Port Phillip Bay Coastal Hazard Assessment

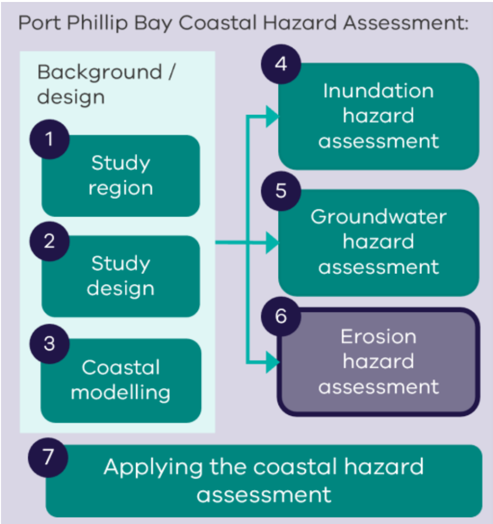
Summary #6: Erosion hazard assessment

Overview

The Port Phillip Bay Coastal Hazard Assessment (PPBCHA) looks at likely coastal hazard impacts around Port Phillip Bay. This includes data analysis and modelling for a range of future climate change scenarios. Results will help land managers and the community to consider climate change in their future planning.

This summary provides an overview of the erosion hazard assessment. This is the sixth in a series of summaries providing an overview of the PPBCHA technical work.

In this summary:



Areas around Port Phillip Bay may be prone to coastal erosion. With sea levels rising, some of our shorelines are moving. Higher water levels, and bigger storms also mean waves can reach further onshore. This will likely cause more erosion.

We need to understand where we may experience erosion hazards now and in the future. To estimate erosion, we have looked at local processes and short and long-term trends and projections.

What is erosion?

Coastal erosion is the process of winds, waves and coastal currents shifting sediment (e.g. sand, silt, or soil) away from a localised area of the shoreline.

Erosion can be:

- **short-term** - resulting from extreme events (storms), temporary high water levels and bigger waves
- **longer term** - due to sea level rise or long-term changes in sand movement. Long term shoreline retreat (recession) or build up (accretion) of sand can occur over several years to decades.

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Key terms	
Short-term erosion (storm bite)	Erosion that occurs on a short-term basis, often during a storm. The shoreline and beach then gradually regains sediment (rebuilds) in calmer conditions.
Long-term erosion (recession or retreat)	Continuous movement of the shoreline position in a landward direction, occurring either gradually over many years, or when the shoreline does not recover following a short-term erosion event.
Accretion	Where sand is deposited (instead of eroded) and builds up over time. Accretion typically occurs during calmer periods. For Port Phillip Bay, some accretion is quite seasonal with beaches moving and rotating at different times of the year. Its timing varies depending on where you are around the Bay. Beach accretion is generally a more gradual process than beach erosion, and may be short term, long term, or episodic.
Vegetation line	A line developed by tracing along the seaward extent (i.e. the side nearer to the sea) of the vegetation visible in aerial images of the coast. We use the vegetation line to represent the position of the shore at different points in time.
Coastal compartment	A segment of coast defined by similar sediment transport processes at a local scale, including within the nearshore areas (just seaward of the shoreline). Compartment boundaries delineate the extent of the compartment.
Setback distance	An estimated distance inland of the current (baseline) shoreline, indicating areas potentially prone to erosion hazard impacts. Erosion modelling and analysis is used to determine this distance.
Planning horizon	An indicative timeframe by which a projected sea level rise scenario, and subsequent coastal hazard exposure, is anticipated to occur.

Dynamic shores

The coastal zone is dynamic and always changing. Sand moves on, off and along the shores of our Bay. We see beach erosion, shifting sands and periodic changes on our coasts.

Seasonal changes occur at known locations around the Bay, where the beach comes and goes at different times of the year and in response to certain weather conditions. Some areas experience dramatic sand loss following high tides and storm events.

Engineering structures, sand nourishment and beach and dune management are evidence of efforts made to manage the impacts of erosion.

Edithvale Beach (Photo: Alluvium)

To assess erosion hazards in Port Philip Bay, we need to understand how waves, tides and water levels interact with the shoreline and nearby coastal areas. How the coast might respond to current and future coastal processes and changing climate will vary.

A range of factors influence the dynamics of our shorelines and how they respond to local coastal processes:

- Local geomorphology and landform
- Local geology and shoreline type
- Land and seabed elevation
- Sediment supply and how it changes
- Human activities or structures, that limit dune movement and/or sediment supplies

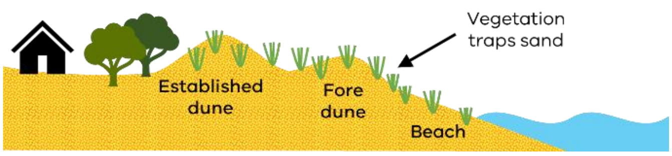
We have examined these factors as part of the PPBCHA. The findings inform erosion modelling.

Types of erosion in Port Phillip Bay

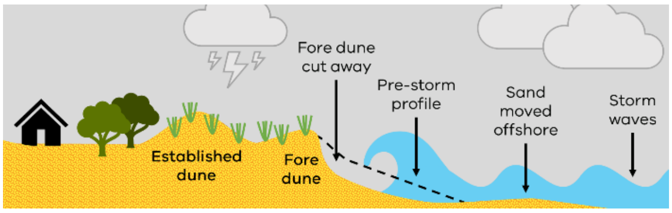
Coastal erosion occurs in a range of different ways, depending on shoreline type.

Sandy coasts

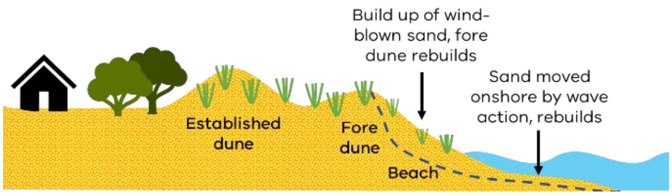
Natural dune systems go through periods of erosion and accretion. Dune vegetation has a key role in assisting dune growth, by helping trap sand.



Erosion can occur when winds, waves and coastal currents shift sediment away or along the shoreline, sometimes just offshore. Short term erosion (storm bite) is associated with big storms.

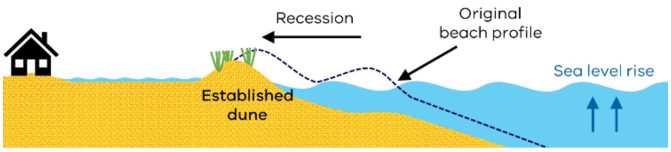


In calm conditions, wind and waves act to transport sand onshore, building up the dune. For a stable beach, all the sand moved offshore in a storm eventually moves back onto the beach, and overall shoreline position stays the same over time.



In some cases, changes in sediment supply or climate conditions (such as bigger or more frequent storms), means the beach may not rebuild fully between storm events.

With less sand retained on the beach over time, long-term erosion (recession) may occur; this means the shoreline position (e.g. vegetated dunes and high tide beach) moves incrementally landward (over several decades).

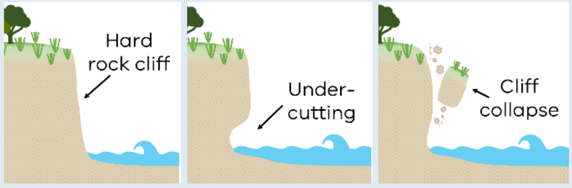


Rocky coasts

Over geological timescales (thousands of years), softer sediments are eroded away, exposing hard rocky coasts. These coasts are more common in areas of high energy (strong wave action).

Hard rock

Hard rock cliff slopes are susceptible to deep-seated mass movements (i.e. cliff fall) that may be initiated by a combination of surface processes (rain, surface runoff) and/or due to marine influences at the base of the cliff (e.g. toe undercutting). Hard rock erosion can occur with little or no warning.



Where a sandy beach is 'perched' on a rock platform at the base of a cliff, increasing sea levels and wave energy can result in sand loss, due to limited sand volumes and increased wave reflection off the rocky coast.

Soft rock

Some rocky coastal areas have softer, more erodible rock. These coasts can be more vulnerable to erosion from both surface processes and cliff toe undercutting. Erosion of soft, rocky coasts can occur as both cliff falls and slumping (material movement down its slope).

Rocky coastlines do not 'recover' after erosion like sandy coasts do. However, as they have some resistance, they also erode less frequently. A beach forming in front of cliff can limit its exposure to waves.

Soft sediment coasts

Soft sediment shorelines (a mix of mud, sand and silt) are common in low-lying, low energy/sheltered environments. With finer sediments than sandy shorelines, they are highly vulnerable to erosion. Similar to soft rock coastlines, surface processes and undercutting due to waves drive shoreline recession (moving its position further landward). Sand availability from nearshore areas or movement along the coast limits recovery (rebuilding).

Narrowing or loss of existing sandy beaches through erosion and sea level rise may see increase in soft sediment shorelines, and erosion potential. Sea level rises may also inundate these low shorelines, leading to long-term erosion (landward recession) of the coast.

Modelling erosion in Port Phillip Bay

Like many parts of the PPBCHA, the erosion hazard assessment brings together a range of inputs, including:

- Waves, water levels and currents (each modelled)
- Local geomorphology and landform analysis – including “sediment compartments”.
- Knowledge /characteristics of shoreline type and natural features and how they might respond to waves, tides and currents.
- Historical records and data of shoreline positions and rates of shoreline change.
- Man-made features and structures (including coastal protection).
- Land and seabed surveys and the position of the present-day shoreline.

The following section explains some of these key inputs further, and how we use them in our analyses.

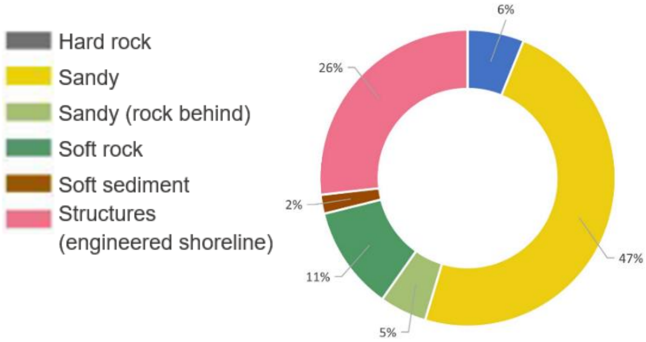
Bellarine Peninsula (Photo: Alluvium)

Key background information

Shoreline types

We can classify the shoreline based natural features, geology, shape and form. Shoreline type can influence how a shoreline responds to erosion drivers. This can include potential rates of erosion or its ability to recover (rebuild) after storm events. It also influences how it might respond to sea level rise.

Using aerial imagery and spatial data sets on geomorphic features, Port Phillip Bay’s coast has been classified into six shoreline types.



Shoreline type (Source: Water Technology)

Surrounding areas (“backshore areas”)

Erosion processes may also impact areas further inland in time as shorelines move. This means the characteristics of areas landward of present day shoreline must also be understood. Port Phillip Bay’s shores are backed by four different area types:

- shoreline similar to current active shoreline
- low-lying wetlands inundated under sea level rise
- buried cliffs that may slow erosion rates once exposed
- functional coastal protection structures (e.g., seawalls) that limit further erosion.

The shoreline/feature types of these “backshore” areas also influence erosion. These details are also incorporated into erosion hazard estimates.

Coastal engineering around the Bay

Much of the Port Phillip Bay shorelines heavily modified through engineered coastal structures.

Over a quarter of the Port Phillip Bay coastline has been classified as "engineered shoreline"

Coastal structures in the Bay include:

- seawalls
- revetments
- breakwaters
- groynes
- training walls
- drainage outfalls

Many of these have been constructed in response to ongoing erosion impacts. This may have been to protect values and assets behind them. As such, they are typically present on actively (or previously active) erosive shorelines.

Masonry seawall at Seaholm (Photo: Alluvium)

These structures influence how water flows, interaction of waves with the coast, and how sand and sediment move. This includes reducing the ability for natural sand build-up (accretion) for some parts of coast, due to the presence of structures.

Our Bay-wide erosion modelling has assumed any existing engineered structures will remain in place and be maintained into the future. These shorelines are considered "stable", compared to the dynamics seen in more natural sections (sandy, sediment). Erosion potential is reduced (mitigated) by these protection structures.

In estimating erosion hazards, modelling has assumed these areas will withstand storm-driven erosion. Any beach or land in seaward of any structures is considered to be part of the erosion hazard zone.

Local-scale studies will be necessary to determine the condition, functionality and fate of some structures into the long-term.

Engineering activities also include dredging and nourishment programs. These works change the natural sediment dynamics in some areas of the Bay. Major, ongoing nourishment works have been accounted for in the modelling for future scenarios.

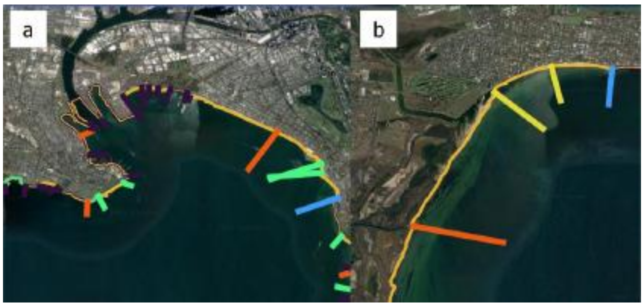
Coastal compartments

Coastal compartments divide the coast into areas of interest. Landscape features and coastal processes (including sediment transport) are the basis for compartments. Drawn at different scales, they can be a single beach or kilometres of coast.

Described in **Summary #2: Study Design,** Port Phillip Bay has two main coastal compartments - west (Point Lonsdale to Williamstown) and east (Williamstown to Point Nepean).

Tertiary compartments are a finer division of the coast. They are based on coastal processes at a local scale – such as similar or linked sand movement. These compartments consider how freely sand moves along the coast ("longshore"), and to and from the coast ("cross-shore"), via wind and water driven processes. Natural landforms and features or manmade structures may act as compartment boundaries.

Developed as part of the PPBCHA project, a tailored method was used to define and map tertiary compartments for Port Phillip Bay. For the ~340 km of the Bay's coastline, 205 tertiary compartments were identified and mapped. This method was based on local sand dynamics, over a ten year timeframe.



The coloured lines show some of the tertiary compartment boundaries defined for Port Phillip Bay. These boundaries divide up the coastline. Compartments are of different sizes and length.

Different colours of the compartment boundaries relate to further technical classification of compartment types, and how readily sand can move around, in and out of the compartments

Example tertiary compartments (Source: Kennedy et all 2022)

These compartments are an important foundation for the erosion modelling. Erosion was examined for each individual compartment, with calculations based on characteristics of each compartment – shoreline type, local processes etc.

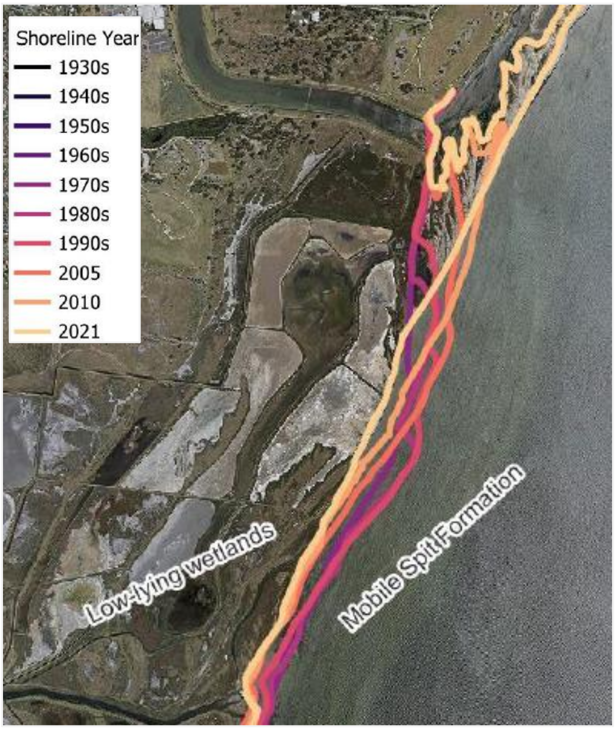
Current and historical shoreline position

Vegetation gives us a good indication of the location of the “active” shoreline (parts of the shore interacting with coastal processes). Using aerial images of the coast, we can trace a line seaward of the vegetation. We use that line to represent the position of the shore at different points in time.

In some areas, shoreline position is relatively stable. This can be due to seawalls, structures, or cliffs. These stable areas are also captured in the shoreline analysis.

Historical change

To better understand local erosion processes, we look at how shorelines change over time, and the rates at which changes have happened. We can consider shorter term changes (over 1-2 years) and long term changes (over decades). For this analysis shoreline change is based on assessing aerial imagery between 1930s and 2021 (~90 year period).



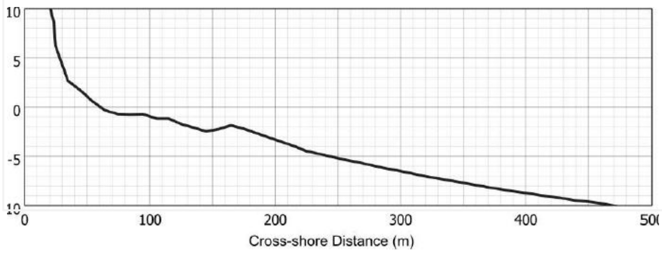
Example of historical shoreline analysis (Source: Water Technology)

Current shorelines

We also use recent aerial imagery to determine present day shorelines. Referred to as the “baseline”, it provides reference line for estimating shoreline change. Movement further landward from this position would indicate erosion (sand loss), while movement seaward would indicate accretion (sand build-up).

Bathymetry and topography

Extending from offshore, to nearshore areas, further inland, to backshore shore areas, our modelling uses representative cross-section profiles for each coastal compartment.



Example cross-section profile, showing elevation change, from onshore to offshore areas (Source: Water Technology)

These are based on offshore seabed elevations (bathymetry) and onshore elevations (topography). Profile shape, slope (gradient) and elevation, as well as sediment type and size, influence how waves, tides and rising sea levels might interact with the coast and how the shore might move and respond.

The profiles are a key input to the erosion modelling. The “backshore” shoreline/feature types, such as steep cliffs or low lying wetlands are captured in elevation data for these profiles.

Estimating erosion

Erosion modelling looks to determine areas that may be prone to short and/or longer-term coastal erosion processes. This might be shoreline change in response to storms, or to longer term changes in waves and rising water levels.

Erosion hazards are estimated based on erosion responses at three different timescales:

- **Short term shoreline change** arising due to storms. This considers the ability of shore to recover (rebuild). This is influenced by shoreline type. Some sandy shores can rebuild over time, while cliffs and softer sediments, are unable to rebuild.
- **Long term shoreline change** based on ongoing trends and fluctuations (based on decades of change)
- **Shoreline response to sea level rise** (shifting further landward due to increasing water levels and waves reaching further inland), based on shoreline elevation and shape, type (i.e. sand, rock, cliff etc.) and how it might respond to wave action.

Referred to as "erosion components", all three influence the dynamics of our shorelines. We use estimates of these components to understand the areas that maybe influenced by erosion processes and how shoreline position might change in the future.

We use leading practice techniques to determine various estimates for each component and a range of scenarios. Methods include well-known theoretical formulas for coastal processes and shoreline response.

Design storms and conditions

Similar to the inundation modelling, we use 'design' events when modelling erosion to determine estimates of each erosion component.

Our storm-tide modelling results and the sea level rise estimates are used to examine current and future erosion processes at the various time scales:

- multiple planning horizons (sea level rise scenarios): present-day (0.0 m), 0.2 m, 0.5 m, 0.8 m, 1.1 m, and 1.4 m
- different storm tide events: 1%, 2% and 5% AEP

Annual Exceedance Probability (AEP) – on average, the probability of an event occurring in any given year. A higher AEP means the event is more likely to occur in any one year.

Summary #2: Study design and **Summary #3: Coastal modelling** details on the development, set up and use of our wave and water levels models.

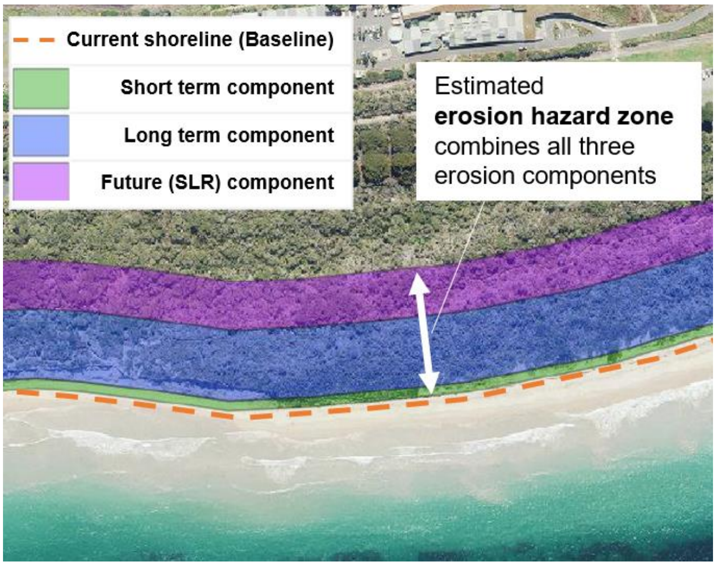
Undertaken at a compartment scale, our erosion modelling considered local coastal process conditions, shore profile and type.

Erosion component estimates combine to form an "**erosion hazard zone"**. These zones show areas that may be prone to erosion.

The zone width relates to an estimated distance inland of the current (baseline) shoreline. The larger the distance, the greater the erosion potential driven by that erosion process (i.e. short-term storms or longer term changes due to trends or rising sea levels).

Overall erosion hazard zones are determined by combining the results of all three erosion components.

Erosion hazard zone	**= Short Term**	**+ Long Term**	**+ Long Term**
	storm event change	historic change	future change due to sea level rise



We combine the estimates of the three erosion components to get an overall erosion hazard zone.

Erosion hazard zones represent areas further inland of the current (baseline) shoreline that may be prone to short and/or longer-term coastal erosion processes.

They have been estimated by combining local estimates of each erosion component.

Erosion hazard zones have been generated for each individual coastal compartment around the Bay. These have been combined in bay-wide data sets.

What do the results tell us?

Understanding erosion prone areas provides a starting point for planning our hazard adaptation. We know that some areas around Port Phillip Bay already experience notable sand loss at different times of the year (seasonal trends) and following storm events.

With increasing sea levels, drivers of erosion are projected to have greater impact, increasing erosion hazard zones. Knowing the locations where erosion might happen allows us to prioritise these areas for further analyses.

Key findings by erosion component

Short term erosion processes

Analysis of shoreline dynamics follow a storm event

- Wave height is a key factor in how the shoreline responds, and the calculated estimates.
- Sediment size and the shape of shoreline profile are also key in the estimates, especially the slope of active nearshore areas.
- Storm driven (short term) erosion components generally account for smallest proportion of the combined erosion hazard zones for Port Phillip Bay.
- For majority of sediment compartments within the Bay, estimated widths of the storm erosion component were less than 3 metres.
- In areas exposed to larger waves that come through Port Phillip Heads, estimated storm erosion widths were greater (5-10 metres) areas exposed to larger waves - this included Point Lonsdale, Queenscliff and parts of Point Nepean and Portsea.
- For some compartments, the estimated storm erosion saw changes (sand movement) seaward of the existing shoreline, in nearshore areas rather than higher up the beach.
- For compartments within the bay, Mordialloc Beach experienced the highest storm driven erosion, with erosion hazard zone widths of around 6 metres.

Point Lonsdale Dog Beach (Photo: Alluvium)

Long term shoreline change

Analysis of long term shoreline dynamics and trends for the shoreline the bay.

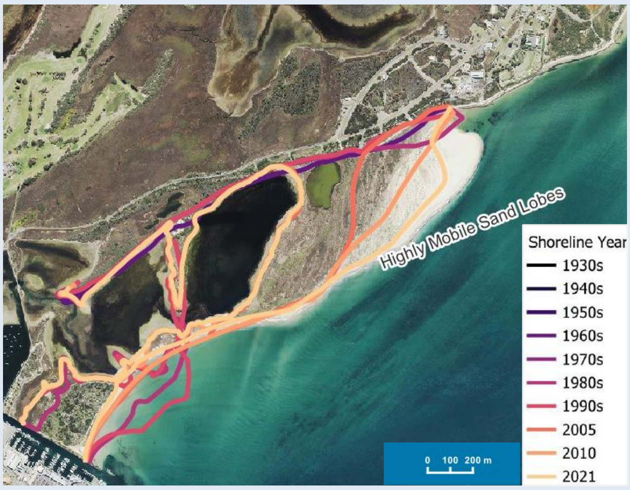
- Point Nepean and near the Western Treatment Plant had the highest erosion trends (~0.7 m/year erosion)
- Accretionary trends were most notable near Queenscliff (0.7 m/year accretion), and behind the Royal Brighton Yacht Club (~1 m/year accretion).
- Coastal structures influence some long term trends.
- Some areas in the Bay, especially sandy shorelines, erosion and accretion trends are highly variable, alternating between sand loss and sand build up over time.
- Variability of sandy areas is linked to longshore sediment transport processes and sand movement between coastal compartments.
- Soft rock shorelines are generally experiencing erosion (east of the bay Mount Eliza, Mornington)
- Some soft sediment shorelines (such as the Spit Nature Reserve near Point Wilson) are generally experiencing accretion.
- Cliff erosion is driven by both coastal and catchment processes. Longer term trends generally show minimal change. There is some uncertainty using aerial imagery for this analysis.
- Cliff erosion processes can also provide additional sediment to the system.

Sand spits

Two significant sand spits are found in the Bay - the eastern side of Swan Island near Queenscliff, and the Laverton Spit at Altona Cheetham Wetlands from Skeleton Creek to Laverton Creek. These areas have seen rapid change in recent decades.

Analysis of shoreline trends in these areas is more complex, due to the dynamic (mobile) nature of these spits. This sees some sections accreting while other nearby areas eroding as the spit moves. Typical shoreline trend analysis may be misleading, so alternate analysis is needed to understand rates of change and possible future outlook for these areas.

We have conservatively assumed these dynamic areas are likely to impacted by future erosion and coastal change.



Vegetation lines at Laverton Spit (Source: Water Technology)

Laverton Spit, Altona (Photo: Alluvium)

In areas with a high level of variability (between erosion and accretion), more local scale analysis, down to a component level, may be required.

Further monitoring may show trends established for some areas, may only be temporary, and unlikely to continue in the long term. Modelling may need to be updated in these instances.

Future shoreline response due to sea level rise

Analysis of future shoreline positions

We used several analytical methods to estimate future shoreline response due to sea level rise:

Method	Application
Bruun Rule	• exposed sandy beaches, shaped by cross-shore wave action
Upper beach slope analysis	• areas with surplus of sand in nearshore areas (just seaward of the shoreline) • sheltered/low energy environments
Cliff retreat	• active cliffs

Method selection is determined by the shoreline type, the local conditions such as sediment transport processes, and profile shape.

We can take results of these analyses to estimate the "future change" component for each compartment, informing the erosion hazard extent for each sea level rise scenario.

The **Bruun Rule** is a well-known formula, used for estimating shoreline retreat due to rising sea levels. Its basis is a theory that considers how sand might move up and down the shoreline slope in response to incoming wave energy ("equilibrium profile"). It takes this concept and uses it to estimate how the shoreline might move both further landward and further upward, as the sea level rises.

Dependent on shoreline shape, the method is suitable for examining more sandy coastlines and areas where cross-shore wave action is dominant.

For Port Phillip Bay:

- Bruun Rule approach was applied mostly on the eastern shores, where sandy beaches with higher wave exposure dominate.
- Due to overall low-energy nature of lots of areas in the Bay, upper beach slope analysis was the main method used for our future shoreline estimates.
- In areas with coastal structures, no sea level rise response was estimated.

Combined erosion hazard zones

We calculated the combined total erosion hazard zone by added the three erosion components together for each compartment.

Using advanced statistical techniques, we examined many different combinations of these three erosion components. The result is estimates of local erosion hazard zones, for each of our defined storm events and sea level rise scenarios.

While there is some uncertainty with our methods, the results give us an understanding of where we may need more detail and localised assessment.

Local scale (site-based) analysis may be needed where long-term trends are highly variable, or where key values or assets are within erosion hazard zones.

> The width of erosion hazard zones can give an initial understanding of potential erosion hazard impacts. However, the level of exposure and risk will depend on the values and assets within and adjacent to the potentially exposed areas.

The combined erosion hazard zones showed:

- Generally, the longer-term erosion components (long-term trends and sea level rise) account for greater proportion of each hazard zones.
- Long-term change (based on trends) component is often the most dominant.
- Storm-event erosion component is only a minor proportion of the combined hazard zones.
- Once we reach 0.8 m of sea level rise, the larger projected erosion hazard zones are predominantly on the western side of the Bay.
- Swan Island and Cheetham Wetlands had the greatest erosion, driven by the spit dynamics. Similarly, Moolap (the saltworks) and the Western Treatment Plant, driven by the presence low lying wetlands (lagoons) behind these areas.
- Several areas on the Mornington Peninsula were found to be accreting in the future.

Locations of larger erosion hazard zones (as combined erosion hazard zone widths) (Source: Water Technology)

Mapping erosion

We can map erosion hazard zones to visualise where sections of shoreline, or coastal compartments, might be prone to impacts of coastal processes. We refer to these as “erosion hazard extents”.

Mapping helps highlight areas potentially exposed to erosion hazards for a certain storm event condition or sea level rise scenarios. They provide an indication of areas that may be impacted by erosion (in the absence of intervention) and assist us to identify focus areas for adaptation actions.

Erosion has been mapped by:

- Planning horizon (sea level rise scenario)
- Storm event (AEP)

The **Hazard mapping supplement** provides more information on the coastal hazard maps and how to interpret them.

We estimate and map erosion extents around the entire Port Phillip Bay region. This mapping covers all coastal communities within ten local government areas adjacent to the Bay.

It uses coloured erosion bands. These bands:

- indicate areas potentially affected by short and/or longer-term coastal erosion processes
- are in absence of any management measures
- highlight areas that may be susceptible erosion for certain local weather (storm) conditions.

The bands do not represent:

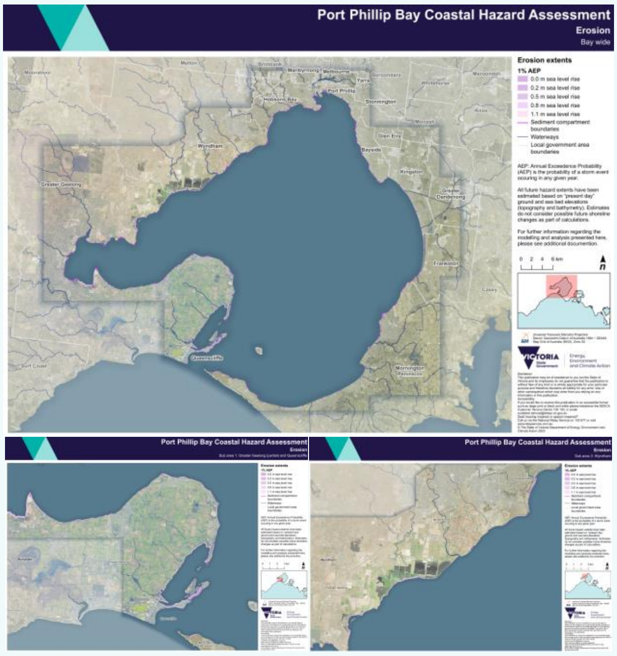
- a ‘loss’ of coastal land or a specific shoreline position
- these areas being eroded all at the same time.

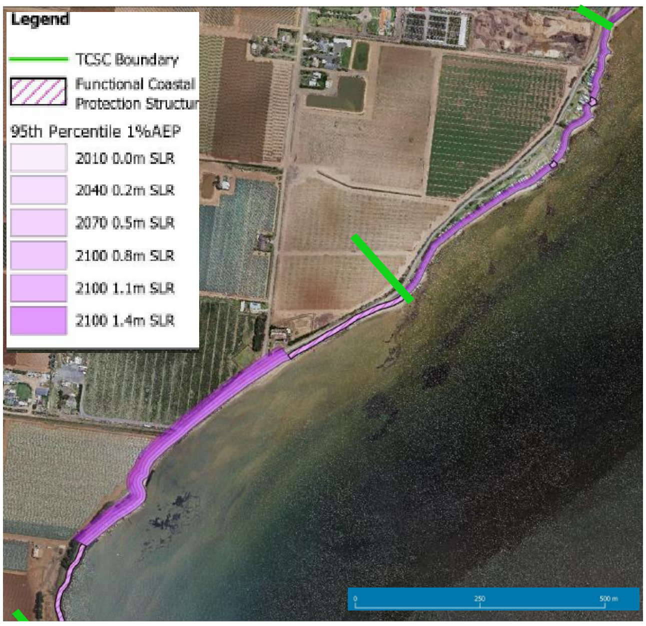
The mapped scenarios are consistent with those presented in the inundation mapping.

We join all the individual compartment results together for bay-wide mapping. Sometimes neighbouring compartments can have quite different estimates - bigger or smaller. When mapped this can appear to look quite “stepped”, rather than smooth bands along the shore.

We include the compartment boundaries on our maps to show where compartment are, and why these jumps/steps exist in the mapping. Engineering structures are also shown.

A map set accompanies this summary, with both Bay-wide and more detailed maps. These represent a selection of scenarios modelled.





Example of mapped erosion bands for various sea level rise scenarios: Campbell’s Cove Werribee south. (Source: Water Technology)

Includes results for several coastal compartments (boundaries in green) and the presence of engineering structures.

Using mapped extents

Mapped model results help us understand coastal erosion areas along the Port Phillip Bay coastline. This allows us to examine how the coastline might respond if certain conditions were to occur.

By mapping results, we can compare extents of different storm events and sea level rise scenarios. We can also explore how hazard extents vary for different hazard types (erosion compared to inundation). We use mapping to assist us in identifying focus areas for adaptation.

Mapping also helps us explore **vulnerability and risk.** We do this by considering the values, uses and infrastructure located in hazard areas/zones. Vulnerability and risk can differ for different hazard types, weather events, conditions and over time.

Improved understanding of hazard processes from these mapped results allows better management decisions.

What next?

These results allow us to think about when hazards may occur and how they change over time. This means we can better plan for the future and develop an appropriate response.

Having larger area/s prone erosion hazards, doesn't necessarily mean a management response is required. It is more important for land and asset managers to look at what is located within these areas - values, uses and infrastructure - and what it might mean if they are impacted by erosion.

Using maps as the foundation, we can determine where to focus our efforts next. This might be analyses and obtaining extra information to aid decision making. Some areas may require a local-scale study of erosion, to better determine risk or adaptation planning.

Summary #7: Applying the coastal hazard assessment details how we can use hazard modelling findings, to make regional and local (site-based) adaptation decisions.

Point Lonsdale (Photo: Alluvium)

We acknowledge Victorian Traditional Owners and their Elders past and present as the original custodians of Victoria's land and waters and commit to genuinely partnering with them and Victoria's Aboriginal community to progress their aspirations.

Accessibility

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