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BELLARINE PENINSULA - CORIO BAY LOCAL COASTAL HAZARD ASSESSMENT

INUNDATION SUMMARY REPORT

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Acknowledgements

A partnership between the relevant organisations from the study area was formed as part of this project. The Senior Strategic Partnership Group (SSPG) and Project Control Group (PCG) was represented by the following organisations:

- **Department of Environment, Land, Water & Planning (DELWP)**
- **Corangamite Catchment Management Authority (CCMA)**
- **City of Greater Geelong (CoGG)**
- **Borough of Queenscliffe (BoQ)**
- **Bellarine Bayside Foreshore Committee of Management (BBFCoM)**
- **Barwon Coast Committee of Management (BCCoM)**

This summary report has been prepared by Cardno as a summarized version of the Inundation Report, Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment 2015.

Contents

1. Introduction

Our iconic coastlines are shaped by wind and waves and are changing over time. These changes influence the way we work, live, play and relax on the coast. There is consensus amongst scientists now that our climate is changing as a result of global warming. Some of the effects we are likely to experience in the future are higher temperatures, changes in rainfall patterns, a rise in sea level, an increase in the magnitude and frequency of coastal storms and as a result, more frequent inundation of low-lying coastal areas. This is likely to have adverse effects not only on infrastructure and the built environment but also the natural, cultural and social environment. We therefore need to adapt to changes we or our children are likely to experience in the future. As such, we need to start planning for the future now and want you to be involved!

The Geelong-Queenscliffe Coastal Adaptation Program (Our Coast) is an initiative to identify future challenges and opportunities that sea level rise may bring to our shores along the Bellarine Peninsula and Corio Bay. The program is part of the City of Greater Geelong, Borough of Queenscliffe and the Victorian Government's long-term climate resilience planning and will assist coastal communities, councils and government to plan and respond together.

To be able to adapt to the impacts of coastal climate change, we need to better understand the drivers causing change. The Inundation Report, Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment 2015, used the latest information and technologies to determine the potential extent of future coastal inundation and the effect this may have on our shores lines.

The coastal inundation modelling did not include coastal erosion or inundation which may occur as a result of erosion. It also did not include the effects of wave set up and run up in all circumstances. These wave effects have been included in some cases such as overtopping of sea walls, but not in general inundation. This is probably not a major issue in many cases, but will be important in some areas.

Information generated from this study can be used to build the capacity of land managers so they are in a better position when dealing with future inundation issues along our coast.

This study is one of four Local Coastal Hazard Assessments undertaken in Victoria in recent years. It is the only one of the four pilot studies that offers a unique opportunity to study both, the open ocean as well as the embayed Port Phillip Bay coast to investigate the effects of coastal inundation on these different coastal environments.

The study area includes the entire Bellarine Peninsula and the northern side of Corio Bay, from Breamlea in the south to Point Wilson in the north (refer Figure 1.1). Figure 1.2 shows the elevation of the land in the study area.

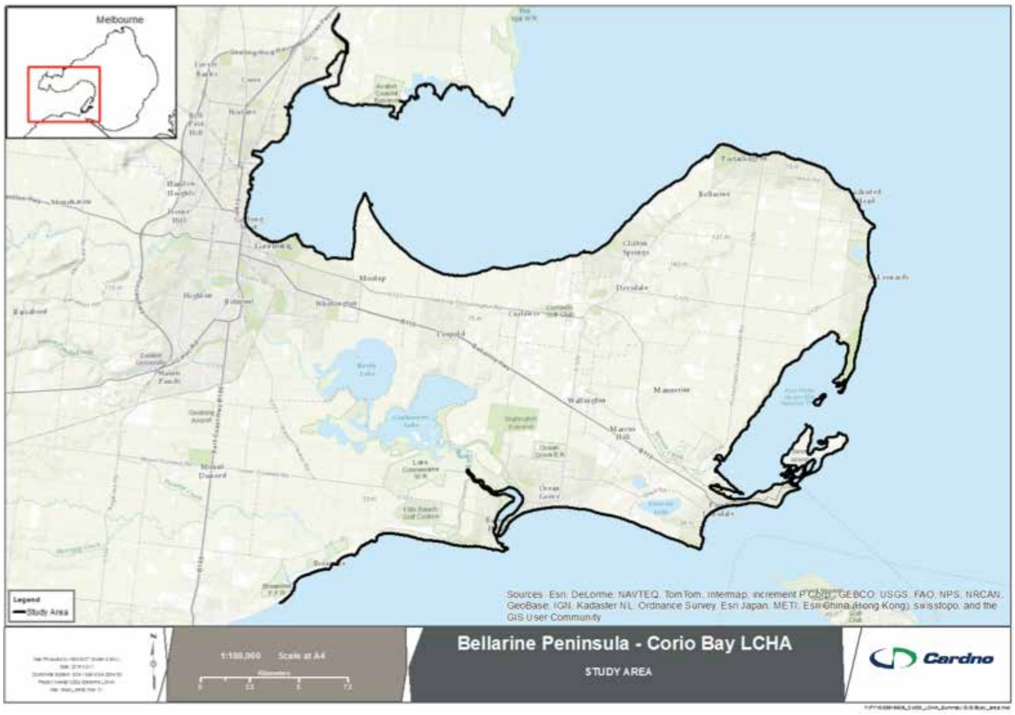


Figure 1.1 *Study area Bellarine Peninsula – Corio Bay LCHA*

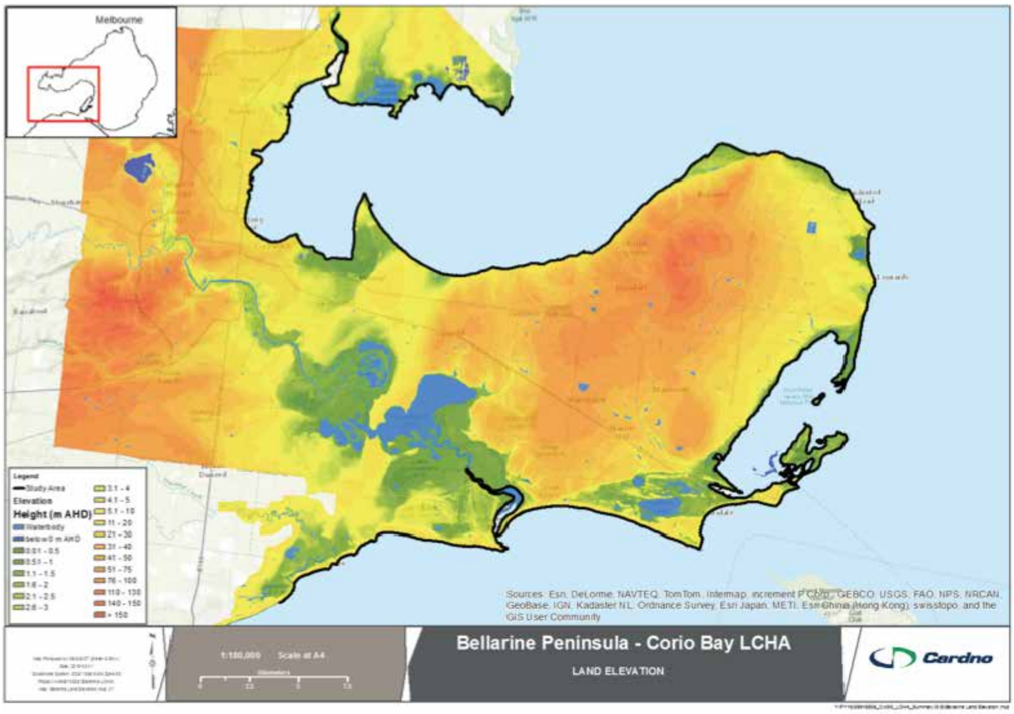


Figure 1.2 *Elevation of the land in the study area*

1.1 Context

The Geelong area has experienced a significant increase in permanent population and visitors over the last ten or more years. These increases are causing greater pressures on one of our most valued environments – the coast. Providing and maintaining facilities as well as preserving the natural environment requires an ongoing effort of land managers and the public alike. To be able to best manage our coast, it is important to understand the pressures this environment is exposed to, now and into the future.

This document summarises the first of a three-step process of coastal zone management, planning and adaptation to coastal climate change. The intention of this study was to identify and provide information about causes leading to coastal inundation, permanent or temporary. It is the first step in the development of a sound coastal management framework that:

- Is functional on a day to day basis. This is to ensure that coastal managers have a good understanding of the coastal processes affecting the section of coast they manage;
- Builds capacity for future challenges – providing technical information to assist in management of future risks, to assist in the implementation of suitable adaptation responses which utilise resources for reducing risk effectively; and,
- Provides information that will enable the establishment of an adaptive management process – ensuring managers review the suitability of management plans and, in particular, regularly review the climate change and sea-level rise science. Management procedures need to be monitored and revised to ensure the long-term capacity of any adaptation responses.

Subsequent steps in the development of a coastal management framework will include risk assessments that relate coastal inundation information established in this study to assets and values. This information can then be utilised to establish and evaluate management options and adaptation responses to minimise the effects coastal inundation will have on our coast, being public and private infrastructure, environmental, or cultural and social assets.

What Are Coastal Hazards?

The Victorian Coastal Hazard Guide, developed by the Department of Environment and Primary Industries (DEPI), now DELWP, states that:

"Coastal hazards such as erosion and inundation are largely the result of the natural processes that occur along Victoria's dynamic coastline. The high social, economic and environmental value that we place on our coastline means that the hazards produced by these processes affect Victorians beyond those just living and working on the coast. However, the processes are highly complex and their effects are difficult to predict with any certainty."

What is coastal inundation and how is it different from catchment flooding?

In summary, coastal inundation is driven by sea level, tides and waves from the sea forcing ocean water onto low-lying coastal land. Riverine flooding on the other hand is caused by rain falling within a water catchment, then flooding low-lying land. One of the most important differences between coastal inundation and riverine flooding is their duration. Riverine flooding may last for many hours, even days or weeks. Coastal inundation on the other hand is influenced by the combination of tides and storms. A high tide occurs approximately every 12 hours in Victoria. A storm surge, or high sea-level due to meteorological forces rarely lasts more than 24 hours in southern Australia (see Figure 1.3). The duration of the highest levels of inundation is thus controlled by the duration of the peak of the high tide.

1.2 Aims and objectives of the underlying study

The primary aim of the Inundation Report, Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment 2015 was to identify the potential landward extent of coastal inundation both present and into the future, considering the effects of climate change. Having coastal adaption in mind while developing the study, the aims were to:

- Improve our understanding of those processes shaping the coast along the Bellarine Peninsula and Corio Bay, now and into the future, considering the impacts of climate change.
- Provide data and other information that assists coastal practitioners in predicting the coast's susceptibility to inundation. This information will directly inform regional, township and local strategic planning, including adaptation planning processes.
- Build the collective capacity and depth of knowledge of land managers and decision makers to use the information generated to plan for and respond to coastal inundation that may occur in the future.

1.3 Physical setting & contemporary coastal processes

The Bellarine Peninsula represents a unique combination of open-ocean and embayed coast. The Bass Strait coast between Breamlea and Point Lonsdale is exposed to ocean waves, has a shallow offshore and cliffs as well as areas with soft beach sand that can reach up to 30 m in height.

These open ocean dynamics change at the entrance to Port Phillip Bay. While the area between Point Lonsdale and Queenscliff experiences large ocean swells and strong currents, the influence of tides and ocean waves decreases inside Port Phillip Bay. The effects of waves at Geelong or Corio Bay are very different from Point Lonsdale or Breamlea because waves north of about Point Edwards are influenced by wind rather than ocean swell.

The Corio Bay area has low coastal energy compared to the rest of the study area. Wind waves are created by strong north easterly winds, typically during winter. The long fetch across the bay allows larger wind waves to develop, occasionally causing temporary inundation of the low-lying areas along the northern side of the Bellarine.

1.4 Coastal inundation scenarios

As described in Section 1.1, the focus of this document is on coastal inundation; that is the temporary or permanent flooding of low-lying land with seawater.

Coastal storms lasting hours at a time are responsible for temporary inundation while future sea level rise will permanently inundate low-lying areas. To gain an understanding of the current and future effects of these two forces, this study examined six different sea-level rise scenarios in combination with a 1% AEP storm. The sea level rise scenarios are based on projections by the Intergovernmental Panel on Climate Change (IPCC); and these are:

- 0.0 m sea level rise (relative to 1990 as a baseline)
- 0.2 m sea level rise
- 0.5 m sea level rise
- 0.8 m sea level rise
- 1.1 m sea level rise
- 1.4 m sea level rise

The majority of studies to date, like those by the IPCC, CSIRO or DELWP Future Coasts Program assume that sea level rises by a certain rate at a given year. For example, the IPCC's best estimate is that sea level will rise globally by 0.82m by 2100. The DELWP Future Coasts Program assumed a rise in sea level of 0.2 m by 2040, 0.49 m by 2070 and 0.82 m by 2100 for the statewide coastal inundation mapping released in 2012.

In contrast to the above studies, this work utilised a different approach, using 'trigger points'. The key difference is that the year that the sea-level rise scenario is likely to occur has not been stated. The aim of this is to avoid tying the scenarios to a given time in the future. It rather says that if a given amount of sea-level rise occurs, inundation will be the consequence. This allows some flexibility with future assessments, but also removes some of the uncertainty associated with having a line on a map that states the shoreline may be in a certain place at a given time. For locations where more comprehensive background data sets exist, this may be appropriate; however, given the levels of certainty within this study, it is not considered the best approach.

What is Annual Exceedance Probability or AEP?

Annual Exceedance Probability (or AEP) is a statistical value. It describes the probability that an event (here coastal inundation) will occur. A 1% AEP level, for example, is the level at which there is a 1% probability of being exceeded in any given year (approximately one year in 100). This does not mean that if this level is reached in one year, it will not be exceeded again for the next 99 years. It also does not mean that if inundation has not occurred for 99 years that it will occur in the following year. It is quite possible that an area may experience two or more 1% AEP events within subsequent or even the same year.

2 Study Area

The study looked at the open coast between Breamlea in the west and Point Lonsdale in the east, entering into Port Phillip Bay along the Bellarine Bayside all the way to Point Wilson. The area studied is approximately 190 km long, including Swan Bay.

The open coast along Bass Strait is generally a high-energy environment with a relatively consistent wave climate, shallow water depths near the coastline, consolidated dunes/cliffs and unconsolidated dunes ranging in elevation from 2 to 30 m above sea level. The two key open coast areas included here are low-lying areas at Breamlea and Barwon Heads.

The influence of waves and ocean waves inside Port Phillip Bay decreases with distance from the bay entrance between Point Lonsdale and Point Nepean. Waves inside port Phillip Bay north of Point Edwards are generated by wind rather than ocean swell.

Near the entrance to Port Phillip Bay, inundation was assessed for the low-lying areas around Queenscliff and Swan Bay. Further north along the St. Leonards and Portarlington coast where coastal elevation is low, areas vulnerable to inundation were assessed in the study. The Clifton Springs coast from Portarlington to Geelong consists of cliffs with narrow beach widths at the base. The hazards here are mostly related to slope stability, with some low lying areas vulnerable to inundation. The Corio Bay area is of very low energy in comparison to the rest of the study area. Waves are typically generated during north easterly wind events, due to the longer fetch from this sector. The northern Corio Bay area is also low energy, the energy increases slightly towards Point Wilson, due to the exposure to the wider bay. The shoreline is mostly rocky with a low-lying hinterland behind.

2.1 Study compartments

The study area was divided into nine compartments to reflect differences of the land surface and observed coastal processes. Priority was placed on areas with assets located close to the coast, such as roads, townships or areas of environmental or cultural value. High-priority areas are often found where many and different assets are located near the shoreline, in particular areas of low-lying land. Areas of moderate priority in this study may also have assets, however, are fewer in number. The low-priority areas are generally low-use areas with little development or assets, and/or which are unlikely to be impacted significantly.

Individual compartments are described in greater detail in Section 3.

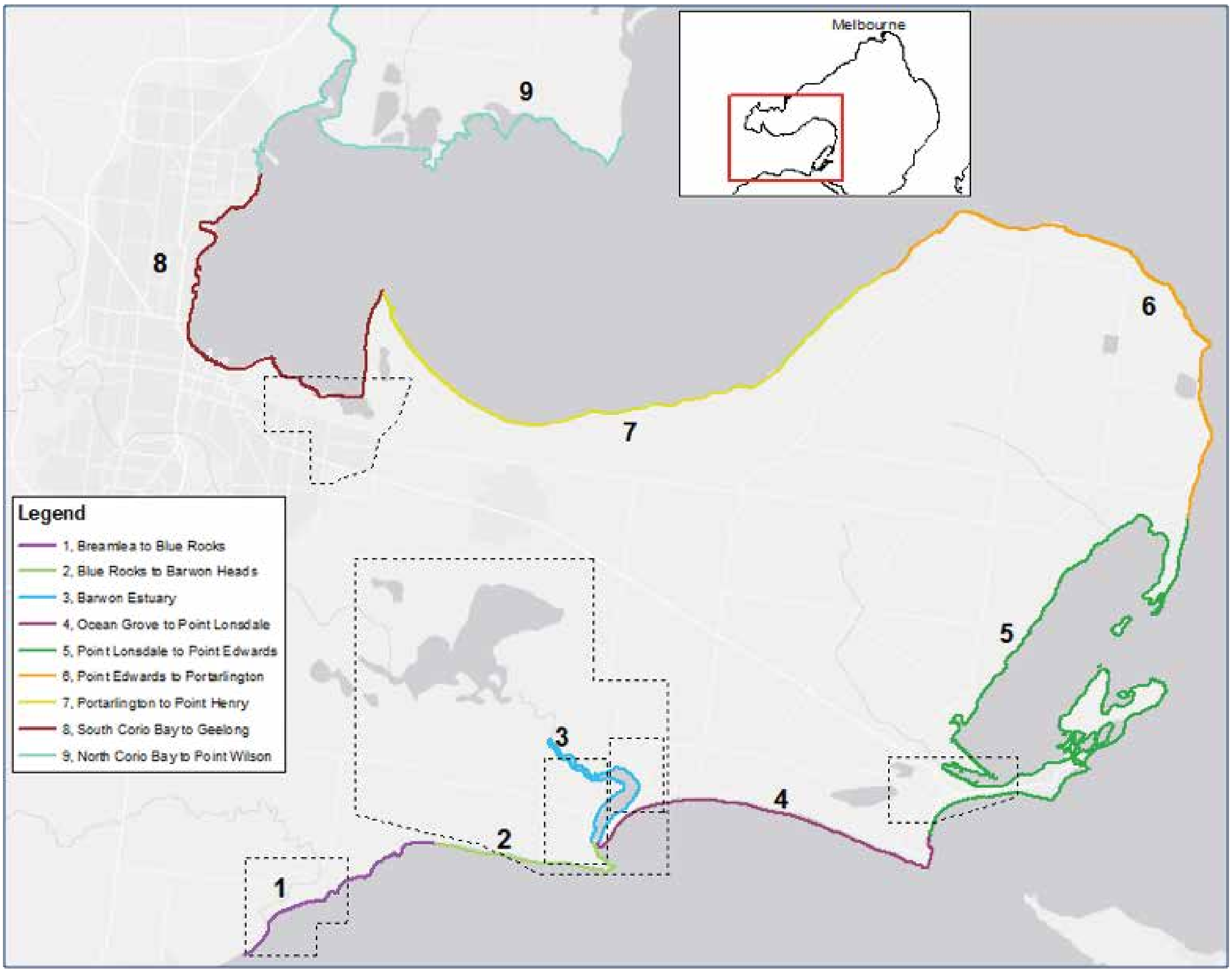


Figure 2.1 *Study Compartments and inundation hydrodynamic model grid boundaries*

3 Key findings

Climate Change science is uncertain, and so are sea level rise scenarios. As discussed in Section 1.4, this study therefore used a 'trigger point' approach to avoid tying sea-level rise scenarios to a given year in the future.

Inundation of some areas may only last a few minutes or hours during a storm and simple measures such as temporary flood barrier activation may be sufficient at that point in time as a coastal protection measure. It is therefore important to be mindful of the potential effects of coastal inundation and at the same time be ready for an appropriate response for that situation.

The following sections refer to the extent of future sea level rise and a storm that has a 1% chance to occur during any given year. The effects and extents of those events vary in different locations along our coast. The following sections summarise the key findings for each of the nine compartments investigated.

3.1 Compartment 1: Breamlea to Blue Rocks

Compartment 1 is located between Breamlea and Blue Rocks. The Breamlea area to the west includes Thompsons Creek and the adjacent creek hinterland, the beach, dunes and rocky shore to Blue Rocks (Figure 3.1). Thompsons Creek meanders through the very low-lying and very flat floodplain hinterland. To the west of the creek is a large area of salty wetland habitat. This is fed by the creek through a culvert under Minya Lane. The inner bends of the creek are armoured with low rock retaining walls to control erosion along the creek but also to minimise any further movements of the channel. There is only one road to access the Breamlea settlement which is potentially at risk from inundation in the future.

The area is showing low inundation vulnerability in the event of a 1% AEP occurrence at present sea level rise (0.0 m SLR). Under this and the 0.2 m SLR scenario, the areas subject to inundation are mostly low-lying floodplain areas with potentially significant impacts to habitats. It is not until the sea-level rises to 0.5 m or more that infrastructure and other assets are potentially affected. Statistically speaking this is unlikely to occur for many years to come. Properties north of the creek, but south of Blackgate Road are likely to be affected in a 1% AEP event combined with 0.5 m of sea-level rise. The Horwood Drive area south of the creek is an area of higher topography than areas north of the creek. This area is only likely to inundate under a 1% AEP event combined with 1.4 m of sea-level rise. This would affect access to the properties along Horwood Drive and potentially some of the lower-lying properties. See Figure 3.2 for more information.

Figure 3.1 *Compartment 1 – Breamlea to Black Rock*

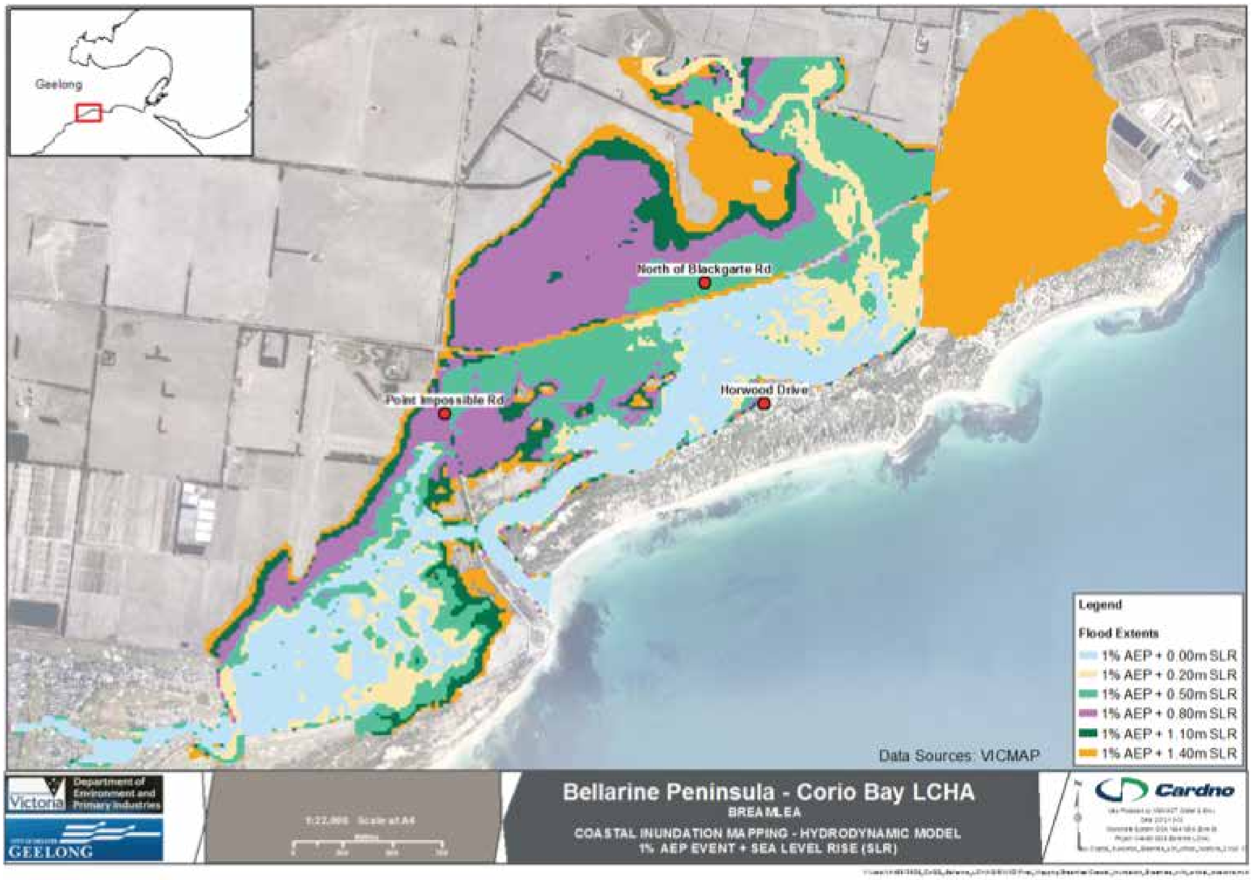


Figure 3.2 *Coastal Inundation Mapping within Compartment 1*

3.2 Compartment 2: Blue Rocks to Barwon Estuary

This 6.5 km long section of coast stretches from Blue Rocks to Barwon Heads.

Thirteenth Beach is backed by high dunes/cliffs with steep, almost vertical, scarps at the central and eastern ends of the beach. The elevation of the dunes/cliffs ranges from approximately 5 m on the western side, to almost 30 m in the east. Coastal inundation is not considered to be an issue here, however, coastal storms could likely cause erosion along this section of coast.

Behind the beach is Murtnaghurt Lagoon, a naturally segmented area that was formerly connected to the Barwon River through a channel that is now disrupted by Plummer's Bank. This is a 4 m high levee constructed in the 1950s to protect against flooding of the Barwon Heads township from the back (Rosengren, 2009). The likelihood of the dune/cliff breaching and flooding the low-lying hinterland and the lagoon is very low due to the elevation and size of the dunes and cliffs.

There is essentially no risk of coastal inundation to the hinterland from this section of coast. The risk of coastal inundation of this area and Murtnaghurt Lagoon is discussed in the Barwon Heads and Lake Connewarre section (Compartment 3).

Figure 3.3 *Compartment 2 – Black Rock to Barwon Heads*

3.3 Compartment 3: Barwon Heads, Barwon Estuary and Lake Connewarre

Compartment 3 includes Barwon Heads, the Barwon Estuary and Lake Connewarre (Figure 3.4). The Barwon Heads township is located on the western bank of the Barwon River estuary. The western bank is protected by a series of high vertical timber and masonry retaining walls to protect properties against river and coastal flooding events. The elevations of the walls range from 1.6 m to over 3 m AHD with numerous properties lying behind.

Previous studies have shown that a risk to assets and the hinterland from riverine flooding exists; the implications of coastal inundation combined with riverine flooding were therefore investigated for this report. It was found that the chance of a coastal storm-tide event and a catchment flow event occurring at the same time is very low. However, should a 10% AEP riverine flood coincide with a 1% AEP coastal storm-tide under present sea-level conditions, both sides of the river would likely be inundated for a short period of time (Figure 3.5). To determine the magnitude of such event and be able to mitigate the impacts, it is possible to use information from tide gauges along the coast to ascertain whether a storm-tide is likely to occur, and the timing of this in relation to the expected maximum river flows.

Figure 3.4 *Compartment 3 – Barwon Estuary & Lake Connewarre*

The newly upgraded stormwater pumping station at Barwon Heads along Clifford Parade will aid in managing the effects of catchment, river and oceanic driven flooding. This is a low-lying area that collects water, and three high-capacity pumps have replaced the previous single pump.

The chance of floods occurring and extending into larger areas over time will increase with future sea level rise (Figure 3.6). The overall vulnerability in the coming decades is likely to be more substantial on the eastern bank of the river at Ocean Grove. This is due to the low land levels and lack of shore protection designed for inundation purposes. Saying that, temporary measures are quite possibly sufficient for the time being.

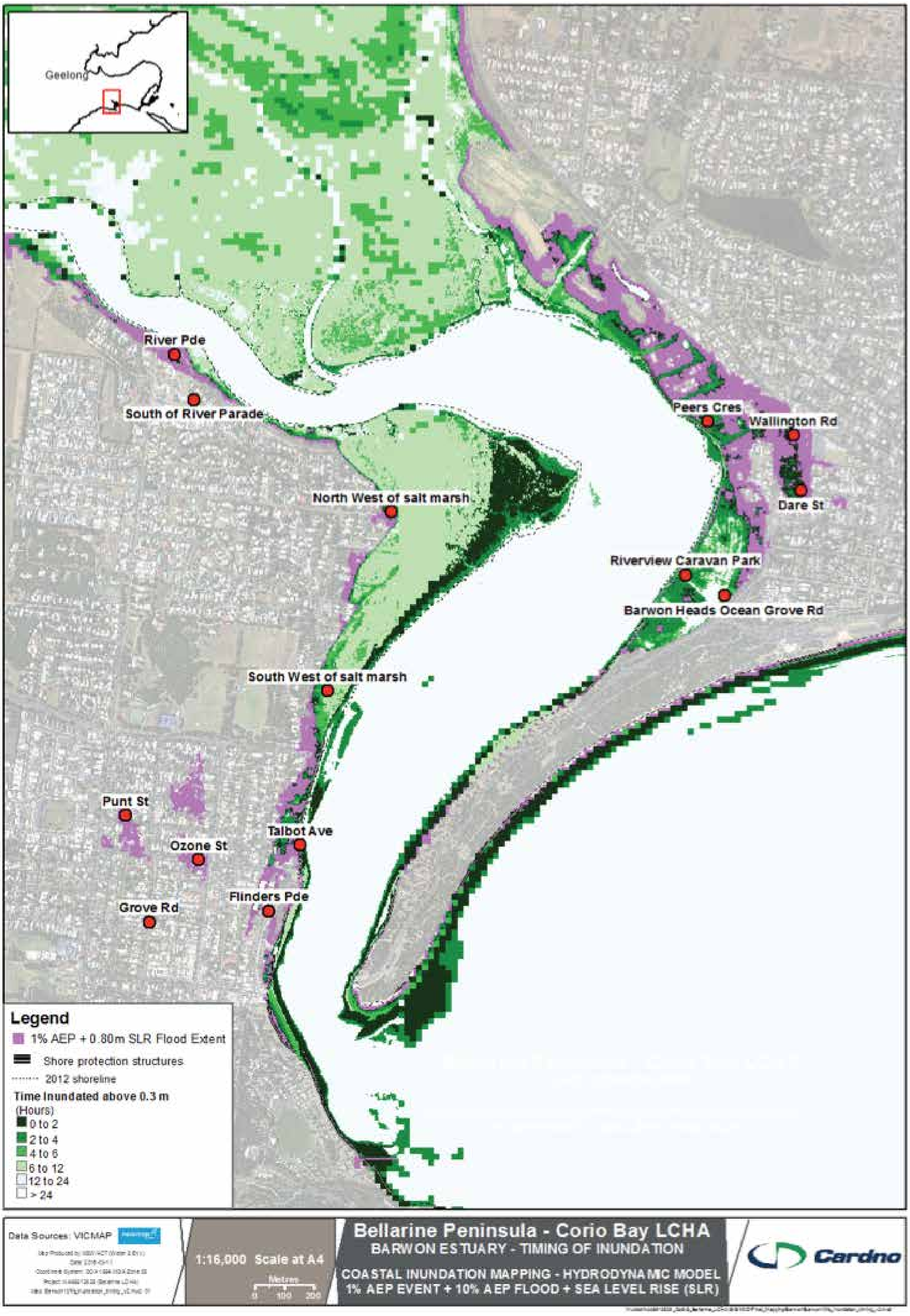


Figure 3.5 *Barwon Estuary – duration of inundation*

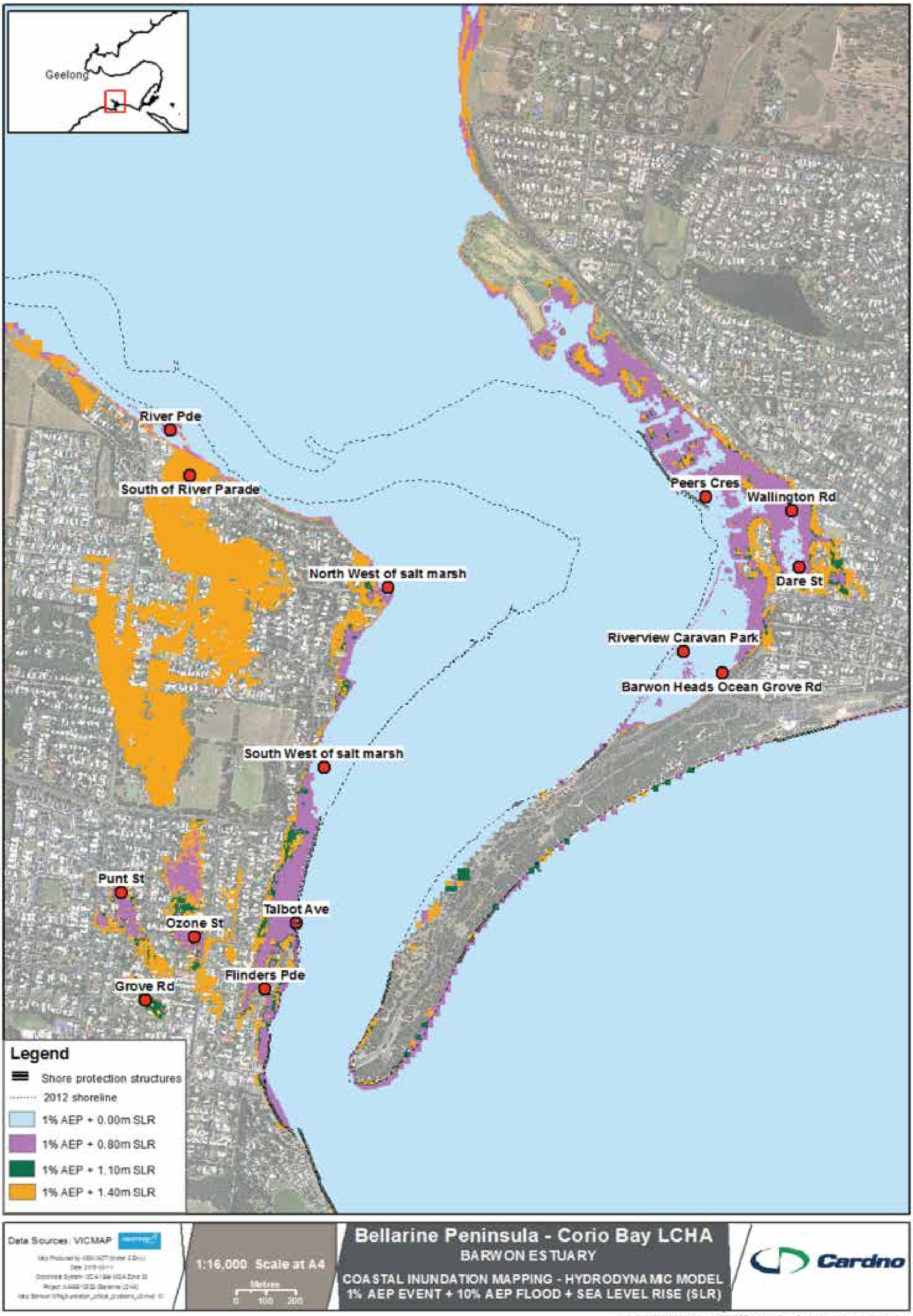


Figure 3.6 *Barwon Estuary – extent of future coastal inundation*

3.4 Compartment 4: Ocean Grove to Point Lonsdale

This includes the coastline between Ocean Grove in the west and Point Lonsdale in the east. The western side of the beach near the river entrance at Ocean Grove Spit is very flat and wide, with well-developed dunes that have a good covering of vegetation. An old low timber wall provides some additional protection to the dunes, and has encouraged the development of a low sparsely vegetated berm seaward of the toe of the dune. Offshore, the bathymetry is very shallow, and the waves are normally less strong than in other regions of the Bellarine coastline. The exposure to the dominant south-westerly swells is limited due to the protection of Barwon Head and shallow offshore reefs (Figure 3.7).

Further east towards Ocean Grove main beach, the beach narrows and steepens slightly. The dunes are high, ranging in elevation from 4 m to 15 m AHD (Australian Height Datum). This section is also where the wave heights and energy increases all the way towards Point Lonsdale.

Figure 3.7 *Compartment 4 – Ocean Grove to Point Lonsdale*

Ocean Grove main beach is similar in nature to the section previously noted, with the addition of a vertical timber and concrete retaining wall in front of the Surf Lifesaving Club. This long 200 m wall was upgraded recently, and is positioned approximately 6 m seaward of the toe of the dune. The effects of this seawall are already apparent, with the beach elevation and gradient immediately in front of the wall differing from the surrounding beach, and terminal scour having occurred at the eastern end.

No inundation maps were produced for this area, as there is no risk of inundation to the hinterland from the sea along this section of coast.

3.5 Compartment 5: Point Lonsdale to Point Edwards

Compartment 5 - Point Lonsdale to Point Edwards extends from Point Lonsdale back beach (open coast) to Swan Bay. It consists of steep eroding cliffs, various shore protection methods, sandy beaches and the Swan Bay area (Figure 3.8).

Figure 3.8 *Compartment 5 – Point Lonsdale to Point Edwards*

The Fisherman's Flats shoreline is significantly lower than the rest of the Queenscliff area, coastal inundation is therefore most likely to originate from there (Figure 3.9). The lowest areas of Fisherman's Flats already collect runoff in high rainfall events. Additional water from coastal inundation will therefore increase the level of inundation. However, similarly to the Barwon Estuary the likelihood of the two hazards occurring at the same time is low.

Lakers Cutting and the Lonsdale Lakes development at the southern end of Swan Bay were investigated closely in this study. It was found that the chance of inundation may extend to the Bellarine Highway and properties in the vicinity of Murray Road (Figure 3-10). The extent of inundation of this area becomes significant under a 1% AEP event with 0.2 m sea level rise. In this event, a low section of the railway embankment overtops west of the Marine Discovery Centre, possibly impacting a small number of properties along Murray Road. The timing and depth of inundation for this area during this event is likely to be low. In a 1% AEP event with 0.5 m SLR, the flood extents increase substantially. In the event of further rising sea level, the embankment would likely be overwashed. This in turn may possibly impact the Bellarine Highway in the distant future (Figure 3.11).

For Swan Bay, the inundation hazards are less significant with regard to infrastructure. There is little development around the bay, thus the key issues are likely to be environmental. The surrounding land areas rises gradually to higher land, landward habitat movement is not inhibited by artificial structures (coastal squeeze), however, may suffer from other effects (Figure 3.12, Figure 3.13).

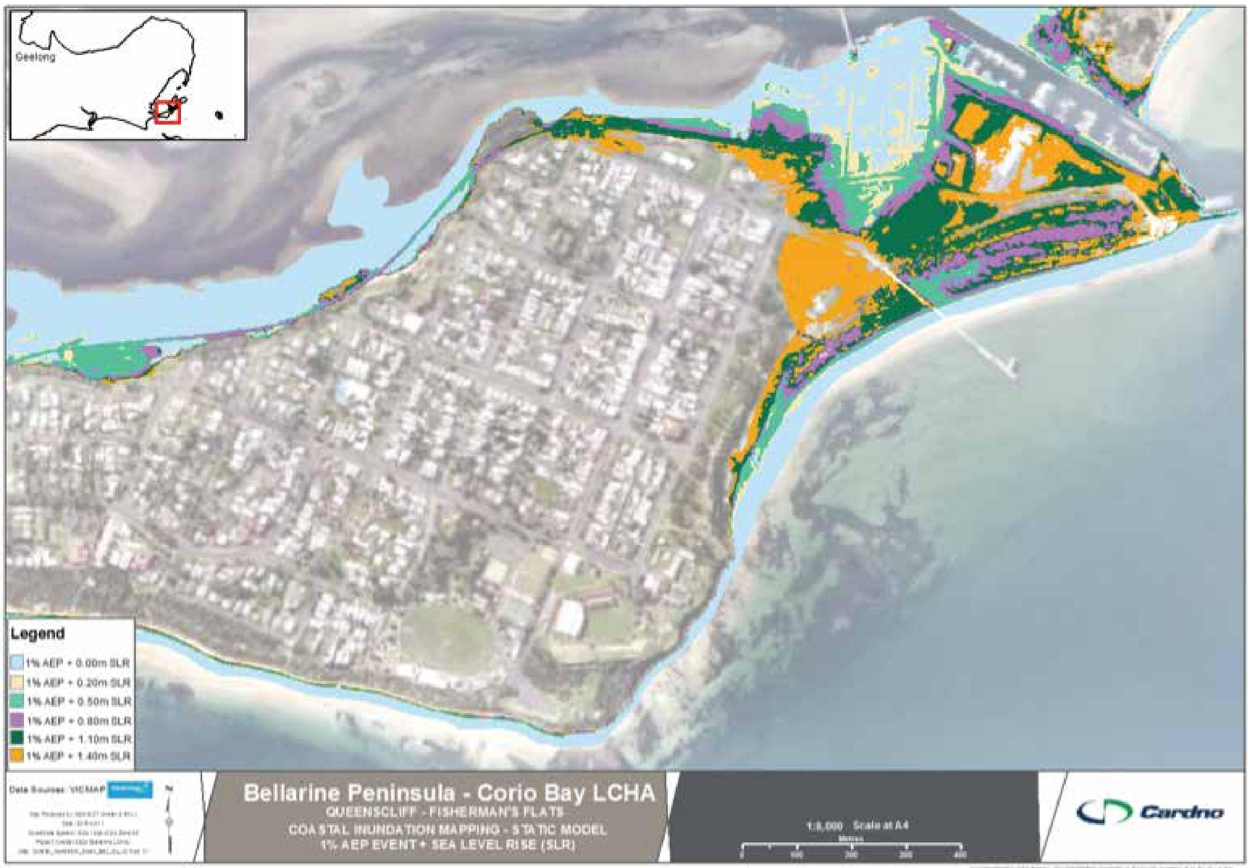


Figure 3.9 *Coastal Inundation Fisherman's Flats*

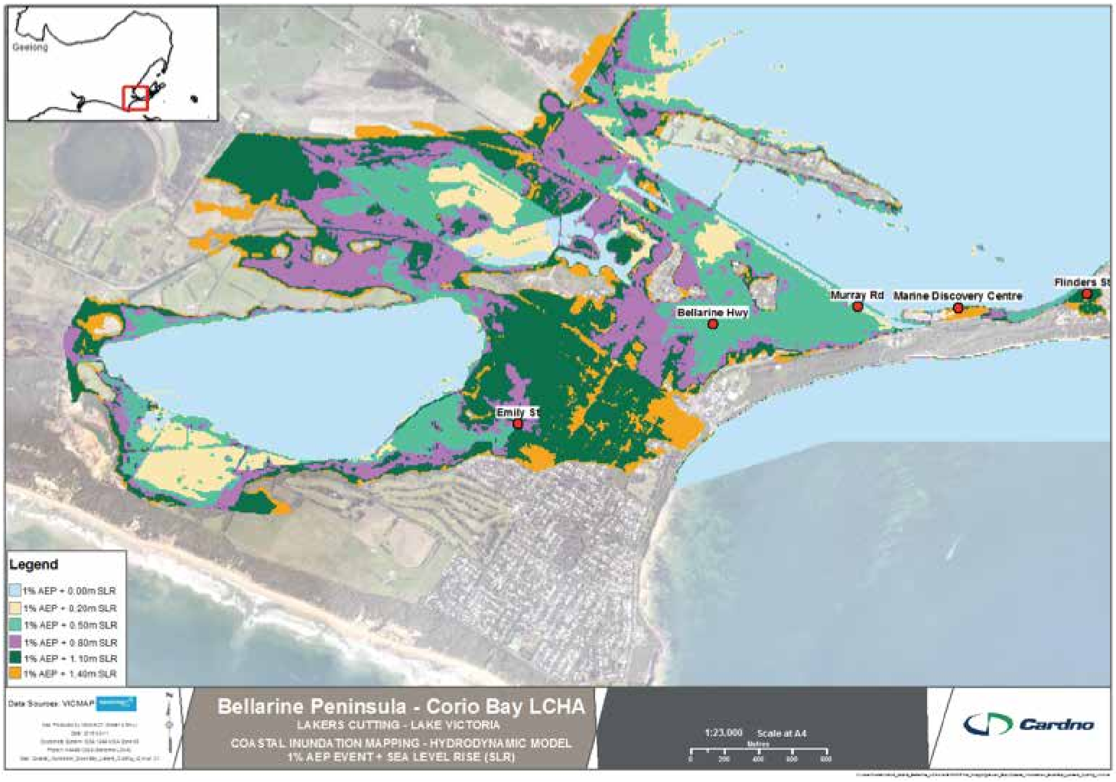


Figure 3.10 *Coastal Inundation Lakers Cutting*

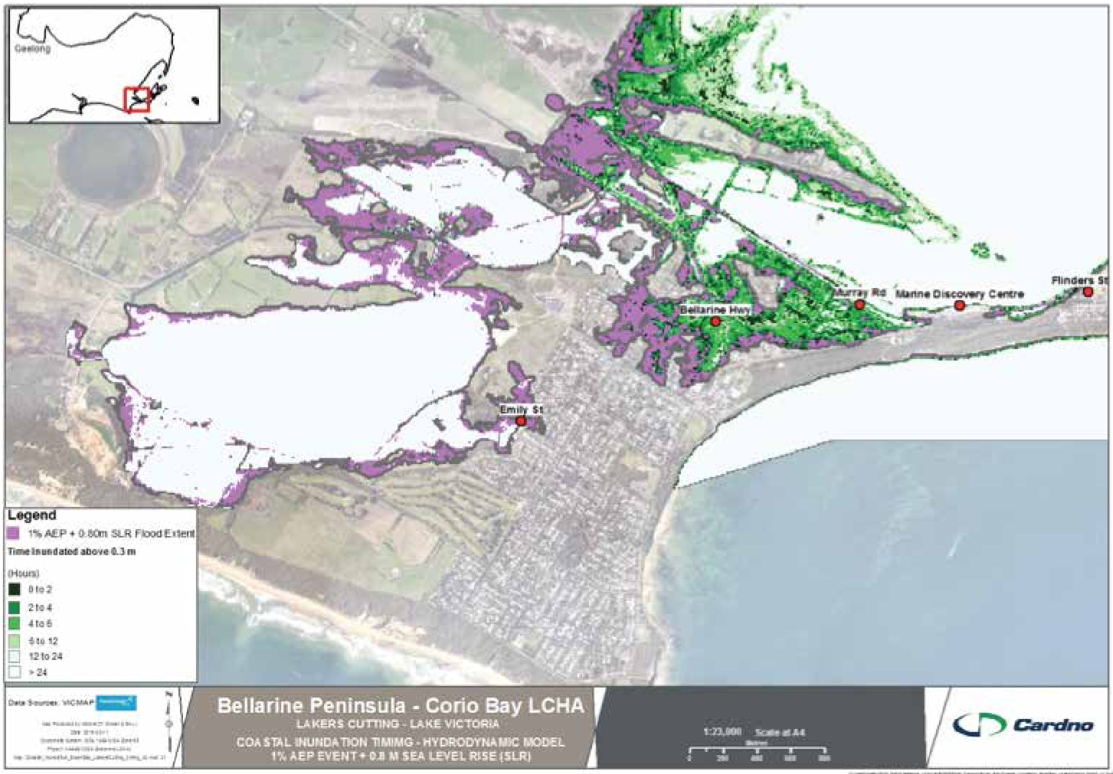


Figure 3.11 *Duration of Inundation Lakers Cutting*

Figure 3.12 *Coastal Inundation Western Swan Bay*

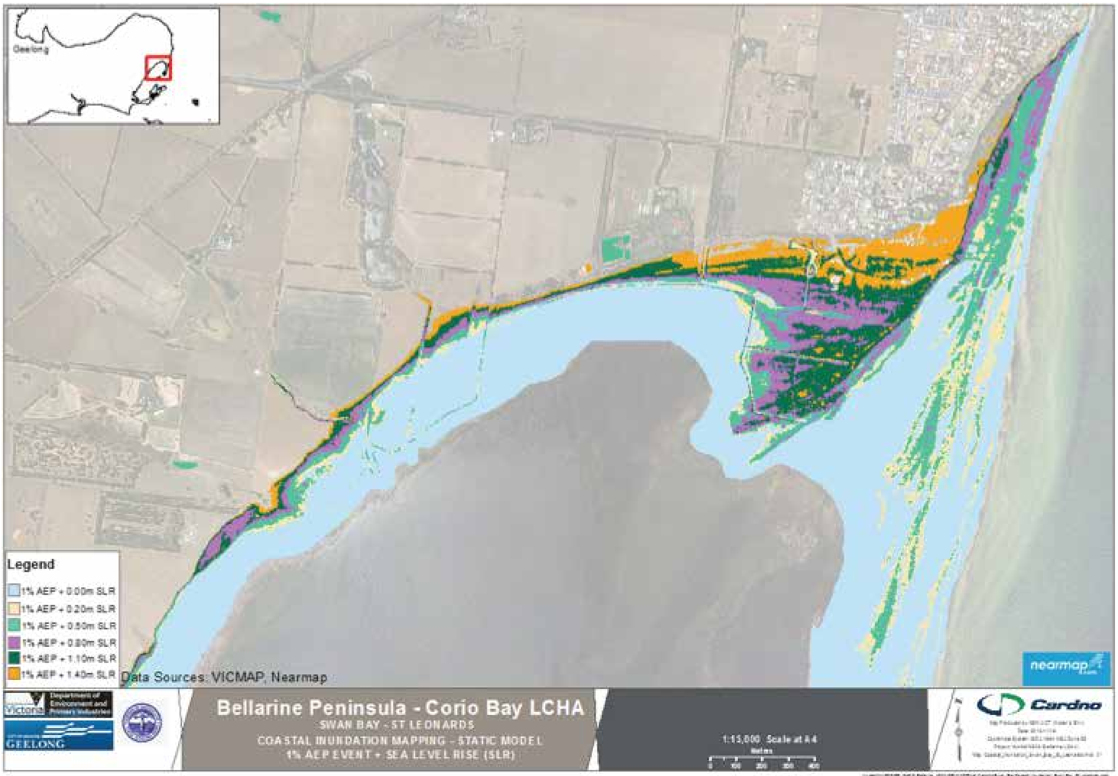


Figure 3.13 *Coastal Inundation Swan Bay to St Leonards*

3.6 Compartment 6: Point Edwards to Portarlington

Much of the shoreline is a very narrow strip of beach backed by eroding soft rock and some low cliffs (Figure 3.14).

Figure 3.14 *Compartment 6 – Point Edwards to Portarlington*

The shoreline is partially protected from wave action by the Great Sands. In the more exposed areas, there are some shore protection works in the form of rock revetments, timber retaining walls and geotextile container walls (near Salt Lagoon). In the south, relict timber groynes have been replaced recently along the frontage of Bell Parade to trap the southwards moving sediments and widen the beaches in front of the properties which run to within metres of the water's edge and are very low-lying.

Further north around Bluff Rd and Harvey Park there is more dune development, and the hinterland rises from the coast.

This area is vulnerable to inundation in discrete areas. Potential for inundation has been identified for St Leonards Lake Reserve (Figure 3.15) and Salt Lake (Figure 3.16). The potential for inundation at Salt Lagoon is that it may be affected in a present day 1% AEP storm. The risk of inundation is lower at St Leonards Lake Reserve, impacts becomes more significant with sea-level rise increases over 0.2 m in a 1% AEP storm event.

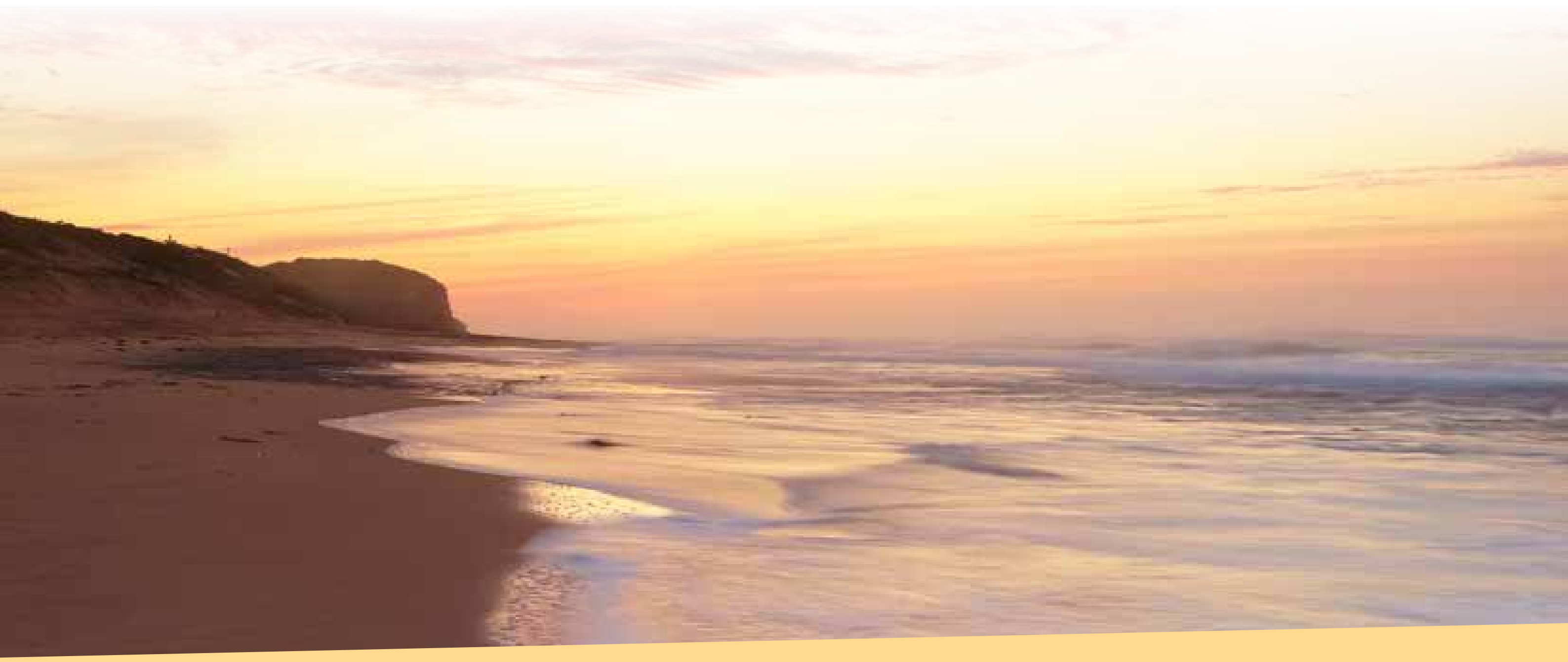
The beach at Salt Lagoon is very narrow and eroding. The properties behind the road are located in a low lying area and have been inundated in the past. Salt Lagoon itself supports some rare hyper-saline habitats, and occasionally dries out completely in summer.

There is a significant inundation hazard at Indented Head near Andersons Reserve to the Esplanade at Portarlington (Figure 3.17) and Ramblers Road (Figure 3.18). These areas are both very low in elevation and flat. There is little to no dune formation fronting the hinterland, with low wooden retaining walls holding the shoreline in place in some locations.

The Esplanade, east of Portarlington, is a very low-lying soft rock foreshore that is vulnerable to inundation. It has little or no protection against the prevailing winds and waves. There is no dune protecting the hinterland, and, where present, shore protection is mostly in the form of low retaining walls that are in various states of repair, from poor to good condition.

The Portarlington area is a combination of low-lying soft rock shorelines and low cliffs. The foreshore west of the harbour fronts the holiday park and is a very popular tourist area in summer. The beach was renourished in 2012 to increase beach widths and provide additional amenity. The area west of here is also vulnerable to inundation, and has been inundated in the past.

The Ramblers Road foreshore is a mostly low-energy environment with narrow strips of beach of medium to fine sand and coarse shell material. Saline shrub habitats occupy the areas behind the very low dunes. Beyond the vegetation, private properties are positioned near the shoreline at very low elevations. These properties have been inundated in the past due to overwashing of the low dune.



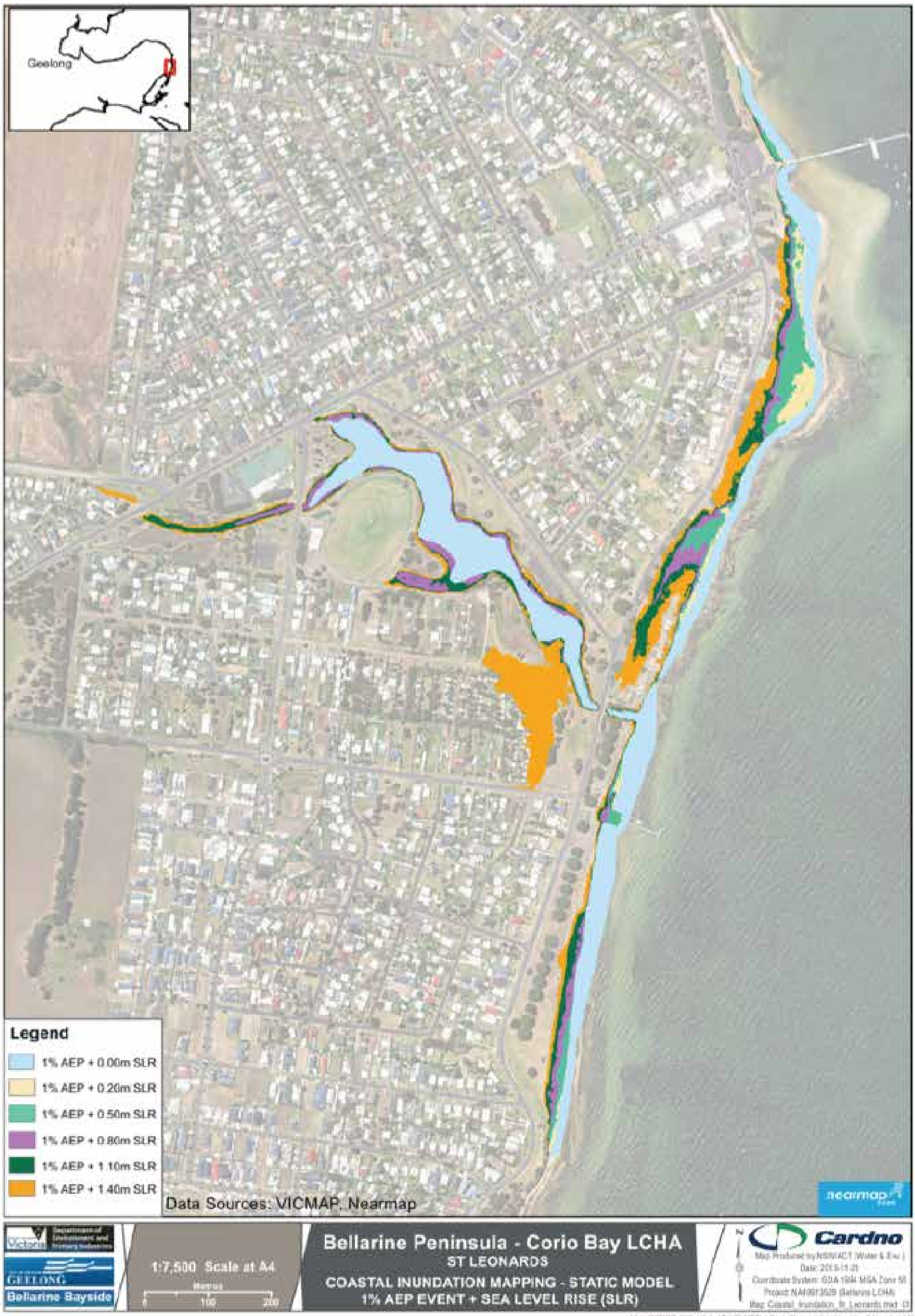


Figure 3.15 *Coastal Inundation St Leonards*

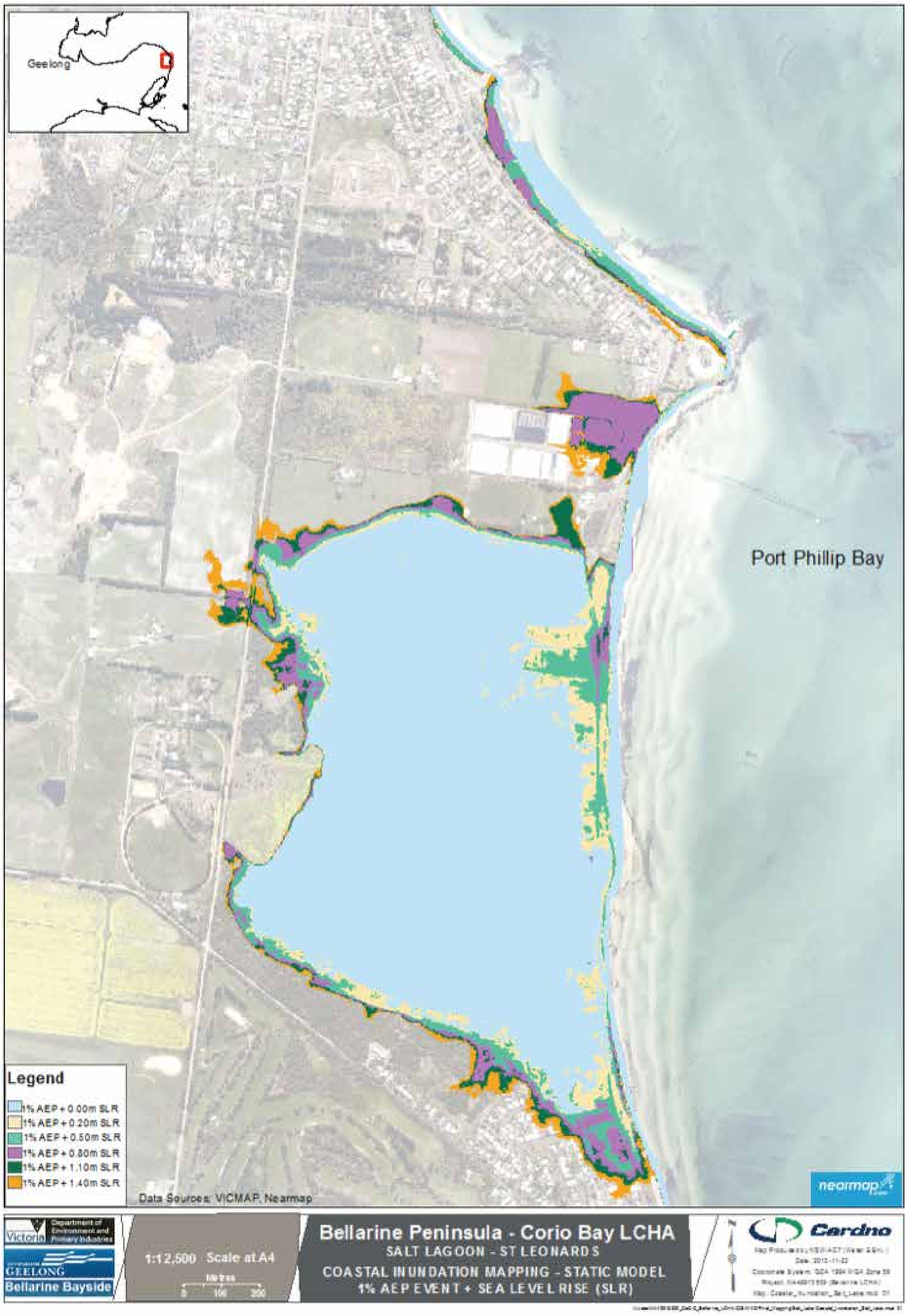


Figure 3.16 *Coastal Inundation Salt Lagoon*

Figure 3.17 *Coastal Inundation The Esplanade Portarlington*

Figure 3.18 *Coastal Inundation Point Richards*

3.7 Compartment 7: Portarlington to Point Henry

Much of the Clifton Springs shoreline consists of a steep cliff backed by a high plateau. Further west towards Point Henry, the elevation decreases significantly near the Sands Caravan Park (Figure 3.19).

Figure 3.19 *Compartment 7 – Portarlington to Point Henry*

The main inundation area is the low-lying land west of Alexander Avenue near the Sands Caravan Park. The results of the inundation assessment are shown in (Figure 3.20). The inundation area is concentrated near the informal man-made harbour east of the Caravan Park.

The consequences of inundation west of the caravan park are likely to be low.

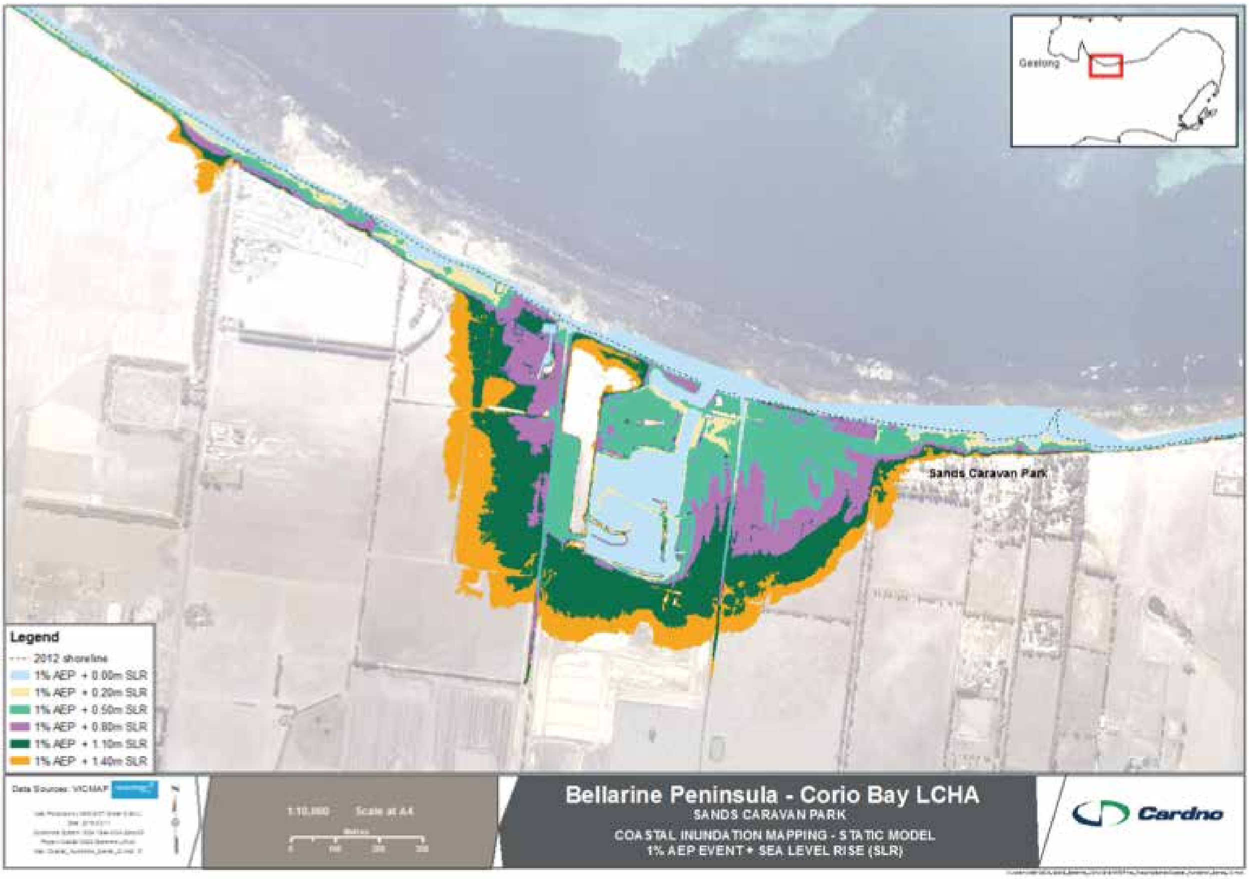


Figure 3.20 *Coastal Inundation Sands Caravan Park*

3.8 Compartment 8: Stingaree Bay to Geelong (South Corio)

The south eastern part of Corio Bay is known as Stingaree Bay and includes the relict saltpans and Point Henry; the western side is the foreshore of the City of Geelong (Eastern and Western Beach). Coastal inundation is the key hazard in this area, due to the low elevation of the land.

Point Henry, Newcomb and Moolap are very low-lying and low-energy environments. Similar to the more eastern areas, the shoreline is very narrow with little to no dunes to protect the hinterland. There is minimal sediment transport in this area due to a lack of material and low-wave action (Figure 3.21).

Figure 3.21 *Compartment 8 – South Corio to Geelong*

The western side of Point Henry (Stingaree Bay) is protected by an informal rock revetment. The eastern side supports almost 20 hectares of saline habitat and small salt lagoons. At the base of Point Henry, the relict salt pans are closed in by a series of unmaintained levees. The levees do not form a consistent barrier, but have been breached to allow water to enter. These offer some protection to the hinterland and will require maintenance in the future to continue to provide protection. The Newcomb and Moolap residential and commercial areas lie behind the salt pans and Portarlington Road; these are similarly very low-lying. Inundation is a key issue for this area, with flow paths from Stingaree Bay and to the east of Point Henry, as indicated by the blue arrows in Figure 3.22

Figure 3.22 *Point Henry and Saltpans and possible inundation routes*

Figure 3.23 shows the area around Moolap and Point Henry. This area is very low lying and in part already subject to temporary inundation from within Corio Bay. Assuming a sea level rise of 0.5 m over the coming decades Point Henry Road is likely to be cut during a 1% AEP coastal storm. The flooding in this instance is likely to be from the western side of the point, with minimal flood inundation from the eastern side. Inundation becomes more significant with further rising sea level.

Inundation in the Newcomb / Moolap area is largely via the large drainage channel around the western and southern edge of the salt pans. The Geelong-Portarlington Road is likely to be overwashed at the western end in a 1% AEP event with more than 0.8 m sea level rise. South of the Geelong-Portarlington Road, inundation is only apparent in a 1% AEP event at more than 0.8 m SLR. Above 0.8 m SLR (1.1 m and 1.4 m scenarios) water flows over the road and inundates significant areas in such storm conditions (Figure 3.23, Figure 3.24), however, likely only for a few hours at a time (Figure 3.25).

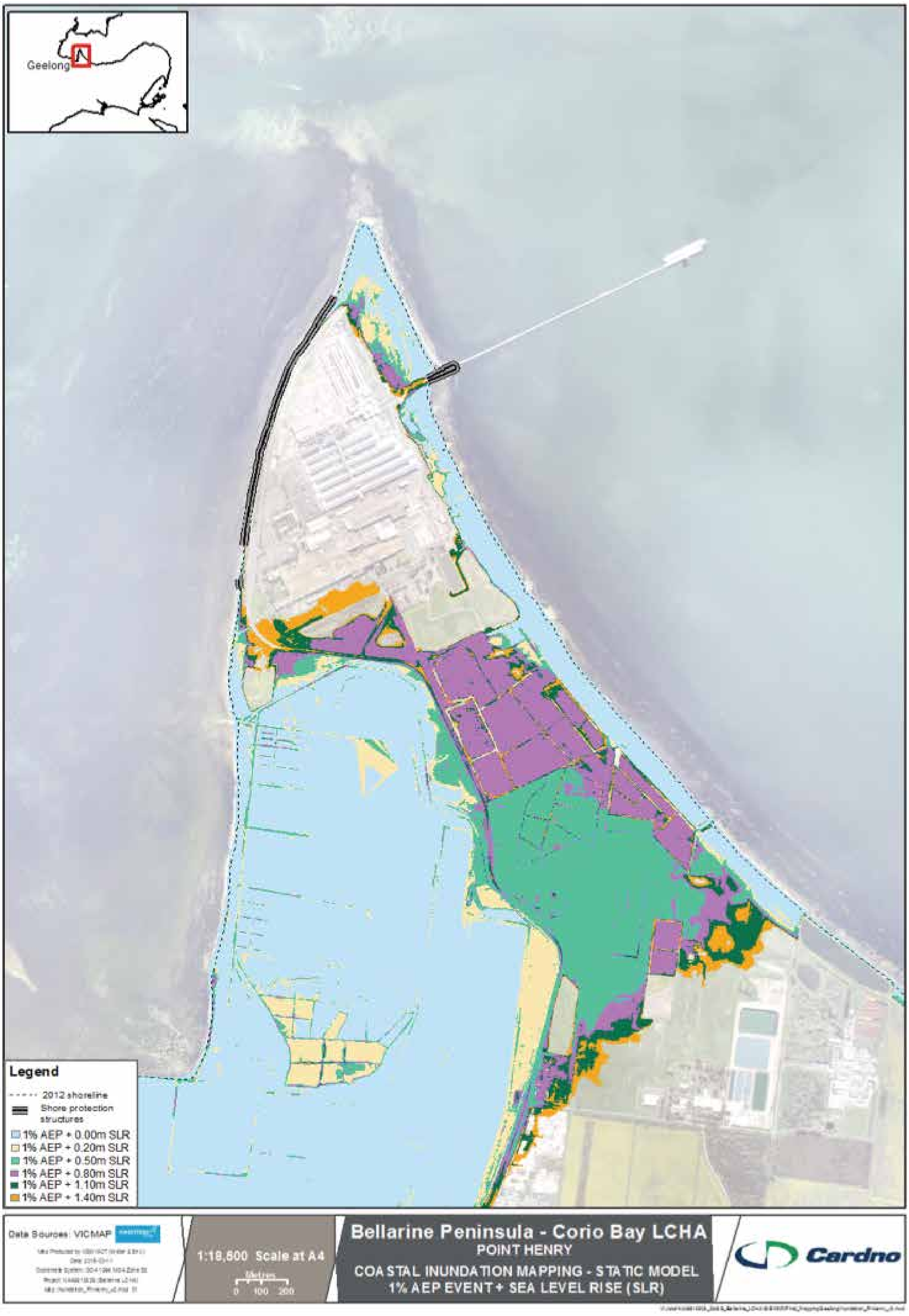


Figure 3.23 *Coastal Inundation Point Henry*

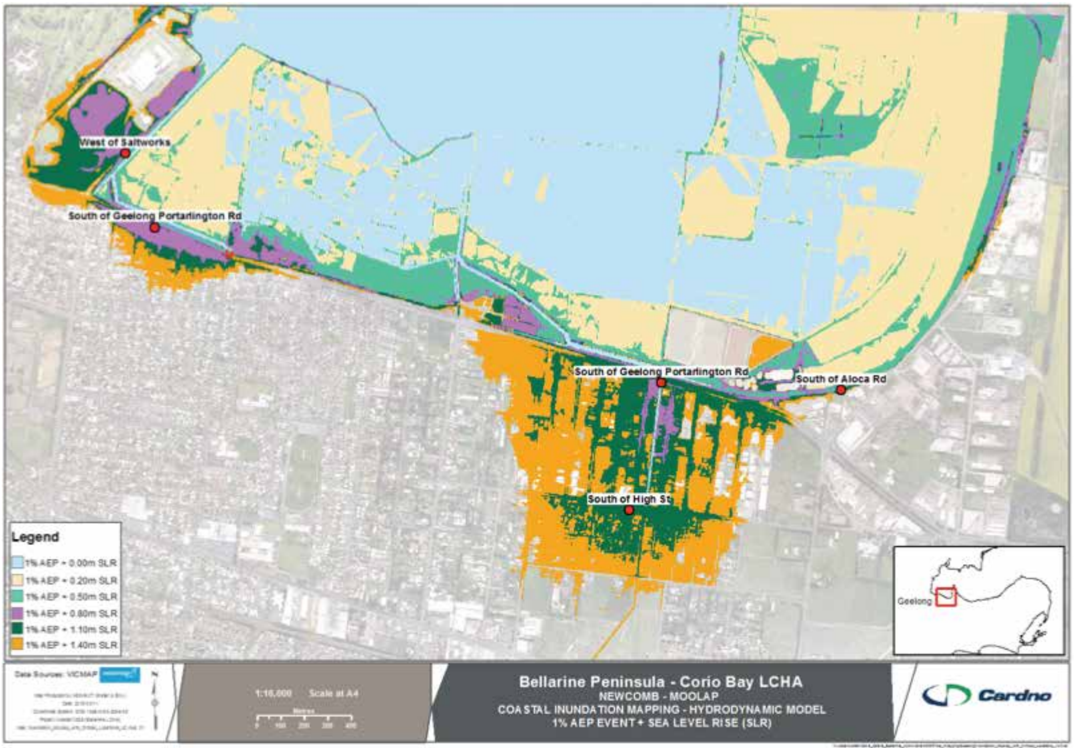


Figure 3.24 *Coastal Inundation Newcomb – Moolap*

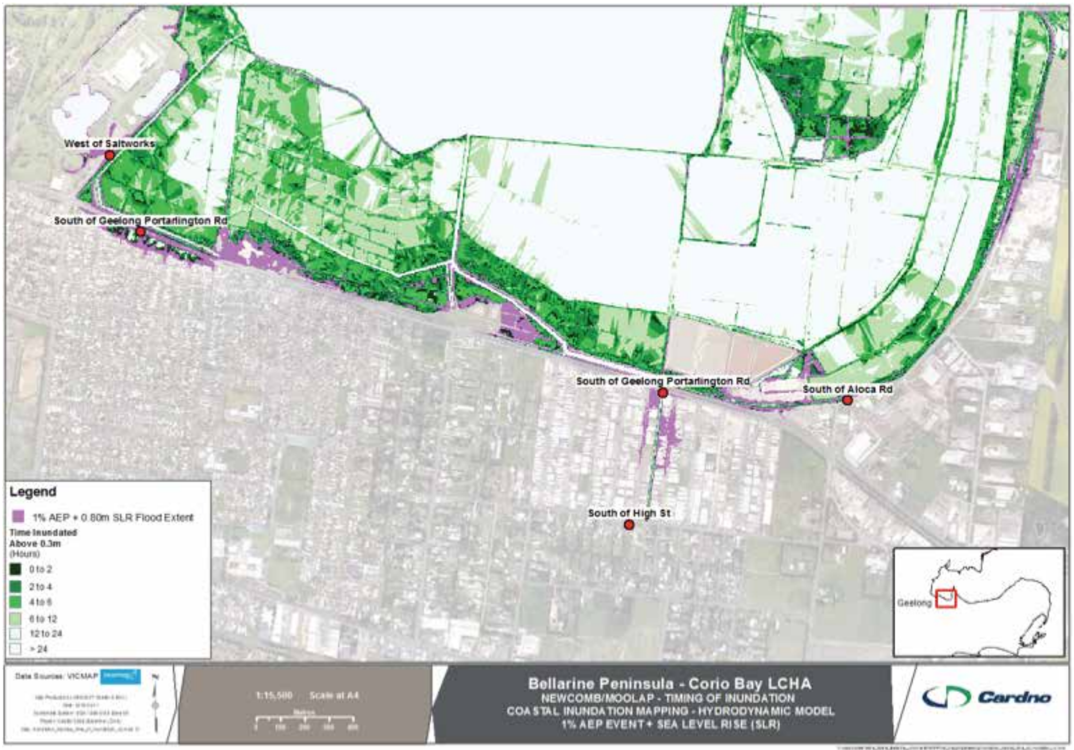


Figure 3.25 *Duration of Inundation Newcomb – Moolap*

3.9 Compartment 9: North Corio Bay to Point Wilson

Compartment 9 – North Corio Bay to Point Wilson extends from the Shell Foreshore, Limeburners Lagoon and Avalon Beach to Point Wilson (Figure 3.26). The elevation in the area is very low and flat.

Figure 3.26 *Compartment 9 – North Corio Bay to Point Wilson*

The north Corio Bay area is a very low-energy environment. The shoreline is a combination of cliffs, rocky foreshores with very narrow beach widths and low angle fine grained sediment beaches with little to no dune formation. There is minimal sediment transport in this area due a lack of material and low wave action. The Avalon area is a relict saltpan site and has levees enclosing the low-lying hinterland areas behind the beach.

The results of the inundation assessment for the Shell Foreshore are shown in Figure 3.27. There is a small increase in flooding of the low-lying foreshore and along the drainage channels. The inundation hazard here is mostly to the road and stormwater infrastructure.

Saline Inundation at Limeburners Lagoon is of low significance and is shown in Figure 3.28. The ground elevations are low along the floodplain of Hovell Creek and the lagoon; however the floodplain is bounded by a steep rise to higher land limiting the inundation extent. The areas likely to be impacted are mostly the riparian habitats, with some potential impacts to Foreshore Road.

Inundation of Avalon Beach is shown in Figure 3.29. There are extensive areas of inundation of the relict saltpans under present day sea-levels including the southern section of Avalon Road. This is of little consequence in terms of flood-risk management, however, will have implications for the saline habitats that have taken over the area since decommissioning of the salt works. The levees fronting the area will provide some additional protection, however, they do not form consistent barrier. Under the higher sea-level rise scenarios, there is inundation of some salt pans in the west adjacent to Avalon Road.

East of Point Lillias, there are extensive areas which will be inundated under present-day sea-levels in a 1%AEP storm event. The embayment east of Point Lillias will be inundated at a sea-level rise of 0.5 m and additional areas are inundated further east as sea-level rises.

Inundation for Point Wilson is shown in Figure 3.30. There are extensive areas of the foreshore that are likely to be inundated under present-day sea-levels in a 1%AEP storm event. The land adjacent to the Point Wilson jetty access road is inundated and the road cut under a 1%AEP storm event with a sea-level rise of 0.8 m. Further north there is a low-lying area which will be inundated; however this is outside the study area.

Figure 3.27 *Coastal Inundation Geelong – Shell Foreshore*

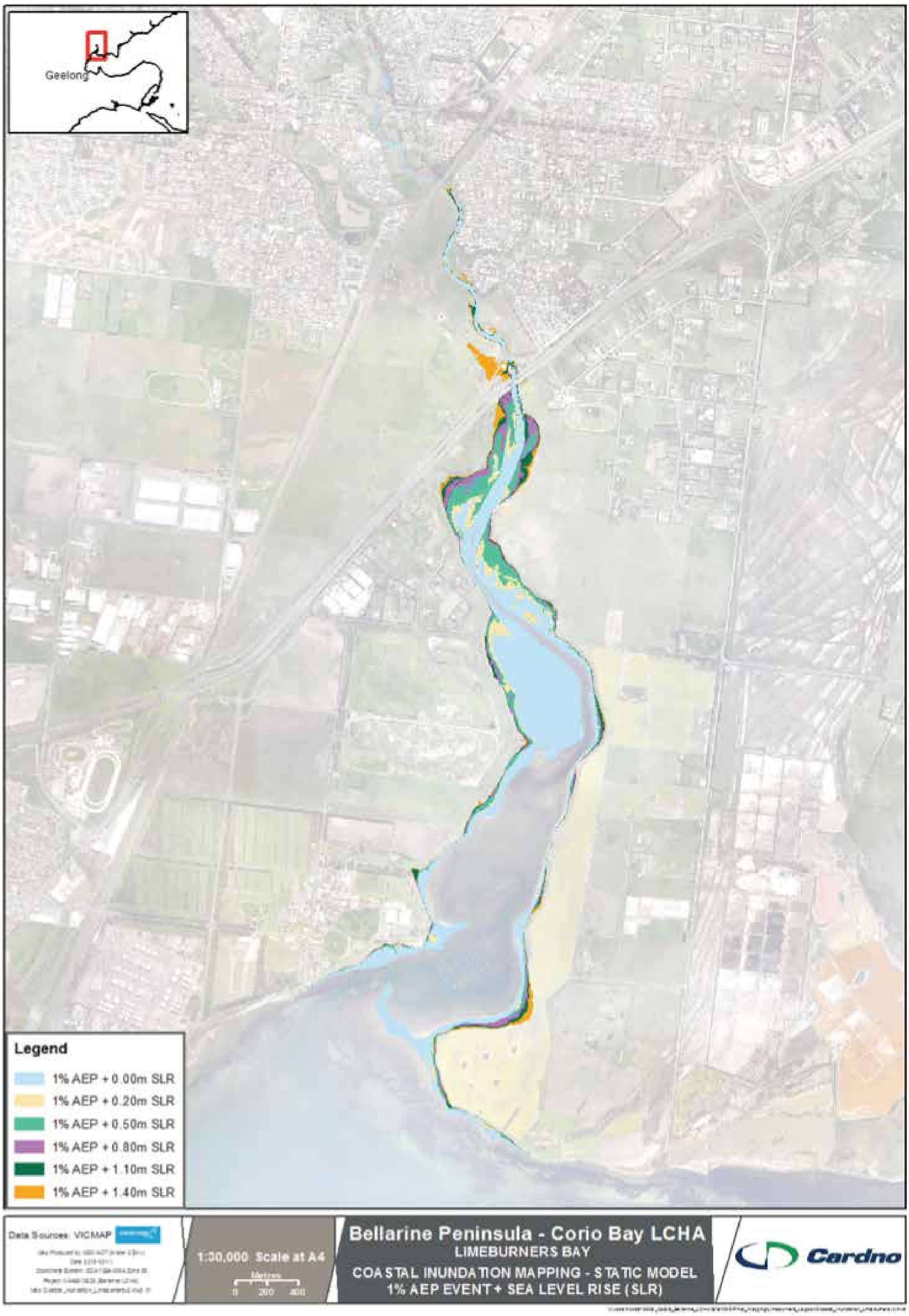


Figure 3.28 *Coastal Inundation Limeburners Bay*

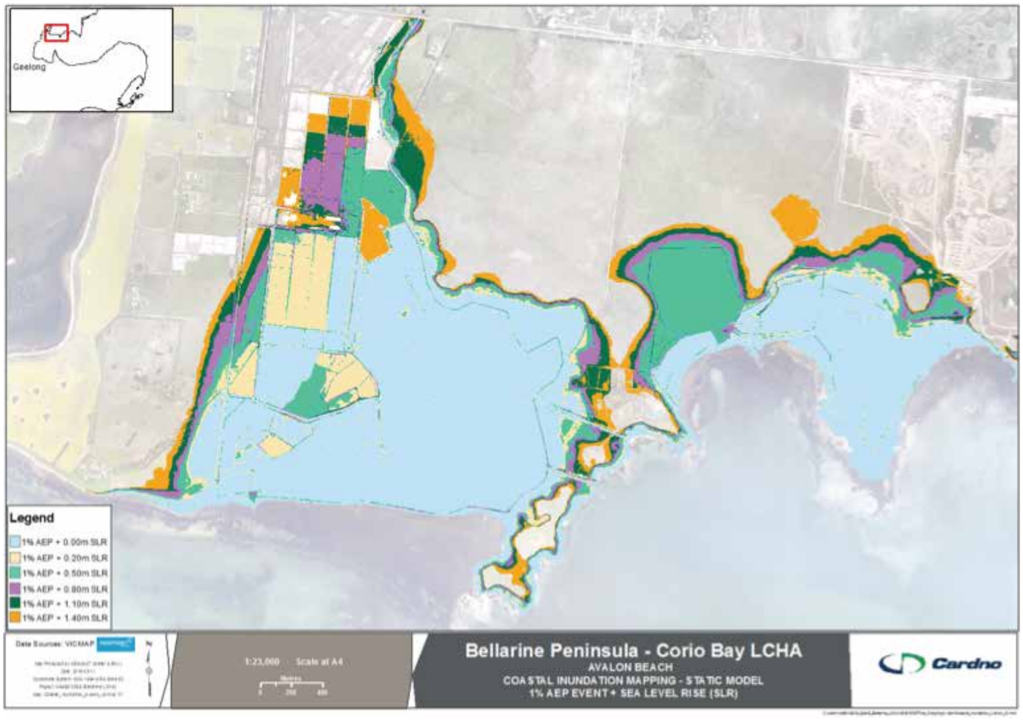


Figure 3.29 *Coastal Inundation Avalon Beach*

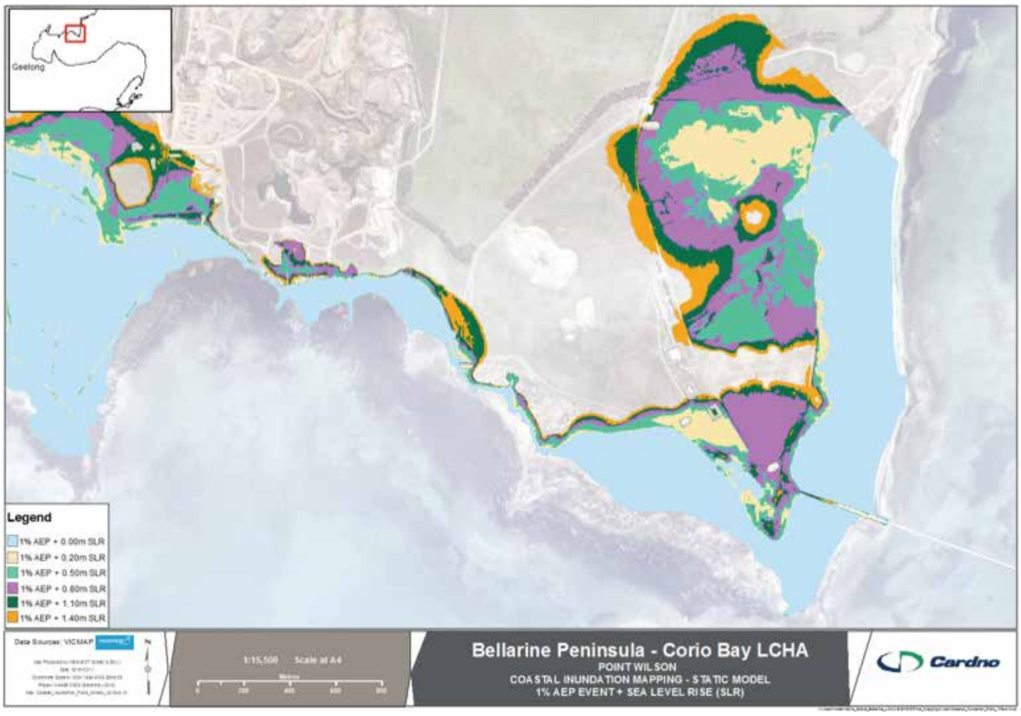


Figure 3.30 *Coastal Inundation Point Wilson*

APPENDIX A: COASTAL CLIMATE CHANGE

Climate Change

Dealing with the effects of climate change will arguably be the biggest challenge coastal managers will face in the future. The effects of climate change are already becoming apparent, and will increase over time. There are four key climate-change related impacts that will affect the coastal environment:

- Sea-level rise;
- Increasing storm activity;
- Increasing rainfall and catchment flows; and
- Increasing groundwater tables.

The Intergovernmental Panel on Climate Change (IPCC) is the international scientific body that compiles and evaluates global studies on climate change. The fourth assessment by the IPCC was released in 2007 and gave information on global warming related to emissions scenarios, and particularly relevant is the advice and guidance on projected sea-level rise. The IPCC projected sea-level rise of between 0.18-0.59 m by 2090-2099 in this assessment. However, the upper values of sea-level rise (e.g. 0.59 m) projected by the models were not considered to be upper bounds of possible sea-level rise by 2099. The fifth assessment by IPCC was released late in 2013. This gives a range of values for each Representative Concentration Pathways (RCP) scenario that relates to estimated global temperature increases. Estimates for the low RCP scenario are 0.26 - 0.54 m by 2100, whilst the highest RCP scenario estimates a rise in sea-level of between 0.53 - 0.97 m by 2100.

With the majority of the Australian population living within close proximity to the shoreline, the implications of sea-level rise are numerous and varied. The first pass national assessment of climate change risks (DoCC, 2009) identified assets to a value of approximately $63 billion at risk with a static water-level increase of 1.1 m. The second-pass Future Coast assessment (Lacey & Mount, 2011) used a static inundation modelling method to determine potential inundation extents under various sea-level rise scenarios. Static inundation modelling uses known water-levels and topographic elevations to determine potential maximum inundation extents. This is a relatively simple method and provides an indication of inundation, but includes significant uncertainty.

Work done recently by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has furthered the knowledge of climate change and sea-level rise risk in Australia. In Victoria, relevant reports include two CSIRO reports that detail the effects of climate change on extreme sea-levels for the Victorian Coast and Port Phillip Bay (McInnes et. al., 2009 a,b).

At present, research into wave height increases in response to climate change has been inconclusive; therefore no increase in the magnitude of future storms has been incorporated in this study.

Sea level rise

Climate change implications on the coast are mostly in relation to rising water-levels. This is a complex process that is thought to be the result of naturally fluctuating global temperature variations, exacerbated by anthropogenically induced global warming. Increases in greenhouse gases result in increases in global temperatures (the greenhouse effect), and the heat causes water to expand. The increase in temperatures also results in the melting of ice caps. The overall effect is an increase in static water-levels in most coastal areas of the world.

Although varying degrees of confidence relating to climate change projections exist, long-term tide gauge records around the world have shown steady increases in static water-levels over the last 50 to 100 years which should be considered and planned for regardless of the climate change debate. In Victoria, recent measured net rates of sea-level rise have ranged between approximately 1.3 and 2.8 mm/yr (http://www.bom.gov.au/oceanography/projects/abslmp/reports_yearly.shtml). However, as the effects of global warming become more apparent, the rates are expected to increase, especially toward the end of this century. Thus, the IPCC sea-level rise estimates vary depending on differing emissions and temperature scenarios, which in turn results in a very wide range of sea-level rise estimates that need to be considered in hazard assessments. For the purpose of this study, six sea-level rise benchmarks have been considered to ensure the wide range of sea-level rise scenarios are considered, these are 0.0 m, 0.2 m, 0.5 m, 0.8 m, 1.1 m and 1.4 m relative to 1990 levels. The amount of sea-level rise that has occurred since 1990 has not been removed from the benchmarks for this study.

APPENDIX B: METHODOLOGY

A site visit and review of all relevant data sets and previous studies was undertaken early in the study.

The initial modelling considered waves and water levels throughout the study area, which enabled the determination of design conditions for subsequent inundation modelling. Inundation hazards were determined using hydrodynamic and static modelling (for less complex areas). Due to the nature of the differing coastal environments there were some limitations within the inundation assessments of this study, and these were considered and reported on within the findings.

Trigger Points

The Scoping Document (Appendix A) detailed the intention of this study to consider trigger points in relation to hazards, rather than tying scenarios to a specific year. This includes producing maps that show potential inundation extents based on various sea-level rise scenarios, regardless of a year. This is in contrast to producing hazard maps that appear to 'predict' the position of the shoreline in a particular year, or the frequency and extent of inundation in a particular year. Generally, the better the background data, the better and more certain the assessment can be. For the Bellarine area, there are few thorough and consistent background datasets available, making a move to trigger points more reasonable and flexible. Although this is not common for hazard assessments, uncertainty related to the lack of background data and future rates of sea-level rise means that the prediction of a shoreline position or frequency of inundation in future years is too uncertain. This use of trigger points also allows for new data, particularly new rates of sea-level rise, to be incorporated as they become available. This will increase the certainty of assessments and provide additional confidence to managers that the planning decisions they are making are appropriate.

The triggers presented are tailored to each location based on the nature of the site, and knowledge of the site. The triggers are likely to be superseded when risk, options and mitigation studies are undertaken, or will remain valid for locations that are of lower priority, where subsequent studies won't be undertaken for a number of years. It is recommended that risk assessment and planning be undertaken before the triggers are met.

The triggers are categorised into planning/investigation triggers and physical triggers. Planning triggers relate to an inundation extent under a particular sea-level rise scenario that alerts to a need for additional investigation and a potential management response. This is to ensure that land managers have a reasonable indication of when work needs to be started to address a forthcoming hazard. The physical triggers are to initiate a response to an imminent hazard, this may override a management trigger, e.g. if a storm of a magnitude greater than the modelled scenario was to occur, this may initiate an immediate emergency management response. In this context, actions are ways to mitigate against the effects of storms and increases in sea-level, either works or planning and management actions.

The aim is to allow managers to better prioritise responses, to make best use of coastal management funds and resources.

Inundation Triggers

There are large areas of low-lying land throughout the study area. At present, these areas are only inundated under extreme events. With increases in sea-level, the frequency of inundation is likely to increase, with some areas likely to become tidal. Land managers require information as to when they should start taking action to mitigate the effects of this potential inundation. Note, that this is based on the occurrence of a 1% AEP event, the triggers provided do not account for events in excess of a 1% AEP. The assessment presents two inundation triggers:

Inundation trigger A - this is to trigger a management response when the measured sea-level rise reaches a certain threshold. Investigation or action should be taken to mitigate against the potential effects of the increase in sea-level. In this context, actions are ways to mitigate against the effects of storms and increases in sea-level, either works (e.g. protection) or planning and management actions (e.g. retreat).

When assessing inundation risk to assets (subsequent to this study), frequency of inundation (i.e. the likelihood) and the consequences will be considered. For example, a property that is inundated, on average, once every 100 years (i.e. in a 1% AEP event) may be considered to be a tolerable risk, however, a property that was inundated yearly, would not. Therefore it is appropriate to determine under which sea-level rise scenario the hazard becomes too great and needs to be dealt with. This will be different for different types of assets. The trigger tables give an indication of when action is required by land managers related to increases in local measured increases in sea-level. It is also noted, that the difference in saline and freshwater inundation should be considered when addressing inundation of certain assets, particularly natural assets, i.e. habitats, as resilience will be dependent on physiological tolerances. This finer detail will be part of the scope of subsequent studies that arise; however, this study initiates the process by identifying which events and sea-level rise scenarios trigger a response. Following from this, risk assessments and determination of adaptation responses will combine all relevant hazard and asset information to address the issues and environment as a whole.

Duration of inundation events

The hydrodynamic models were thematically mapped to demonstrate the duration of time for which the inundation water depth at a point remained above a threshold of 0.3 m. These results highlight the fact that inundation arising due to storm-tides only lasts for a short period of time. The results of the inundation timing assessments are presented for each location where a hydrodynamic inundation assessment has been carried out, in Section 6. This information will aid in subsequent risk, options and mitigation assessments.

Uncertainty

The type of assessment undertaken in this project has some inherent uncertainties that must be documented. This is to ensure that users of the information understand the limitations, and this is kept in mind when using the information to inform subsequent assessments. Each assessment has its own uncertainty and there are some generalised project-related uncertainties. It is worth nothing that this type of assessment is indicative and uses the best scientific practice to produce the best outcomes possible with the information available. The results are fit for a defined purpose, but are not to a level of detail to facilitate detailed design. The purpose of this study is to inform strategic flood management decisions and provide an insight into what may happen in future.

APPENDIX C: GLOSSARY

ABBREVIATION	DEFINITION
AEP	Annual Exceedance Probability
AHD	Australian Height Datum The Australian Height Datum is a geodetic datum for altitude measurement in Australia, "In 1971 the mean sea level for 1966-1968 was assigned the value of zero on the Australian Height Datum at thirty tide gauges around the coast of the Australian continent"
ARI	Annual Recurrence Interval
Astronomical tides	The fall and rise of sea levels caused by the gravitational effects of the Earth, Sun and Moon, without any atmospheric influences.
BCCoM	Barwon Coast Committee of Management
BBFCoM	Bellarine Bayside Foreshore Committee of Management
Beach berm	A nearly horizontal plateau on the beach face formed by the deposition of beach material by wave action. The berm area is often eroded during storms and reformed in periods of gentler wave activity.
BoQ	Borough of Queenscliffe
CoGG	City of Greater Geelong
Conservative / conservatism	This refers to overestimation in an assessment (or overdesigning in engineering) to ensure a 'worst case scenario' is considered for additional safety and caution, but also to account for uncertainty i.e. 'the unknown', taking a "cautious" approach. Contrast with underestimation which may lead to management actions which are not sufficient.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	digital elevation model
DEPI	Victorian state government Department of Environment and Primary Industries
Directions	Have been given as bearings in degrees clockwise from True North or as compass points (e.g. east = 90°T). Directions for currents have been specified using the oceanographic convention as the "going to" direction. Wind and wave directions are referred to by the meteorological convention as "coming from". There may be occasions where directions are referred to in an alternative convention and the convention is indicated in the relevant text;
DSE	Victorian state government Department of Sustainability and Environment
Ebb tide	Outgoing or receding tidal current, (that is, when water is flowing away from the shore line) leading to low tide.
Fetch	The maximum distance over water that winds of a constant speed and direction can generate waves. Areas such as Port Phillip Bay are defined as fetch-limited meaning that wave heights will always be restricted by the area over which wind can blow.
High water	Maximum height reached by a rising tide.
High water mark	The highest level that water has reached up the beach, also known as the "strand line" for the seaweed and debris that are stranded at this point. It is a line which can often be identified in aerial photographs.

ABBREVIATION	DEFINITION
Hs, (m)	Significant wave height The significant wave height is originally defined as the average height of the largest one third of the waves in a given record. With the advent of digital processing techniques and spectral analysis of wave records, the significant wave height is now commonly defined as Hs=4Öm0 where m0 is the variance of the wave spectrum or the "zero order moment". For the purposes of this study the definition based on variance is used. For practical purposes, the significant wave height is close to the value reported by an experienced observer making visual observations of the wave height.
Intertidal	The range between the mean higher high water and mean lower low water lines.
IPCC	Intergovernmental Panel for Climate Change
LADS	Laser Airborne Depth Sounding
LiDAR	Light Detection and Ranging. This is a remote sensing technology that measures distance by use of a laser. Alternatively it can also mean a topographic dataset created by using this method.
NTC	National Tidal Centre
PCG	Project Control Group
PoMC	Port of Melbourne Corporation
Ramsar	Convention on Wetlands of International Importance signed in Ramsar, Iran in 1971.
Saline inundation	This is inundation by sea water, as opposed to riverine flooding by fresh water.
SLR	Sea-level rise
Spit	A finger-like depositional landform that extends (often perpendicular) from the coast into a body of water.
Storm surge	A combination of barometric set up, wind set-up, and coastal trapped-waves leading to an increase in sea level above the predicted tide.
Storm-tide	A storm-tide is an extreme sea-level event during a storm, the combination of a high astronomical tide and a storm surge.
STL	Storm-tide Level. The combination of astronomical tide and storm surge and thus the sea-level anticipated or measured during a storm event.
Swell	Waves which have travelled away from the area where they were generated such as a remote storm system. Often appearing as a series of regular spaced waves of unbroken appearance. The waves may have travelled many 100's of kilometres from their point of origin.
Tidal current	Movement of water associated with the rise and fall of the tides
VRCA	Victorian Regional Channels Authority
Wave direction	Direction from which the waves are coming from and are given as the bearing, in degrees, clockwise from true north.
Wave height, H, (m)	The vertical distance in metres between the crest (top) and trough (bottom) of a wave.
Wave setup	This is an increase in the mean water-level due to the presence of waves.
Wave runup	This is the extra height or extent that broken waves reach as they run up the beach.

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