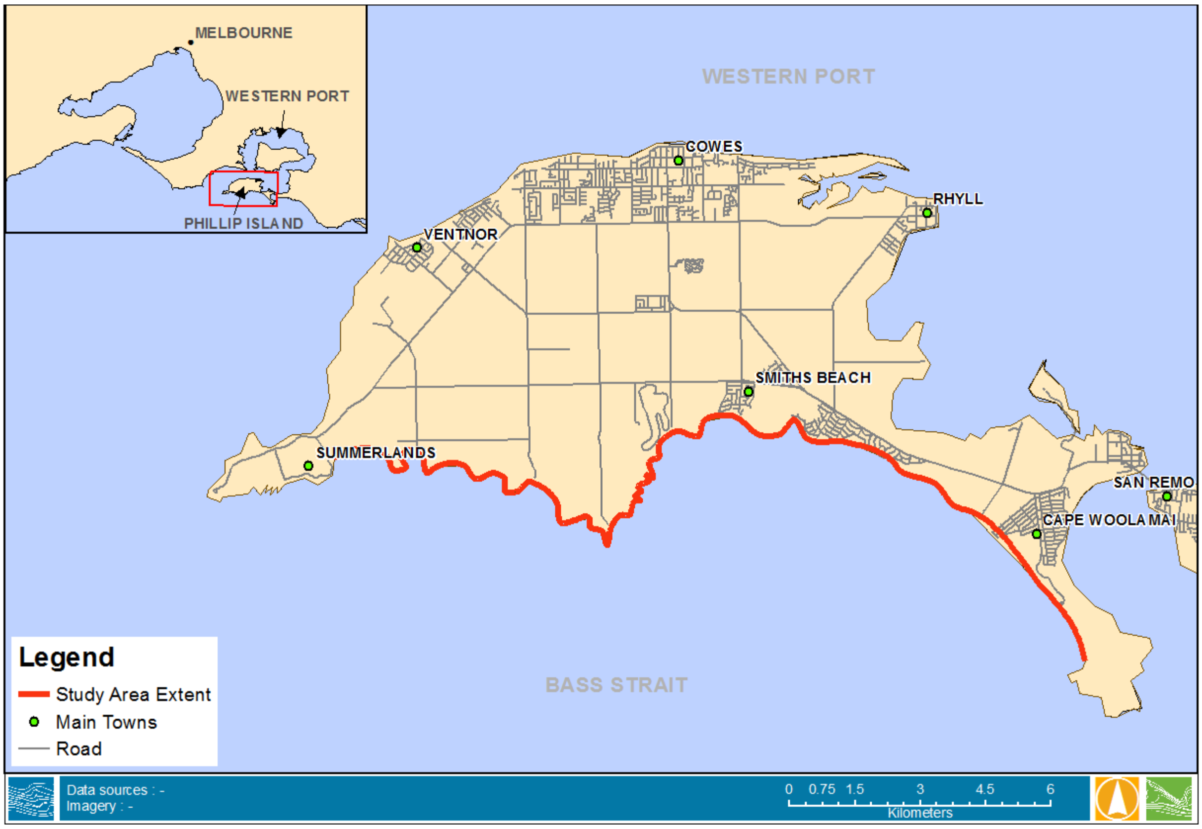


Figure 1-1 **Phillip Island Coastal Process Study Area Overview**

2. THE STUDY AREA

Phillip Island is oriented west-east across the entrance to Western Port – the south coast faces Bass Strait and the north coast faces into Western Port. This orientation produces marked contrasts in geomorphology and coastal processes along the study area.

2.1 Geology

The main body of rock across Phillip Island is a substantial thickness of multiple flows of basalt lava, predominantly the Flinders Basalt, and other altered and fragmental lavas, Figure 2-1. These basaltic layers overlie weathered granite at Pyramid Rock and Cape Woolamai, Figure 2-2.

Figure 2-1 Vertical jointing in coherent basalt at Sunderland Bay (A) and close-spaced irregular jointing in fine-grained fragmental lava at Smith Beach (B)

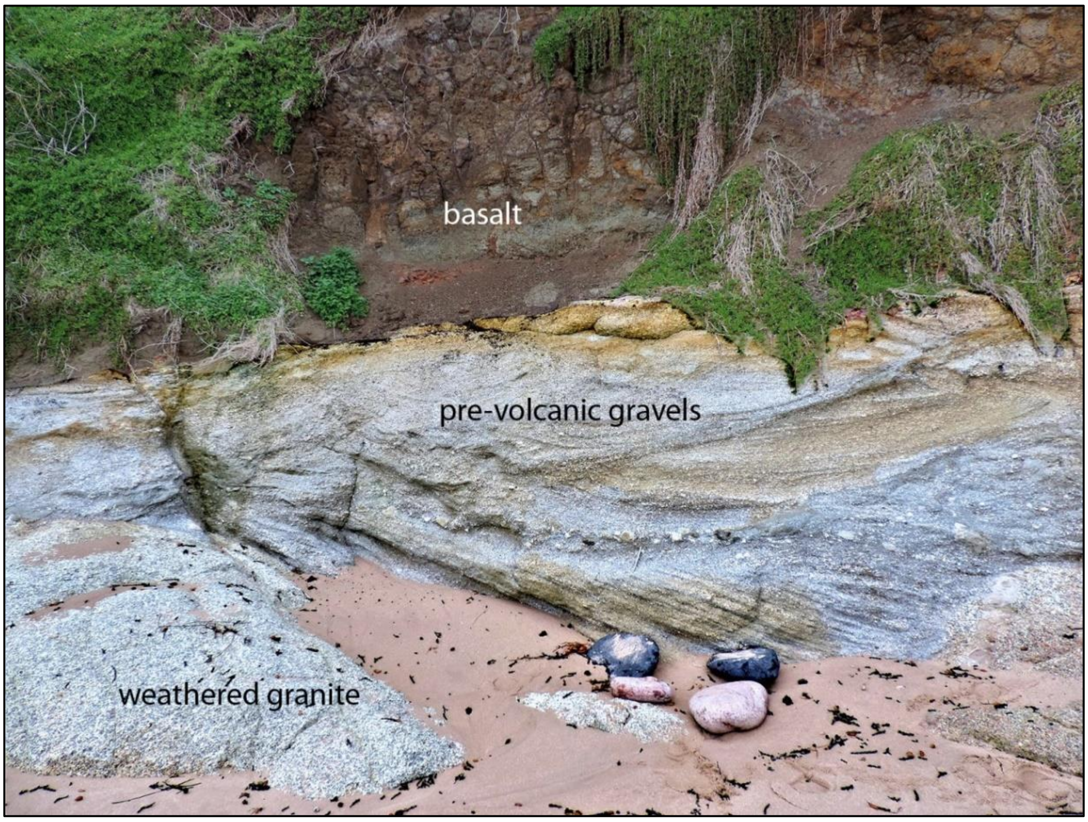


Figure 2-2 Weathered granite, sediments and basalt at the eastern end of Woolamai Beach

Across the main body of Phillip Island the basalts have developed an *in situ* layer of clay and decomposed basalt often more than 10 m thick. This layer is variably covered and mixed with water or wind transported sediment (sand and silt) with locally thick organic deposits.

Apart from the accumulations of sand at Summerland, Woolamai and several embayment heads (e.g. Thorny Beach), there is only a limited occurrence of sand away from the coast.

2.2 Geomorphology

Phillip Island has a continuously steep southern shoreline with no estuaries and one stranded coastal lagoon (Swan Lake). There are several dune bodies but the broad and the detailed character of the coast is determined largely by the physical characteristics and structural variation in the underlying and outcropping basalts. There is no sand input from river sources and sandy beach materials are predominantly sourced from off-shore with limited inputs sourced from disintegration of basalt and associated rocks, shell debris and local re-activation of beach ridges and dunes. Coastal processes are dominated by high wave energy. Apart from inherited (relict) landforms, aspect, and exposure to wave action accounts for local variation in morphology.

Contrary to previous geomorphic interpretations, the present assessment indicates that the terrain and stratigraphy between Summerland Bay and Cat Bay are not consistent with the area being a tied-island and the tied-island model for Woolamai Isthmus has also been re-evaluated.

Overall, the following six major geomorphic landform classes have been identified along the coast: Steep Coasts, Shore Platforms, Beaches, Dunes, Stream Mouths, and Coastal Lagoons. Each of these landforms is described in the following sections and a map of their locations is provided in Figure 2-3.

2.2.1 Evolution of Phillip Island

Phillip Island has previously been described (Edwards, 1945) as forming its present configuration by the attachment of several smaller adjacent islands of basalt and granite to the larger central volcanic island. As sea-level stabilised, 6,000 years ago, it was thought that wave refraction around the islands and adjacent headlands caused deposition of sediment as bars and spits (“tie-bars”) eventually linking the islands to other and to the main body of Phillip Island.

Although this model has been accepted by later authors (Gliddon 1958 [based on unpublished material provided by G. Baker]; Hills, 1975; Seddon, 1975; Rosengren, 1984; Bird, 1993), details on which this model was developed have not previously been reviewed. Therefore the concept of the tied-island morphology was reviewed and updated for this study.

An analysis of borelog data revealed that the terrain and stratigraphy between Summerland Bay and Cat Bay and the Woolamai isthmus are not consistent with the area being a tied island. Between Summerland Bay and Cat Bay the logs show the top of the basalt at above present sea-level and these areas would have been continuously connected during the Holocene period (up to 10,000 year ago) when sea levels were up to 1m higher that at present.

For the Woolamai Isthmus the granite plateau and slopes of Cape Woolamai are linked to the basaltic terrain of The Colonnades by a complex of sands of varied age and origin. Analysis of the main body of sand layers indicates they were likely deposited in the Late Pleistocene (around 10,000 years ago), while the surface layers although of Holocene origin are located several meters above present sea-level. This sand layering is not consistent with the deposits as cuspate forelands or any other type of spit or barrier necessary to support the tied-island model.

Therefore, it is proposed that the form of Summerland Beach and the Woolamai isthmus should be considered more typical of mainland beaches and this is reflected in the assessment of coastal processes and changes associated with sea level rise.

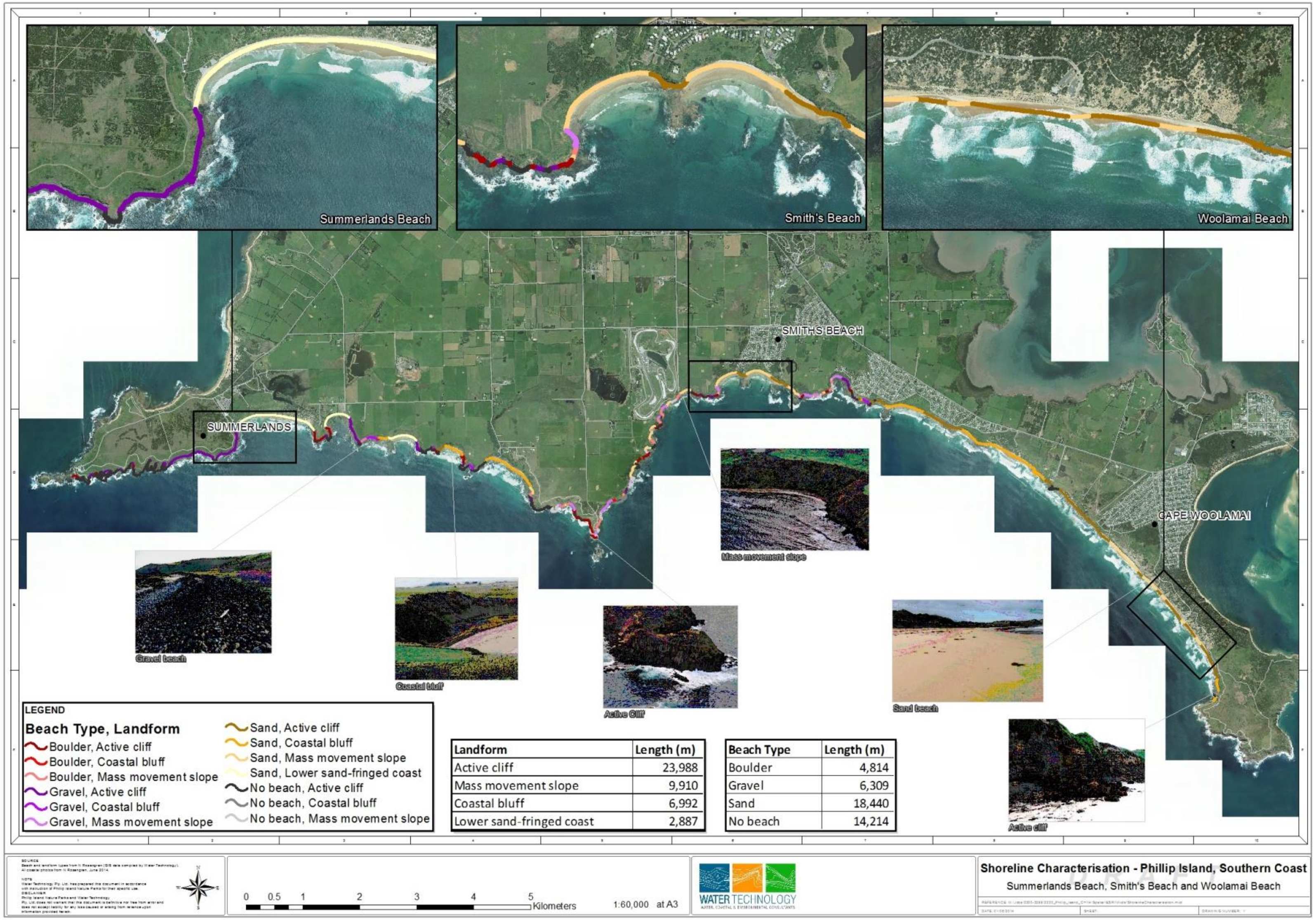


Figure 2-3 Coastal Landforms

2.2.2 Steep Coasts

Five classes of steep coasts are recognised on the south coast of Phillip Island: Active Cliffs, Active Mass-movement Slopes, Bluffs, Amphitheatres, and Plunging Cliffs as shown in Figure 2-4 and summarised in Table 2-1. Active cliffs and active mass movement slopes represent the steep coast landforms most susceptible to instability and erosion as a result of coastal processes. Coastal bluffs and amphitheatres are landforms now generally isolated from direct marine action and not currently subject to active erosion, while plunging cliffs (which occur at Cape Woolamai) are not generally active within the timescales considered by this project.

Figure 2-4 Examples of Steep Coast Landformd (photo: Neville Rosengren)

Table 2-1 Steep Coast Geomorphic Classes

Geomorphic Class	Description
Active cliffs	Exposed coherent rock or earth material with minimal vegetation, slopes ≥45^{0}. Release of fragments and/or bulk units by processes ranging from toppling to sliding and flow mechanisms. Varied time scale of slope failure ranging from frequent (rarely continuously) to annual-decadal.
Active mass-movement slope	Poorly consolidated or deeply weathered substrate. Slopes variable ± 45^{0}. Variable vegetation cover. Frequent to intermittently active with release of bulk units by creep, slide and flow mechanisms.
Bluffs	Slopes usually ≤45^{0}, variable and often complete vegetation cover.
Amphitheatre	Bowl-shaped depression – part or whole of slope profile, usually with complete vegetation cover. Inactive to rarely active.
Plunging cliffs	Exposed slope ±45° of coherent resistant rock with minimal vegetation. Minimal and slow rate of material loss. The slope profile remains constant on decadal to centennial time scale.

A brief overview of active cliff and mass movement slope morphologies is provided below.

Active Cliffs

The presence of various coastal materials, ranging from resistant, thick coherent basalt flows to poorly consolidated sands, results in a range of active cliff types along the Philip Island coast, summarised in Figure 2-4.

A. Active cliffs in coherent basalt

The cliff form is controlled by factures in the basalt, so slope angles can be near vertical. Discrete blocks are loosened and dislodged by wave action.

Complex 50 metre high slopes at Red Bluff

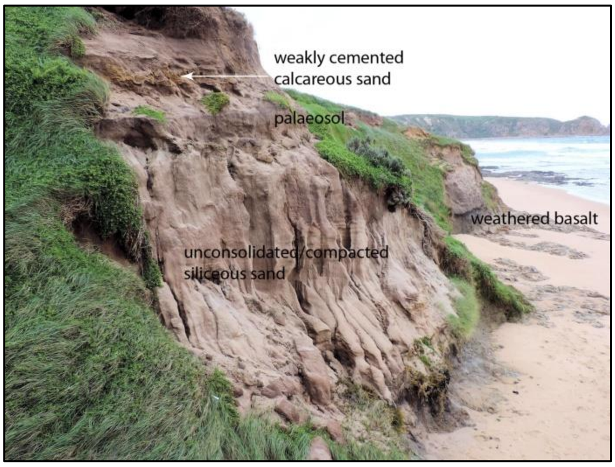
B. Active cliffs in weathered basalt and pyroclastic beds

Highly variable in form and structure. The most susceptible to slope failure of this cliff type are the deeply weathered volcanics along short sectors between Surfies Point and Forrest Caves, and at Magic Lands.

Active cliff in deeply weathered volcanics and palaeosols and overlying dune sand backing Magic Lands beach

C. Active cliffs in sand

Active cliffs in unconsolidated and poorly consolidated sand bodies occur intermittently backing Woolamai Beach. Cliffs in sands are partly activated by runoff and groundwater seepage forming rills and washing sand and clay to the base where they form short-lived alluvial and colluvial fans. As high tide storm waves reach the cliff base, these deposits are frequently dispersed, exposing the cliff to direct wave action.



Active cliff in weakly consolidated & unconsolidated sand, Magic Lands

Figure 2-5 Overview of Active Cliff Types on Phillip Island (Photos: N. Rosengren, June 2014)

Mass Movement Slopes

This sub-group of steep coast morphologies is developed on materials with similar low load-bearing strength to those described previously. They are distinguished here as a separate sub-group that experiences deep-seated slope failure as well as surface degradation. Mass movement slopes may extend the full height of the slope or be a segment of a compound profile that includes active free-fall cliffs, bluffs and amphitheatre slopes. Both the top and base of a slope can retreat and the mid-slope regions be re-shaped by large-scale failures independent of marine action. The processes are episodic and responsive to extreme weather events, particularly intense rainfall, and changes in groundwater levels (either recharge or drawdown) that may in part be a result of human action in adjacent areas.

These are slopes with variable and often extensive vegetation cover and loss of vegetation results in slope instability. Large woody vegetation also acts as mass loading and may lead to slope failure under some conditions, including when trees are uprooted by wind.

The ability of coastal processes to reactivate these mass movement slopes is dependent on wave action on the toe of the slope and removal of material from the slope toe.

2.2.3 Shore Platforms

Shore platforms are sloping or sub-horizontal rock or earth surfaces that extend seaward from the high tide level to below low water mark. Shore platform development is a complex process and it is now generally agreed that shore platforms are created by the combined effects of wave and weathering processes (Trenhaile, 2011). The elevation and slope of shore platforms are the combined results of wave strength, rock resistance (lithology and structure), weathering regime and tidal range (Trenhaile, 1987; Sunamura, 1991).

Their importance for coastal processes is in the dissipation of wave energy across the rock surface. On wider shore platforms the role of waves decreases as wave energy is dissipated across the rock surface.

2.2.4 Beaches

Beaches are deposits of wave-lain sediment in the coastal zone and hence coastal processes are the key driver of change in these landforms. Based on size of beach material, three main beach sub-classes are recognised for the south coast of Phillip Island, (a) boulder/cobble, (b) cobble/gravel, (c) sand. Many beaches are composite with more than one sub-group at the same place e.g. sand beach in front of gravel beach, gravel beach in front of a boulder-blocky beach.

Long sand beaches occur in coastal embayments with long projecting headlands at Summerland Beach (Figure 2-6), Kitty Miller Bay, Hutchison Beach, Berrys Beach and Smiths Beach and in several pocket beaches east of Pyramid Rock e.g. Jessie Island. East of Sunderland Bay to Magic Lands, are two long sectors of almost continuous beach backed by cliffed slopes and divided by the low headland at Forrest Caves.

Figure 2-6 Summerland Beach profile (N. Rosengren 4 June 2014)

Gravel beaches are widespread and in places include abundant cobbles and fine to medium boulders, Figure 2-7. They are steep, reflective beaches with storm scarps, ridges and berms preserved for months.

Figure 2-7 Steep gravel beach with multiple storm scarps and berms, Watt Point (N. Rosengren 4 June 2014)

2.2.5 Dunes

A range of dune forms and ages is present along the southern shoreline with almost 8km of the shoreline backed by coastal dune, not including the granite coast at Cape Woolamai. A range of dune forms and ages is present including low, narrow incipient foredunes confined to embayments, high ridged established foredunes, trough and elongated blowouts, parabolic dunes and cliff-top dunes. Each dune type is defined in Table 2-2, and an example provided in Figure 2-8.

Wind is the primary factor in mobilising and moving sand although the presence and density of vegetation on a dune will affect its form and response to wind or wave action. All vegetated dunes are initially *backshore* features in that they develop beyond the reach of normal wave swash, thus forming a landform that will persist beyond the tidal extent.

Table 2-2 Description of Dune Classes

Dune Type	Description
Incipient foredunes	Low ≤1.5 m sandy hummock, ridge or terrace located at the limit of normal wave swash and including wind-blown sand. They typically have variable cover of sand and salt tolerant vegetation.
Established foredunes	Variable height ridge or terrace located behind the incipient foredune but may be within the reach of very large storm waves. May be single or multiples separated by swales. Extensive vegetation cover including sand and salt tolerant vegetation and secondary species.
Transgressive dunes	Sand moved by wind from the beach, backshore and foredunes and covering existing dunes and immediate hinterland. Includes varied ridge shapes and depressions.
Cliff-top dunes	Transgressive dunes that are active or stabilised by vegetation resting on a coastal plateau or elevated plain or on older dunes. May be isolated by a cliff or bluff from modern sources of sand including beaches.

Figure 2-8 Incipient, established foredunes and transgressive dunes, Summerland (N. Rosengren 6 June 2014)

2.2.6 Stream Mouths and Coastal Lagoons

Stream mouths are defined by a channel in a valley opening to the coast or closed off by dunes. They are a minor landform type in the study area.

Swan Lake is the only significant coastal lagoon system on the southern shoreline of Phillip Island.

2.3 Coastal Vegetation

Vegetation communities along this coastline are determined not only by wind exposure, salt-spray, soil composition and geology but also by other factors such as the presence of seabird colonies (Little Penguins and Short-tailed Shearwaters) and past land management practices.

Dune vegetation affects dune development and morphology, with introduced species such as Marram Grass and Sea Wheat-grass more effective in binding sand. This function is important when considering the impacts of storm erosion on beaches and dunes.

2.3.1 Vegetation Changes on the Dune System

The dunes at Phillip Island were largely vegetated at the time of European colonisation. In 1842 the vegetation of the Woolamai Isthmus was described as “open heath land devoid of grass” on the south-western side, with “dense scrub of gum and prickly tea-tree behind”. There is no mention or indication of bare dunes at this time (Smythe 1842, cited in DCFL 1987 and Bird et al. 1975).

Bird et al. (1975) comment that at Woolamai, as on other dune sections of the Victorian coast, there has been a long history of alternating stability and instability, related primarily to fluctuations in climate, resulting in the formation of superimposed and partly overlapping dune forms. They also note that under existing climatic conditions the Woolamai Isthmus would be expected to be well vegetated. Bird et al. (1975) conclude that ‘the dune terrain at Woolamai seems to have been a man-made desert’.

The sand deposits at Woolamai were destabilized by burning and grazing following the arrival of European settlers (Gliddon 1958, DCFL 1987, Bird et al. 1975), which led to largely unvegetated mobile dune systems. Severe erosion was evident by 1874 (DCFL 1987). By 1939 the dune area was almost completely devoid of vegetation, with sand spilling onto the shoreline of the Eastern Passage due to the onshore winds blowing the soils from the seaward fringe (Bird et al. 1975). In the early 1970s, dune buggies and trail bikes caused extensive damage and erosion before fencing and regular patrols were carried out (Bird et al. 1975, Oates and Frood 2010).

At Cape Woolamai, Marram Grass was first planted in an attempt to control the movement of the sand in 1910, and a team of unemployed people conducted plantings of it during the Great Depression (Cuttris and Bird 1995). Marram Grass was later used in conjunction with tube stock of native shrubs and trees to stabilize and revegetate the dunes once these disturbance factors were controlled, during large scale revegetation efforts by the Soil Conservation Authority in the 1970s and 1980s on the isthmus (Oates and Frood 2010).

2.3.2 Impacts of Introduced Species on Dune Morphology

Hilton et al. (2006) note that Marram Grass and Sea Wheat-grass have produced new dune morphologies. They summarize the impacts of these grasses as having:

- Replaced irregular, sparsely vegetated established foredunes with continuous incipient foredunes,
- Encouraged accretion and progradation,
- Increased the extent and evenness of vegetation cover,
- Rapidly displaced native species,
- Altered dune habitats for indigenous flora and fauna.

Other literature variously reports that Marram Grass invasion leads to changed foredune morphology, with much steeper profiled and taller foredunes, reduced open sand and a reduction in cover of native sand-binding plants, and facilitation of the invasion of native shrubs (e.g. Anon 1987, Heyligers 1985, Hibbert 1999, Parks and Wildlife Service Tasmania (2003), Hilton et al. 2007, Hayes and Kirkpatrick 2012, Cousens et al 2013). In locations along the Gippsland Coast, the low and wide foredunes characteristic of areas dominated by native grasses has been replaced by hummocks 5 m high dominated by Marram Grass (Anon 1987).

Sea Wheat-grass forms low, wide foredunes that are generally in low to moderate energy conditions; however as wind conditions increase, dunes dominated by Sea Wheat-grass become increasingly hummocky (Hilton et al. 2006). Sea Wheat-grass is highly salt tolerant and forms a denser cover than the native Hairy Spinifex, extending more towards the high-tide line, potentially resulting in a narrower beach and broader incipient dunes, particularly on prograding coastlines.

Both species (Marram Grass and Sea Wheat-grass) along with the native dune grass, Hairy Spinifex, as shown in Figure 2-9.

Figure 2-9 Marram Grass (central foreground), Sea Wheat-grass (right foreground), and Hairy Spinifex (rear) growing on incipient dunes at Forrest Caves (Photo by Doug Frood, June 2014)

2.4 Oceanographic Setting

2.4.1 Winds and Waves

Waves and the variability associated with their height, period and direction comprise the principle source of energy for mobilising sediments along the shoreline. Waves and wave driven processes (such as sediment mobilisation and alongshore currents) result in both accretion and erosion processes. The relative difference between these two opposing processes subsequently influences coastal evolution.

The following types of wave conditions are of particular importance for coastal processes:

- Wind waves – these waves are generated and influenced by the local wind field. Wind waves are normal relatively steep (high and short duration), often irregular, and reflect the dominant wind direction; the south coast of Phillip Island is dominated by west to south-west wind conditions. Locally generated wind waves tend to move sediment offshore, resulting in erosion of the shoreline.
- Swell waves – these waves have been generated be a wind field far away, which in the case of Phillip Island is the Southern Ocean, and have travelled over long distances. Their direction is not necessarily the same as the local wind direction. Swell waves are often relatively long, regular and unidirectional, and tend be move sediment onshore, building up the shore profile.

2.4.2 Coastal Water Levels

Storm surge is the common term used to describe variations in coastal water levels that exceed that which can be attributed to the astronomical tide. Storm surges are generated by a combination of different forcing factors and are important when assessing coastal processes as they can be a driver of short term erosion on a shoreline, Figure 2-10.

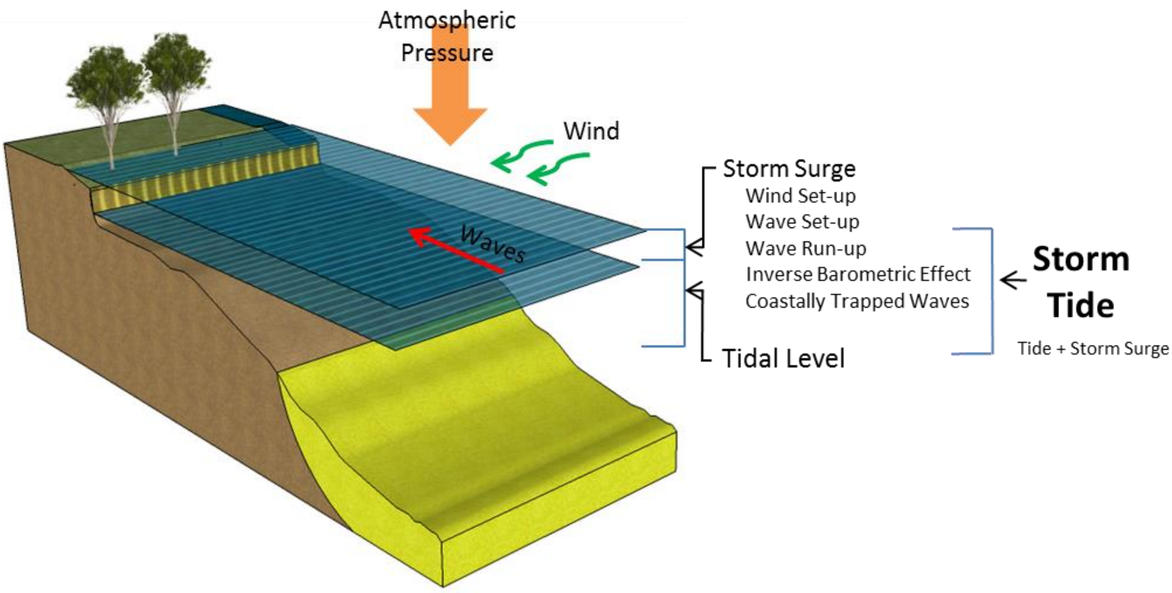


Figure 2-10 Schematic Displayed the Key Components of Storm Tide

2.4.3 Sea Level Rise

Sea levels undergo a range of climate related changes such as seasonal and annual cycles, transient events as well as decadal fluctuations. Underpinning these fluctuations is a longer-term trend of relative sea level rise. A long term trend of increasing mean sea level has important implications for coastal processes and future geomorphic responses to those processes.

The Australian Baseline Sea Level Monitoring Project provides a network of SEAFRAME (SEA-Level Fine Resolution Acoustic Measuring Equipment) sea level monitoring stations around Australia which have been operational for around 20 years. These stations accurately measure sea levels and provide information on longer term trends. A SEAFRAME monitoring station is located at Stony Point in Western Port, and was installed in January 1993. The long term record of sea level at this station indicates a net sea level trend of +2.6 mm/year.

Based on the guidelines in the Victorian Coastal Strategy (Victorian Coastal Council, 2008) when assessing threats to assets and infrastructure in the medium term in this study a sea level rise of up to +0.2 m (2040) has been assumed.

3. COASTAL PROCESSES AND FUTURE CHANGE

To develop an understanding of the potential extent of shoreline change and erosion hazard along the study area each of the six major geomorphic landform classes was reviewed to define the key coastal process affecting the landform, whether erosion or change is actively occurring, and what the future trajectory of change is likely to be.

The "immediate" scale coastal process impacts on the shoreline are typically associated with short-term storm events which predominantly effect sandy beach and dune areas. Medium-term changes are likely to be variable across the different landform classes, as they respond in a variety of ways to on-going processes and potential future environmental changes. The most likely future environmental changes are those associated with sea level rise.

The trajectory of change for steep coasts and beach/dune landform types is summarised in Table 3-1, while an overview for the specific locations of Summerland Beach, Smiths Beach and Woolamai Beach is provided in this section.

Table 3-1 Landform Susceptibility to Erosion and Responses to Future Sea Level Rise

Landform Class	Current Susceptibility to Erosion	Potential Changes to Coastal & Terrestrial Processes with Sea Level Rise	Likely Landform Response
Steep Coasts			
Active Cliffs	Active Cliffs, particularly those in sands or weathered volcanics	Increased frequency of wave impact at the cliff base, resulting in increased hydraulic action, abrasion, and mass movement.	There will be selective change due to varied rock resistance of the different cliff materials. An increase in cliff slope angle is likely to occur due to removal of material from the toe of the slope and increased slope failure. There is likely to be a loss of sandy beach and increase in gravel/boulder beach volume.
Active mass movement slopes	Only where marine processes interact with the toe of the slope	Increased wave impact through hydraulic action, abrasion, and mass movement.	There is likely to be a depletion of sandy beach areas, an increase in gravel/boulder beaches, a loss of vegetation on lower slopes, increased rate of slope failure, and increased delivery of slope debris to the base of the slopes.
Bluffs	Not currently active	Potential reactivation of the base of inactive cliffs through wave impact. This is dependent on the width and volume of beach and dune areas fronting the bluffs.	Reactivation of currently stable slopes through the depletion of the beach and dune areas fronting the bluffs, which would likely result in mass movement of slopes being initiated.
Amphitheatres	Not currently active	Potential reactivation of the base of inactive cliffs through wave impact.	Reactivation of currently stable slopes.
Beaches & Dunes			
Boulder, cobble, gravel beaches	Erosion in response to storm events	Increased inundation as a result of higher wave energy. Increased abrasive action on platforms and cliffs.	The introduction of larger material sizes through increased erosion of adjacent steep slopes. An increase in the width and steepness of gravel beaches. Recession of the shoreline, with the migration landward of the beach-dune interface and berms.

Landform Class	Current Susceptibility to Erosion	Potential Changes to Coastal & Terrestrial Processes with Sea Level Rise	Likely Landform Response
Sand beaches	Erosion in response to storm events	An increase in high energy wave events will result in a more dynamic beach environment. Increased inundation as a result of higher wave energy.	An increase in the rate of shoreline retreat. This occurs inversely proportional to beach slope, with gently sloping profiles retreating at a faster rate. There will likely be a decrease in the steepness of the beach and a narrowing of beach area above the high tide mark.
Dunes	Erosion in response to storm events	Those closest to the shoreline likely to experience: • An increase in high wave energy events. • Increased inundation with higher wave energy. • Increased potential for weeds.	An increase in overwash and scarping of berms. Erosion/retreat of foredunes, and loss of foredune vegetation. Initiation of dune blowouts.

3.1 Summerland Beach

The sandy beach at Summerland is formed in an embayment between two headlands, with cobble and gravel beaches and extensive shore platforms present at the base of these headlands. The beach sand is of marine origin; however there is little new sand being added to the beach from off-shore sources.

The beach and backshore systems are complex:

- The sand beach has a double profile, with a narrow reflective high tide beach, and
- The backshore comprises a range of beach-dune morphologies.

Long term change to the beach and dune system, as analysed through comparison of historical aerial imagery (1939-2013) and surveyed beach profiles, has been limited in terms of the shoreline location over the 75 year period, but there have been distinct landform changes:

- Increased vegetation cover,
- Encroachment of vegetation seaward at the eastern end of the bay,
- Recession at the western end of the bay, with increasing exposure of the underlying cobble/gravel beach,
- Locally enhanced erosion of the beach-dune interface in the vicinity of the Penguin Parade stands.

A selection of historical images is shown in Figure 3-1 and Figure 3-2.

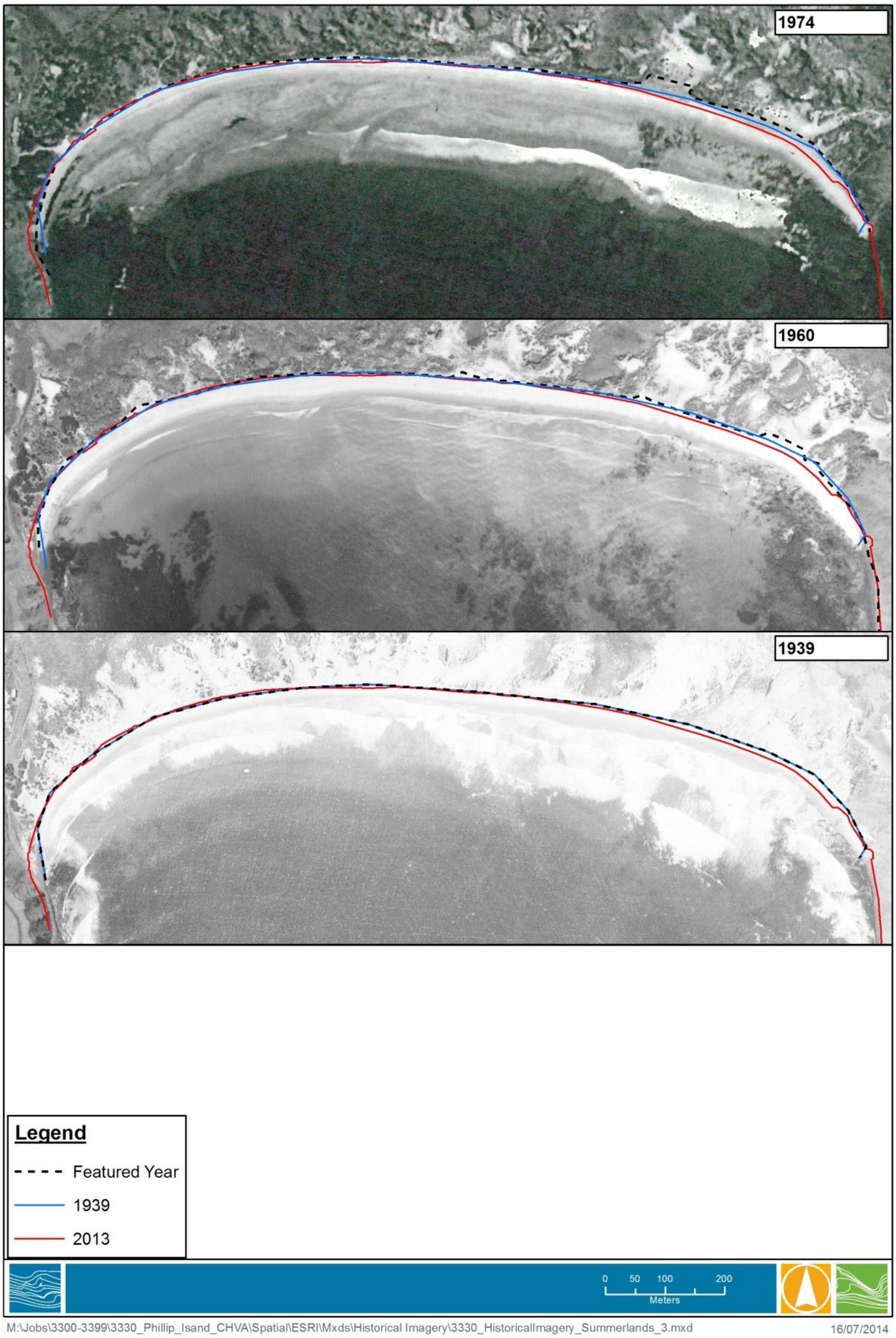


Figure 3-1 Comparison of Historic Aerial Photographs, Summerland (1939-1974)

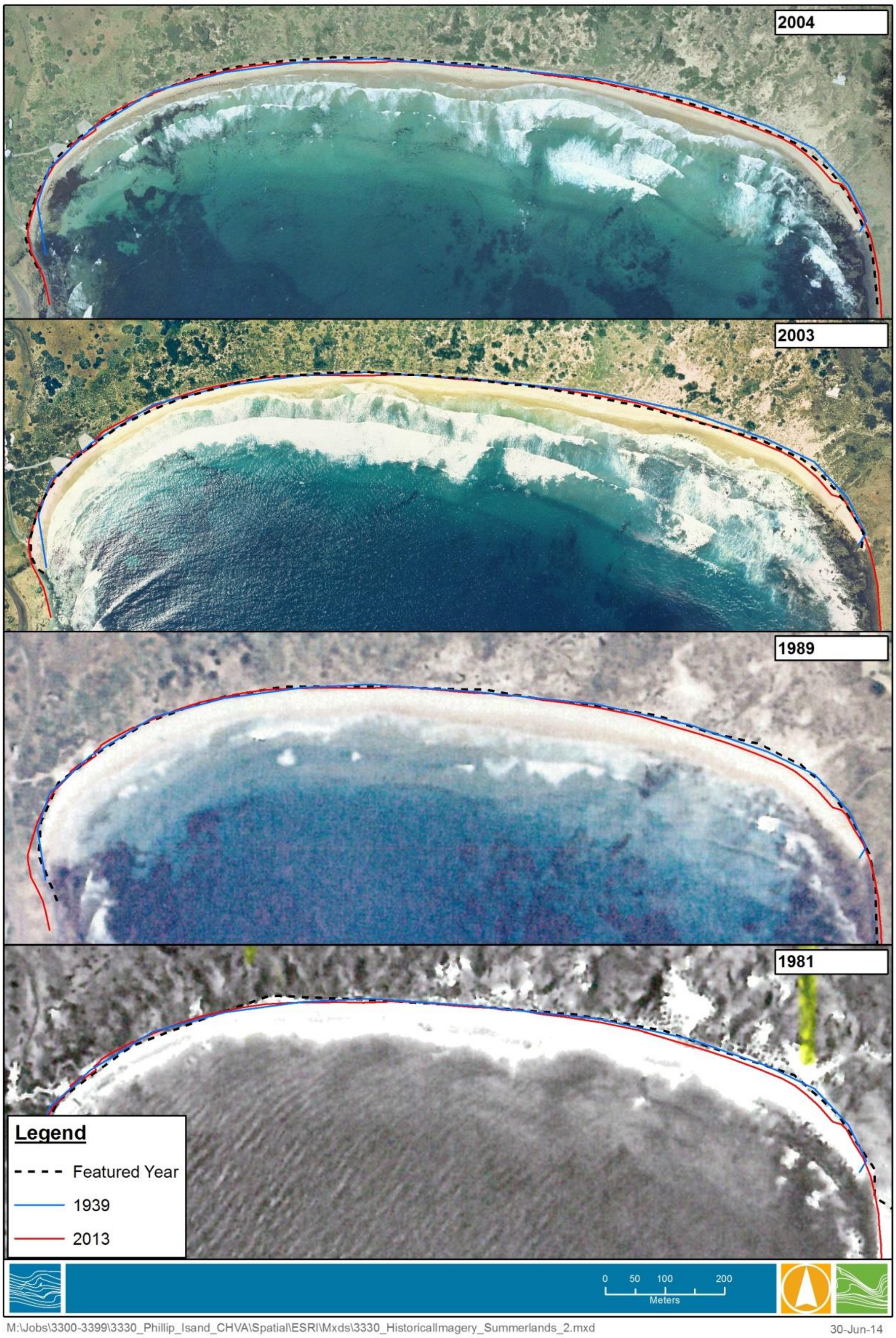


Figure 3-2 Comparison of Historic Aerial Photographs, Summerland (1981-2004)

As well as long term change, short term changes to the beach-dune profile occur as a response to storm events, specifically the formation of erosion scarps (Figure 3-3). The current form of the erosion scarps may be steeper than in the past due to the presence of introduced dune vegetation species. An example of an erosion scarp and the recent response to a storm event is shown in Figure 3-4.

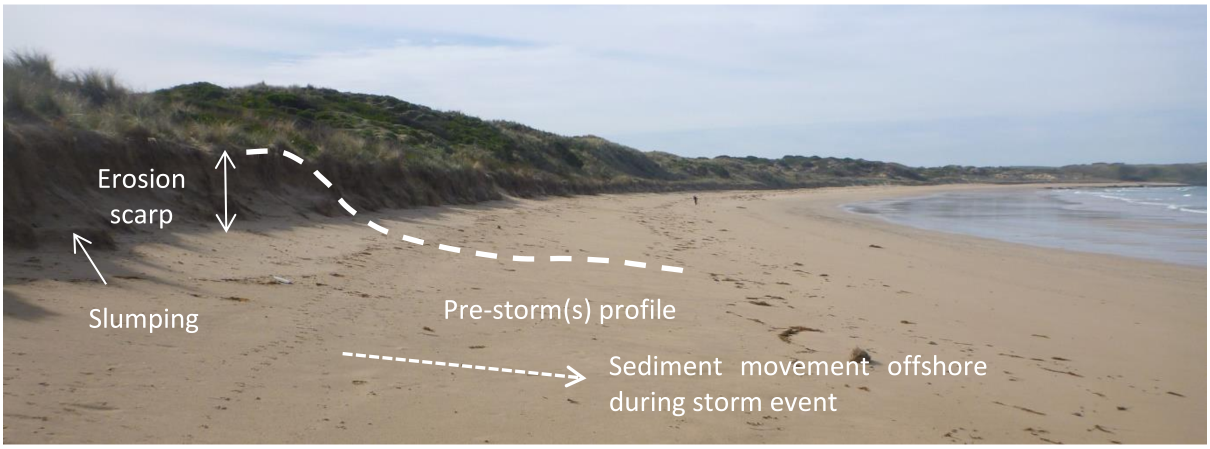


Figure 3-3 Generalised Beach-Dune Processes (photo 4 June 2014)

Figure 3-4 Dune-foot scarp at the far eastern end of Summerland Bay: (A) 17 Nov 2013, (B) 18 July 2014 (photos: N Rosengren)

Erosion of sand from in front of and adjacent to the Penguin Parade viewing stands has also been an issue since their construction. Figure 3-5 shows an example of the current active erosion at the interface between the stands and the adjacent dunes. Recession of the dunes has occurred at the eastern end of the east stand in particular.

The current localised erosion of the dunes adjacent to the viewing stands is being exacerbated by the exposure of the lower steps of the stands during storm events.

Figure 3-5 Erosion exposing and undermining sections of the concrete stands

Future Changes

For Summerland Beach the trends for the medium term future are as follows:

- Recession of the beach-dune profile with sea level rise - Assuming a +0.2 m of future sea level rise (medium term), the resultant predicted future shoreline recession to 2040 is around 8 m depending on the height of the foredunes.
- Change in beach-dune interface morphology due to on-going changes in dune vegetation - The binding ability of the vegetation (native and non-native) can act to slow the rate of active erosion of the shoreline. However, with a reduction in shoreward translation of the beach-dune interface there is potential for general lowering of the gradient of the sandy beach profile. Estimates of future beach-dune erosion rates or the rate of lowering of the gradient of the beach profile are uncertain.
- Short term responses to storm events will continue - Storm surges can result in significant short term erosion of the beach profile. Given time, these profiles can return to their pre-storm form depending on the wave and sediment supply conditions. Conversely, a series of storm events can result in significant on-going recession of the beach-dune interface. With on-going sea level rise there will be increases in high tide elevation and wave energy onto the upper beach and dune. This will result in increased rates of erosion at the dune-beach interface and retreat of the shoreline associated with storm events.
- Coastal structures, such as the Penguin Parade viewing stands, are currently impacting on erosion of the beach–dune interface and these impacts are likely to increase with on-going sea level rise.

3.2 Smiths Beach

Smiths Beach and the adjacent YCW Beach are both fine sand beaches confined within headlands to the west and east, which have very wide complex shore platforms at their base. The beaches are both backed by mass movement slopes, with minimal to no dunes present.

Long term change, as analysed through a comparison of historical aerial imagery (1939-2013) and surveyed beach profiles, indicates there has been a loss of sand volume at both beaches over the 75 year period. This is shown by:

- Increased exposure of the underlying cobble/gravel beaches,
- Increased exposure of an underlying thin cemented layer overlying weathered volcanic material (such as at the foot of the current access ramp, Figure 3-6), and
- Exposure and erosion at the foot of the backslope.

Due to the lack of backshore dunes and the presence of the steep slope at the back of the beach, the dominant response to storm events is a flattening of the beach profile and increased exposure of the toe of the slope.

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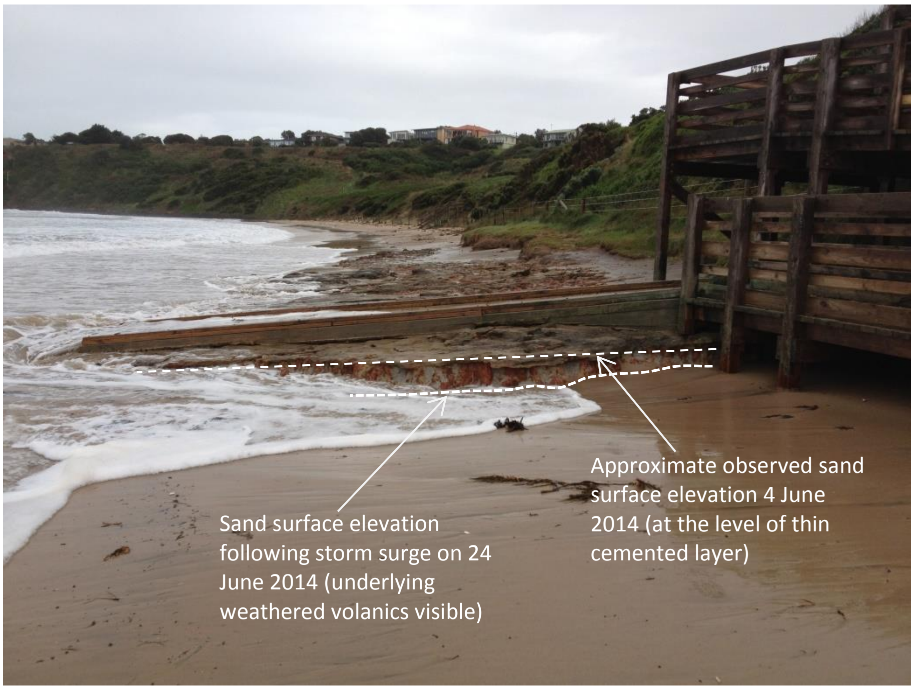

Figure 3-6 Interface between the beach and backshore in June 2014, following a storm surge event

The steep slope at the back of the beach is defined as a mass movement slope and although the analysis of recent slope profiles did not identify any significant changes over the period 2009-2014 there is an existing and future risk of slope failure of these areas. These areas have been identified using the available terrain data and are shown in Figure 3-7.

Both the top and base of a mass movement slope can retreat and the mid-slope regions can be re-shaped by large-scale failures independent of marine action. To date, at Smiths Beach the movements are typically triggered by groundwater loading or surface flows. These are very large slope failure bodies and have been active on a geological time scale - not initiated by human activity, although human activity can initiate future failures.

Figure 3-7 Location of Mass Movement Slopes at Smiths Beach

If wave energy and inundation increases at the base of the mass movement slope due to the loss of beach sand and increases in mean sea level, slope surfaces within the weathered material could potentially be reactivated, triggering a failure.

Future Changes

For Smiths Beach the trends for the medium term future are as follows:

- The lack of backshore dunes means that there is no gradual, landward migration of the beach with sea level rise. The sand extent is constrained by the backshore slope. The trajectory over the past 74 years for the beach appears to be a gradual loss of sand volume, particularly where the area adjoins the backshore. This has led to increasing expose of the toe of the backshore slope, which then increases the likelihood of slope failures being initiated by marine processes.
- Into the medium term future, with on-going increases in sea level there will be a continuing net loss of sandy material with very little high tide beach remaining. The increased marine influences (swash and waves) will increasingly interact with the toe of the mass movement slope. As this occurs, the dissipation of wave energy afforded by the beach is reduced or ceases and the reflection of wave energy from the toe of the slope would be expected to rapidly flatten the gradient of the remaining beach in front of the slope.
- The lowering of the beach gradient and erosion of the material comprising the toe of the slope would then be expected to reactivate the mass movement slope resulting in slope failure and extensive erosion.

3.3 Woolamai Beach

Woolamai Beach is a long sandy beach backed by a steeply rising slope. As with the other beaches along the southern shoreline of Phillip Island, the source of the sand is predominantly marine, with only limited contributions from cliffs, shore platforms, or the Cape Woolamai headland. It is likely that, similar to the other sand beaches on this coast, little new sand is being added to this beach system.

The form of the steeply rising slope at the back of the beach changes in both time and space. At times it is an active cliff or mass-movement slope and the exposed grey sand and overlying organic and calcareous beds are washed by high tide storm waves. At times part of the cliff is covered by a steeply sloping sand apron, either wave-deposited or wind-blown, Figure 3-8.

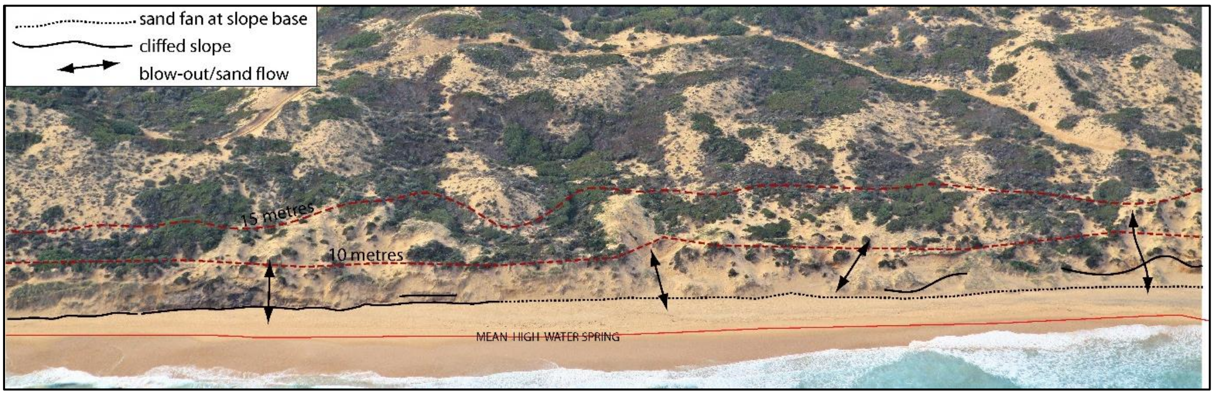

Figure 3-8 Detail of steep slope backing Woolamai Beach north of Magic Lands (N. Rosengren 2 June 2014)

Long term change, as analysed through comparison of historical aerial imagery (1939-2013) and surveyed profiles indicates only limited large-scale changes in shoreline location over the 75 year period. As at Summerland, the density of vegetation cover is the most marked change over this time. A selection of historic imagery is provided in Figure 3-9, Figure 3-10, and Figure 3-11.

The increased vegetation coverage has worked to stabilise the cliff top dunes and limit windblown sediment transport across the isthmus. This has reduced the sand supply to the beaches of Cleeland Bight and beach narrowing and shoreline recession here has been documented (Bird, 1993). There is no record of these cliff top dunes supplying sediment to Woolamai Beach directly and any sand that was or is deposited in Cleeland Bight is not returned to Woolamai Beach as the water and sediment movement patterns through the Eastern Entrance of Western Port bay are predominantly inward, while west to east movement dominates offshore of Cape Woolamai (Marsden and Sternberg, 1976; Marsden and Mallet, 1974). Removal of the dune vegetation will likely reinitiate wind-blown sediment transport, resulting in blowouts and transgressive dunes forming, however these cliff top dunes are unlikely to provide a supply of sand to Woolamai Beach or adjacent near-shore areas.

Areas where dunes are clear of vegetation, such as in front of the Woolamai Surf Life Saving Club or along coastal access ways, provide a preferential pathway for transport of windblown sand transport from the beach.

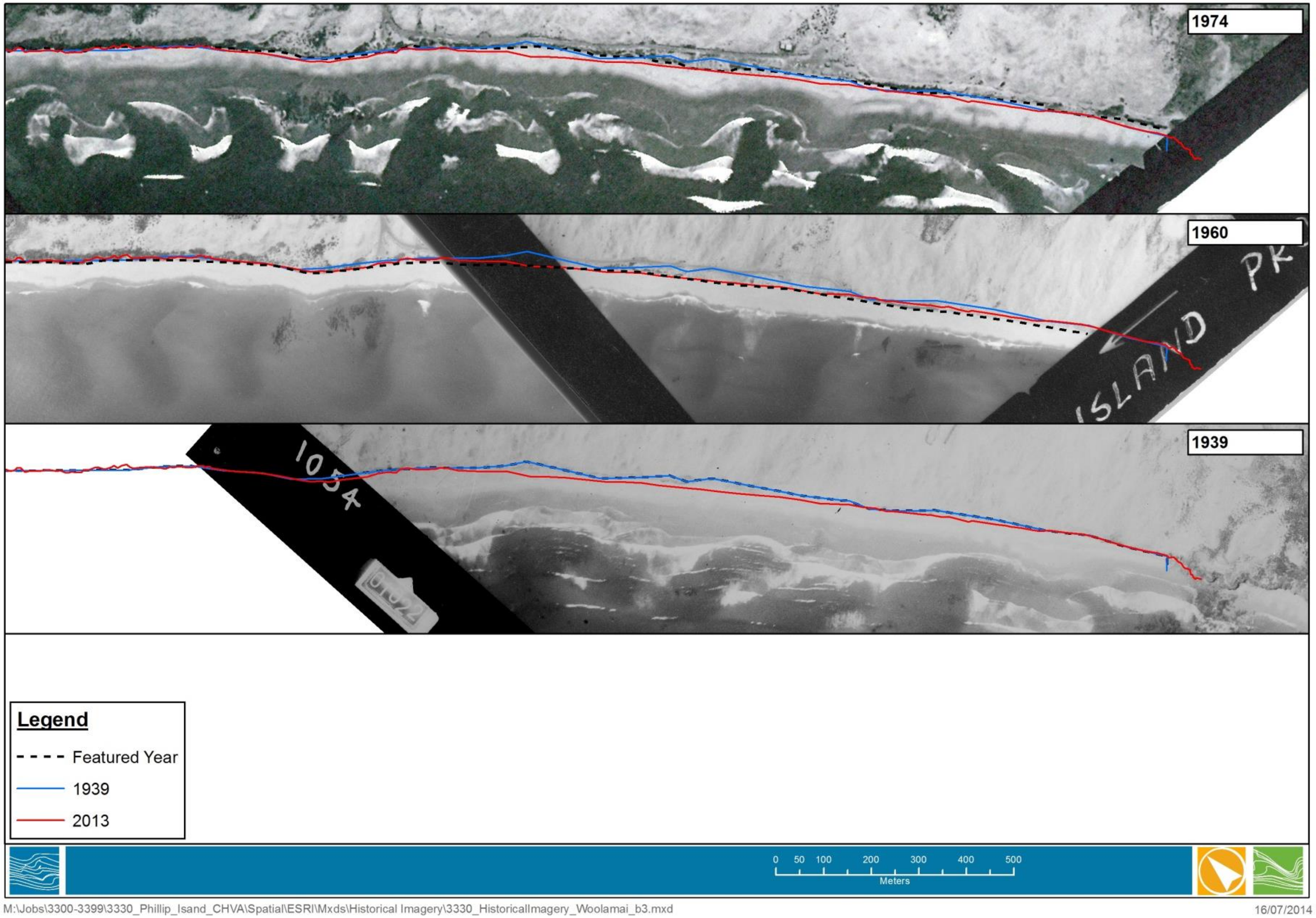

Figure 3-9 Comparison of Historic Aerial Imagery, Woolamai Beach (1939-1974)

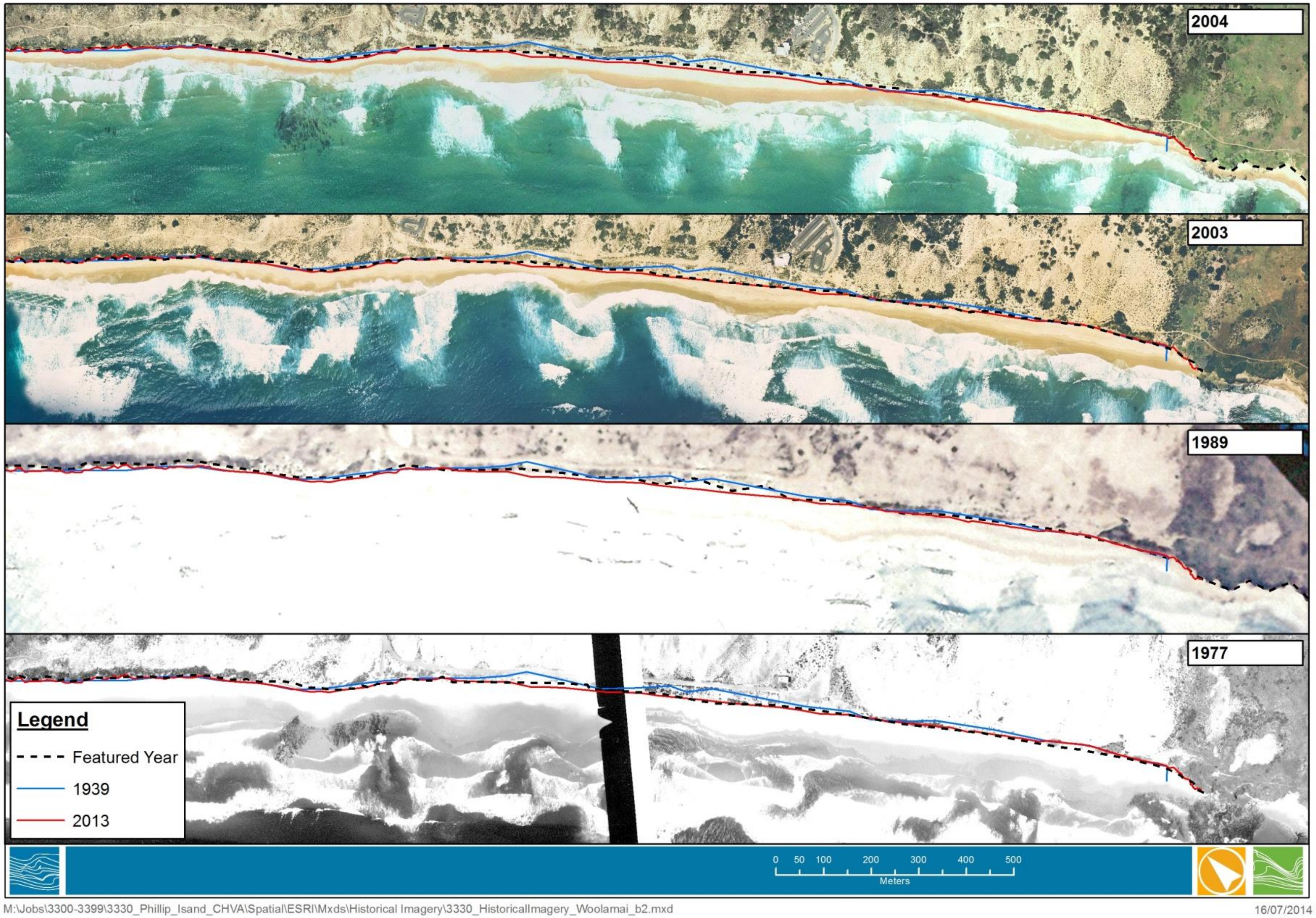

Figure 3-10 Comparison of Historic Aerial Imagery, Woolamai Beach (1977-2004)

Figure 3-11 Comparison of Historic Aerial Imagery, Woolamai Beach (2006-2013)

Future Changes

For Woolamai Beach the trends for the medium term future are as follows:

- With on-going increases in sea level there will be a continuing net loss of sandy material from the beach which will potentially reduce the scale of the sand fans that form in front of the active sand cliffs.
- Marine influences (swash and waves) will increasingly interact with the toe of the active cliffs or mass movement slopes. This interaction would then be expected to activate failure of the active cliffs and increase rates of recession of the shoreline.
- The same process would also apply to the mass movement type slope sections along the beach.

4. THREATS TO NATURAL AND INFRASTRUCTURE ASSETS

As described in Table 3-1, the current and future trajectory of change for the different types of shoreline along the southern shoreline of Phillip Island is complex and varied. For steep coasts, marine influences on erosion and recession of the shoreline may or may not be an important factor, whereas for sand beaches and dunes, water levels and waves are the dominant physical processes.

The assessment of consequences associated with the various coastal erosion threats to natural and infrastructure assets in this study focussed on the three locations of Summerland Beach, Smiths Beach and Woolamai Beach. For each location the key likely impacts of the threat to the natural assets and infrastructure were identified and an initial consequence rating was assigned. The results of the assessment are summarised in Table 4-1.

A risk level or rating was not assigned to each threat, as the definition of what is an acceptable or tolerable risk associated with a coastal hazard can vary significantly between stakeholders. It is recommended that the risk associated with each threat be evaluated when prioritising management strategies to mitigate the threats identified.

Table 4-1 Coastal Threats Assessment for Natural and Infrastructure Assessments

Location	Threat	Timeline	Likelihood	Impacts on Infrastructure and/or Natural Assets	Consequence
Summerland	Dynamic, short term recession or breach of the dune system by wave action and elevated water level.	Present	**Likely**	Erosion and possible undermining around Penguin Parade Stands	**Minor**
				Loss or reduction in access to penguin habitat	**Minor**
				Loss of beach/dune habitat	**Minor**
		2040 (+0.2 m SLR)	**Likely**	Erosion and possible undermining around Penguin Parade Stands	**Minor**
				Loss or reduction in access to penguin habitat	**Minor**
				Loss of beach/dune habitat	**Minor**
	A sustained and progressive erosive/recession of the beach-dune interface	Present	**Likely**	Erosion and possible undermining around Penguin Parade Stands	**Minor**
				Loss or reduction in access to penguin habitat	**Minor**
				Loss of beach/dune habitat	**Moderate**
		2040 (+0.2 m SLR)	**Likely**	Erosion and possible undermining around Penguin Parade Stands	**Moderate**
				Loss or reduction in access to penguin habitat	**Minor**
				Loss of beach/dune habitat	**Moderate**
Smiths Beach	Erosion at the base of the backshore slope by wave	Present	**Likely to Possible**	Loss of beach access infrastructure	**Minor**
				Loss of other infrastructure	**Minor**

Location	Threat	Timeline	Likelihood	Impacts on Infrastructure and/or Natural Assets	Consequence
	action and elevated water levels, resulting in localised slope failures			Loss of beach areas	**Minor**
		2040 (+0.2 m SLR)	**Likely to Possible**	Loss of beach access infrastructure	**Minor to Moderate**
				Loss of other infrastructure	**Minor**
				Loss of beach areas	**Minor**
	Sustained and progressive erosion of beach material and widespread failure of the backshore slope.	Present	**Likely**	Loss of beach access infrastructure	**Minor to Moderate**
				Loss of other infrastructure	**Minor to Moderate**
				Loss of beach areas	**Minor**
		2040 (+0.2 m SLR)	**Likely**	Loss of beach access infrastructure	**Moderate**
				Loss of other infrastructure	**Minor to Moderate**
				Loss of beach areas	**Moderate**
Woolamai Beach	Erosion at the base of the backshore slope by wave action and elevated water levels, resulting in localised slope failures	Present	**Likely to Possible**	Loss of beach access infrastructure	**Minor**
				Loss of other infrastructure (e.g. SLSC, carpark)	**Minor**
				Loss of beach areas	**Minor**
		2040 (+0.2 m SLR)	**Likely to Possible**	Loss of beach access infrastructure	**Minor to Moderate**
				Loss of other infrastructure (e.g. SLSC, carpark)	**Minor**
				Loss of beach areas	**Minor**
	Sustained and progressive erosion of beach material and widespread failure of the backshore slope.	Present	**Likely**	Loss of beach access infrastructure	**Minor to Moderate**
				Loss of other infrastructure (e.g. SLSC, carpark)	**Minor to Moderate**
				Loss of beach areas	**Minor**
		2040 (+0.2 m SLR)	**Likely**	Loss of beach access infrastructure	**Moderate**
				Loss of other infrastructure (e.g. SLSC, carpark)	**Minor to Moderate**
				Loss of beach areas	**Moderate**

5. MANAGEMENT AND MITIGATION STRATEGIES

Based on the coastal hazard risk management guidelines from the Victorian Coastal Hazard Guide (DSE, 2012), potential management approaches to protect natural and infrastructure assets were developed. The potential approaches focus on risk avoidance and risk reduction and relate to specific assets or infrastructure at the key locations of Summerland Beach, Smiths Beach and Woolamai Beach; however they are applicable across the whole study area.

Risk avoidance focusses on not starting or continuing an activity that is at risk from a coastal hazard. This can include taking a precautionary approach to planning new development, infrastructure or services to avoid coastal hazards. In some locations this can be the relocation of key infrastructure assets at the end of their natural design life.

Risk reduction can be achieved by either reducing the impact of hazards or the consequences of the hazard. Methods include:

- Engineering protection works (e.g. seawalls, groynes)
- Soft engineering approaches (e.g. dune and beach nourishment)
- Planning and regulatory controls (e.g. control and limit future development and redevelopment of existing uses, a strategy of planned retreat in vulnerable areas)

5.1 Summerland Beach

A series of potential management strategies to address threats to infrastructure and natural assets at Summerland Beach are outlined in Table 5-1.

Table 5-1 Proposed Management and Mitigation Strategies for Summerland Beach

Mitigation Strategy	Time scale	Mitigation Option
Infrastructure		
Risk Avoidance	All	Undertake dune and beach management works including formalising beach access points with timber walkways to prevent beach access points from becoming focal points for erosion. No new infrastructure should be located at or forward of the present beach-dune interface. An appropriate offset should be adopted when siting any new infrastructure, based on the structure design life.
Risk Reduction	Short term	Options following erosion of sand in front of the large concrete structures: • Local sand renourishment - placement of sand in front of the steps and regrading of the beach profile following storm events, • Protection – placement of cobbles/gravels in front of the vertical face, grading to existing beach profile. • Any locally scoured areas between the ends of the stands and the beach/dunes should be armoured to limit continuing local scour which could undermine or erode the structure. Any armouring should gradually transition to the natural surface. Options following erosion around pile foundations of small viewing platform: • Re-establishment of pre-erosion profile using sand or cobble/gravel material.

Mitigation Strategy	Time scale	Mitigation Option
Risk Reduction	Medium	Options include: • Renourishment – beach renourishment to slow the rate of retreat of Summerland Beach with on-going sea level rise. Requires investigation of sand sources, placement methods, and environmental impacts on beach/dune habitat. • Retreat - Investigate options for the gradual retreat of the lower sections of the large concrete stands that are currently forward of the beach-dune interface. • Retreat – move small viewing platform back in line with the beach-dune profile
Risk Reduction	Long Term	Retreat: • Removal of solid concrete stand structures. • Any replacement structures to utilise more porous materials (e.g. timber) to reduce wave impacts and encourage energy dissipation. • Replacement structure design should consider the requirements for gradual removal of sections closest to the beach in line with overall recession of the beach-dune interface as it occurs.
Natural Assets		
Risk Reduction	All	Inclusion of Sea Wheat-grass as an established weed (medium priority) on PINPs prioritisation lists. Herbicide trials to investigate reducing the impacts of the introduced sand-binding grasses (Marram Grass and Sea Wheat-grass), particularly where they are compromising habitat condition in the Hooded Plover nesting areas. Continued provision of beach-dune access for Penguins where steep erosion scarps form.

Structural options to armour around the ends of the viewing stands in order to reduce the short term risk of scour include:

- Sand filled geotextile bags,
- Rock Armour.

Both types of structure can be buried to minimise visual impact and combined with localised replanting of native dune grasses to stabilise the sand. Any localised erosion protection will likely will require on-going maintenance following storm events.

5.2 Smiths Beach

A series of proposed management strategies to address threats to infrastructure assets at Smiths Beach are outlined in **Table 5-2**.

Table 5-2 Proposed Management and Mitigation Strategies for Smiths Beach

Mitigation Strategy	Time scale	Mitigation Option
Infrastructure		
Risk Avoidance	All	Undertake beach management works including formalising beach access points with timber walkways to prevent beach access points from becoming focal points for erosion. No new infrastructure should be located at or forward of the present beach-slope interface. An appropriate offset should be adopted when siting any new infrastructure, based on the structure design life, slope stability of the mass movement and steep cliff slopes and potential extent of slope failure.
Risk Reduction	Short term	Options following erosion of sand in front of the access structures: • Local sand renourishment - placement of sand in front of the steps and regrading of the beach profile following storm events, • Removal of structures such as steps where they have been undermined by erosion of the beach.
Risk Reduction	Medium	Options include: • Renourishment – beach renourishment to slow the rate of erosion of Smiths Beach with on-going sea level rise. Requires investigation of sand sources, placement methods, and environmental impacts on beach/dune habitat. Volumes required for an effective beach nourishment program are likely to preclude this as a viable option.
Risk Reduction	Long Term	Options include: • Investigation of alternative beach access sites to avoid mass movement slopes. • Removal of existing access structures.
Risk Sharing	All	Provision of information and education around coastal processes and potential hazards.

5.3 Woolamai Beach

A series of proposed management strategies to address threats to infrastructure assets at Woolamai Beach are outlined in **Table 5-3**.

Table 5-3 Proposed Management and Mitigation Strategies for Woolamai Beach

Mitigation Strategy	Time scale	Mitigation Option
Infrastructure		
Risk Avoidance	All	Undertake beach management works including formalising beach access points with timber walkways to prevent beach access points from becoming focal points for erosion. No new infrastructure (buildings, roadways, walking paths etc) should be located at or forward of the present beach-slope interface. An appropriate offset should be adopted when siting any new infrastructure, based on the structure design life, slope stability of the mass movement and steep cliff slopes and potential extent of slope failure.
Risk Reduction	Short term	Options following erosion of sand in front of the active sand cliffs at the SLSC: • Local sand renourishment - placement of sand in front of the steps and regrading of the beach profile following storm events – potentially using sand from carpark areas. • Removal of structures such as steps where they have been undermined by erosion of the beach.
Risk Reduction	Medium	Options include: • Renourishment – beach renourishment to slow the rate of erosion of the base of the active cliffs with on-going sea level rise. Requires investigation of sand volumes, sources, placement methods, and environmental impacts on beach/dune habitat. Volumes required for an effective beach nourishment program are likely to preclude this as a viable option.
Risk Reduction	Long Term	Options include: • Investigation of alternative beach access sites to avoid exposed active cliffs or mass movement slopes.
Risk Sharing	All	Provision of information and education around coastal processes and potential hazards.
Natural Assets		
Risk Reduction	All	Inclusion of Sea Wheat-grass as an established weed (medium priority) on PINPs prioritisation lists. Herbicide trials to investigate reducing the impacts of the introduced sand-binding grasses (Marram Grass and Sea Wheat-grass), particularly where they are compromising habitat condition in the Hooded Plover nesting areas.

6. RECOMMENDATIONS

Effective implementation of management strategies to address coastal hazard threats requires that information on the physical condition of the shorelines is regularly gathered for the study area. To do this, it is recommended that regular coastal profiles be surveyed (at approximately 6 month intervals) at critical locations at each key area (Summerland Beach, Smiths Beach, Woolamai Beach). The surveys should be undertaken from approximately mean water and extend landward over the crest of the foredune or backshore slope. The surveys should be reduced to Australian Height Datum (AHD). Each profile should be reviewed against previous profiles to identify and quantify changes.

Regular coastal profile monitoring of critical locations within the study area would improve the implementation of coastal hazard management strategies by assisting in the following:

- Improve the understanding of the physical processes and assist in refining the estimates of coastal hazard extents in the study area in the future,
- Prevent reactionary responses to isolated storm erosion events by providing a longer time series of coastal change to compare against,
- Assess the performance of the management measures,
- Assist in establishing appropriate triggers for transitioning to more significant management measures to mitigate coastal hazards in the study area.

An alternative approach is to utilise continuous imaging such as occurs at the Gold Coast beaches (http://ci.wrl.unsw.edu.au/about-coastal-imaging/history-of-wrl-coastal-imaging/).

Additionally, complimentary monitoring program could also be developed using the existing and future images collected through the Woolamai Surf Cam (http://www.coastalwatch.com/surf-cams-surf-reports/vic/phillip-island---woolamai). The existing images/videos could be analysed to identify changes in beach/wave conditions over time, depending on the resolution of the images. Higher resolution imagery may be required. A similar set-up at Summerland and Smiths Beaches could be implemented in conjunction with Coast Watch.

7. REFERENCES

Anon (1987) Alien dune plants reshape our beaches. Ecos 54, Summer 1987/88, pp. 3-6.

Bird, E.C.F. (1993) The Coast of Victoria – the Shaping of the Scenery. Melbourne University Press, Parkville. 323 p.

Bird, E.C.F., Seddon, G., Turner, J.S. and Waterman, P. (1975) 'Foreshore management in relation to the preservation of flora and fauna on Phillip Island at Red Rocks, Cat Bay and Woolamai Surf Beach'. Report to the Phillip Island Conservation Society Centre for Environmental Studies, University of Melbourne. 44 pp.

Cousens, R., Kennedy, D., Maguire, G. and Williams, K. (2013). Just how bad are coastal weeds? Assessing the Geo-eco-psycho-socio-economic Impacts. Rural Industries Research and Development Commission, Barton, A.C.T. RIRDC Publication No.13/032. 70 pp.

Cuttriss, L. and Bird, EC.F. (1995). 500 Million Years on Phillip Island. Bass Coast Shire Council, Wonthaggi.

DCFL (1987) Cape Woolamai State Faunal Reserve. Provision of public recreation facilities. Department of Conservation, Forests and Lands, in conjunction with Shire of Phillip Island. 40 pp.

Department of Sustainability and Environment (2012). The Victorian Coastal Hazard Guide, The State of Victoria Department of Sustainability and Environment

Gliddon, J.W. (1958) 'Phillip Island in picture and story'. Ch. 18. The evolution of Phillip Island, pp. 195 - 215. Committee of Trust, 'Warley', Cowes Bush Nursing Hospital, Phillip Island.

Gliddon, J.W. (1958). Phillip Island in Picture and Story. Cowes Bush Nursing Hospital, Cowes, Victoria. (Based in part on unpublished material supplied by Dr. George Baker)

Hayes, M. and Kirkpatrick, J.B. (2012). Influence of Ammophila arenaria on half a century of vegetation change in eastern Tasmanian sand dune systems. Australian Journal of Botany 60: 450-460.

Heyligers, P.C. (1985) The impact of introduced plants on foredune formation in South-eastern Australia. Proceedings of the Ecological Society of Australia 14: 23-41.

Hibbert, D. (1999) Coastal sand dunes stabilisation / revegetation at Powlett River and Woolamai: An assessment of techniques. B.Sc. (Honours) thesis, Department of Geography and Environmental Science, Monash University, Clayton. 120 pp.

Hills, E.S. (1975). Physiography of Victoria. Whitcombe & Tombs. Melbourne. 372 p.

Hilton, M., Harvey, N. and James, K. (2007). The impact and management of exotic dune grasses near the mouth of the Murray River, South Australia. Australian Journal of Environmental Management 14: 220-230.

Hilton, M., Harvey, N., Hart, A., James, K. and Arbuckle, C. (2006). The impact of exotic dune grass species on foreshore development in Australia and New Zealand: A case study of Ammophila arenaria and Thinopyrum junceiforme. Australian Geographer 37(3): 313-334.

Oates, A. and Frood, D. (2010). Cape Woolamai native vegetation management plan. Report prepared for Phillip Island Nature Parks. Oates Environmental Consultancy, Newhaven, Victoria.

Parks and Wildlife Service Tasmania (2003). Threats: Marram Grass. A hazard to our beaches. 2 page pamphlet. Department of Tourism, Parks, Heritage and the Arts.

Rosengren, N. J. (1984). Sites of Geological and Geomorphological Significance in the Westernport Bay Catchment. Department of Conservation, Forests and Land, Environmental Studies Publication 401.

Seddon, G. (ed.) (1975). Phillip Island, Capability, Conflict Compromise. Centre for Environmental Studies, University of Melbourne.

Sunamura, T. (1991). The elevation of shore platforms: a laboratory approach to the unsolved problem. Journal of Geology. 99.(761-766).

Trenhaile, A.S. (1987). The Geomorphology of Rock Coasts. Clarendon Press, Oxford. 387 p.

Trenhaile, A.S. (2011). Cliffs and rock coasts, in: Wolanski, E., McLusky, D.S. (Eds), Treatise on Estuarine and Coastal Science 3, 171–191. Academic Press, Waltham.