Eastern View Coastal Adaptation Plan

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Executive Summary

Eastern View Beach is a high-energy surf beach on the Surf Coast, approximately 130 km SW of Melbourne, Victoria. The beach is popular with tourists and local boat owners predominantly in the summer months, and surfers, walkers and fishers all year round. The Great Ocean Road runs along the coast immediately behind the dune system and comes very close to the beach in various places, affording road users broad views of bass strait (Figure 1).

Continued erosion of the beach and dunes occurring along the study site since approximately the year 2000 has seen the loss of much of the dune area and loss and reconstruction of multiple beach access stairs. Over the last 5 years erosion has begun to impact the seaward edges of three carparking areas along the stretch of beach. Dune erosion escarpments are also currently close to power poles and the Great Ocean Road in areas.

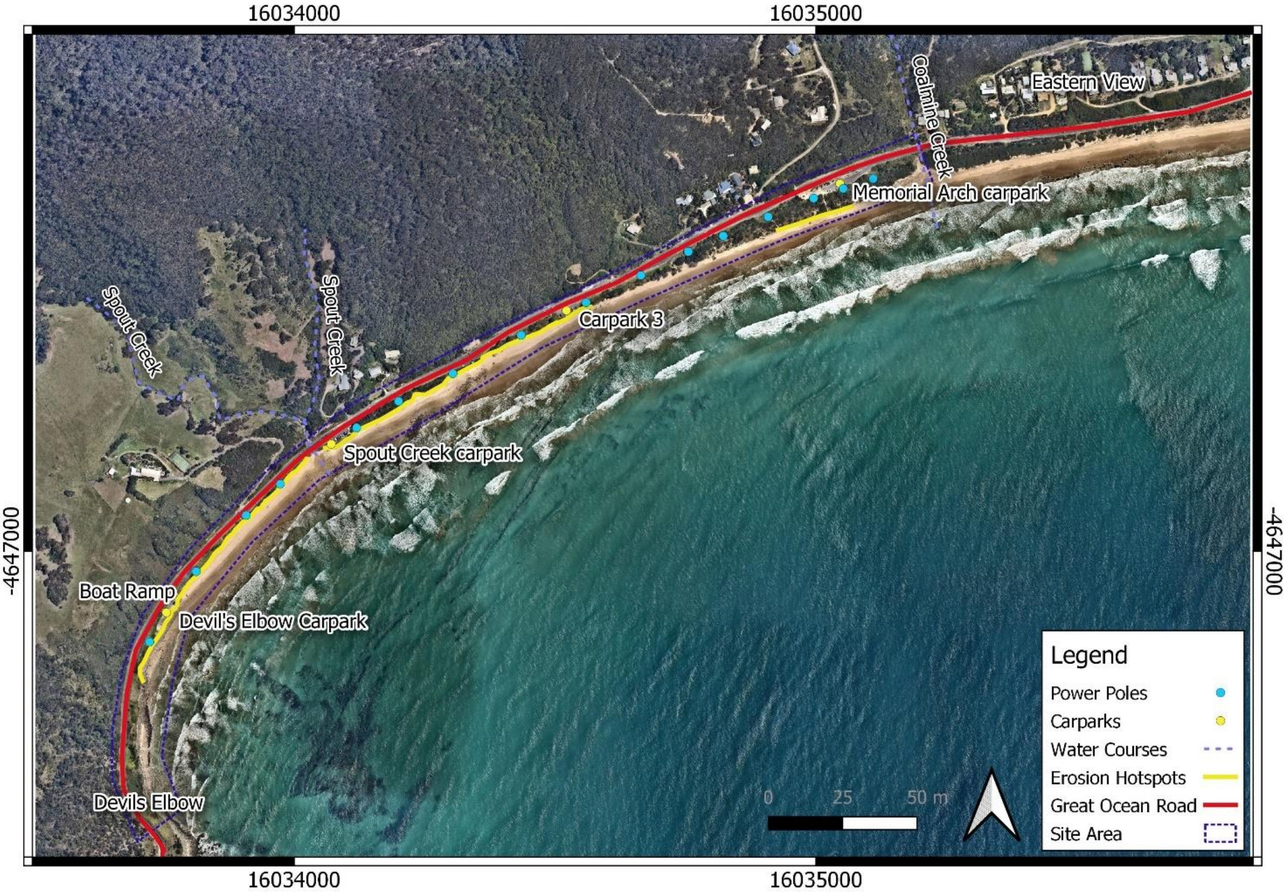

Figure 1 Study Area

The Department of Land Water and Planning (DELWP) have engaged BMT to prepare this Coastal Adaptation Plan for the area between Devil's Elbow and Coalmine Creek. In accordance with the Victorian Marine and Coastal Policy (VMACP) (DELWP 2020) development of the plan includes:

- a coastal process review for the area
- mapping of coastal hazard
- assessing vulnerability for the various assets

- assessing a range of possible coastal adaptation options/measures for the site
- Using an adaptation pathways approach to recommend immediate actions and identify decision points for longer term adaptation decisions.

The coastal process study and coastal hazard assessment identified the key coastal hazards at the site as coastal erosion and inundation by wave run up and over topping.

Coastal erosion is already impacting on several car parks, the boat ramp and several power poles are considered to be at immediate risk of undermining by coastal erosion in a major storm. Erosion in the study site is predicted to continue and increase in severity with rising sea levels. Within 10 years, further power poles and the Great Ocean Road are predicted to be at risk of erosion.

Figure 2 Erosion at Carpark 3 seen on 20th April 2021

Inundation of the carparks and Great Ocean Road by storm waves running up the beach and overtopping the dunes may occur by 2031and could present a serious hazard to road users.

Eight adaptation options for Eastern View were investigated, as described below. No feasible options for 'avoid' or 'retreat' of the Great Ocean Road were identified.

- **Minimum Intervention Consistent with public Safety (Non-Intervention) -** The purpose of including this option is to explore how minimal action regarding coastal adaptation would impact the relevant coastal assets in the area. All built assets would remain in their current positions. When erosion/inundation impacts these assets, they would be fenced where necessary for safety. When assets are at imminent risk of failure, they would be closed indefinitely and allowed to erode. This option does not maintain the values of the site.
- **Seaweed Dune Toe Armouring (Nature Based) –** This option involves pushing naturally occurring seaweed wrack which accumulates on the beach up to the dune toe as a means of protection from waves washing directly onto it. This is described as a 'no-regret' option in the VMACP due to its ease of implementation and minimal cost, however, it affords minimal actual protection for the dunes with waves removing the seaweed away in days – weeks.
- **Beach Nourishment and Beach Scraping (Nature Based) -** This option would nourish the beach and re-build the dune in severely eroded areas to protect assets from erosion. Due to a lack of identified sand sources, quarry sand may need to be trucked in, which could be very expensive. This may only be effective for weeks – months due to the high energy wave climate and strong longshore transport. This option is not recommended for this site because of the high cost and short effective lifetime.
- **Upgrade Beach Access Structures (Accommodate)** – Beach access ramps and stairs could be rebuilt with deeper foundations, more resilient materials and extending further landward to accommodate a level of erosion. While preserving access, these measures would not address the erosion risk to other assets and as such this is not a stand-alone option, but one that could be used in combination with protect type options.
- **Retreat and Stabilise Power Poles (Retreat/Accommodate)**– This option would retreat at-risk power poles and use a process called over-sinking to drive poles deeper into the soil for greater resilience to coastal erosion. Due to limited room available for retreat, this option may only be effective for 1 – 5 years.
- **Short-Term Protection –** This option would use Rock Bags or geotextile sandbags as immediate protection for at-risk assets such as carparks, power poles and the Great Ocean Road. This is an immediate option to minimise erosion of the dune and protect assets in critically at-risk areas. These protection options are only intended to be short term, intermediate measures before longer term solutions (e.g., protection or retreat) can be designed and implemented. Effective timeframes vary between the various options for immediate short-term protection.
- **Long-Term Protection with Revetment -** This option would construct a rock-revetment along the back of beach to protect assets from erosion. Revetment structures have been used previously along much of the Great Ocean Road with great success (e.g., Apollo bay and Skenes Creek). When well designed, revetments can protect assets for 50+ years. This would be very expensive and would have significant impacts on coastal processes. This type of adaptation option is designated as an 'option of last resort' in the VMACP.

- **Long-Term Protection with Sand Retention Structures -** This option would use rock structures such as groynes, intertidal reefs or offshore breakwaters to lower wave energy impacting the shore and trap sand on the beach. When well designed, these structures can protect assets for many years into the future and have a positive impact on beach amenity. This would be very expensive and would have significant impacts on coastal processes. This type of adaptation option is designated as an 'option of last resort' in the VMACP.

Considering the merits of these options, their effectiveness, impact, cost and inter-dependency, a recommended Adaptation pathway has been developed as shown in figure E-3 below. The key point is that trigger points for implementation of short-term protection have already been met in many areas and intervention is required to prevent the complete loss of carparks and potential undermining of the power lines. Alternatively, some of the at-risk power poles could be moved a short distance inland but this would only be a temporary solution.

If erosion trends continue as expected, larger scale long term protection measures will be needed, and the recommended option is a rock revetment.

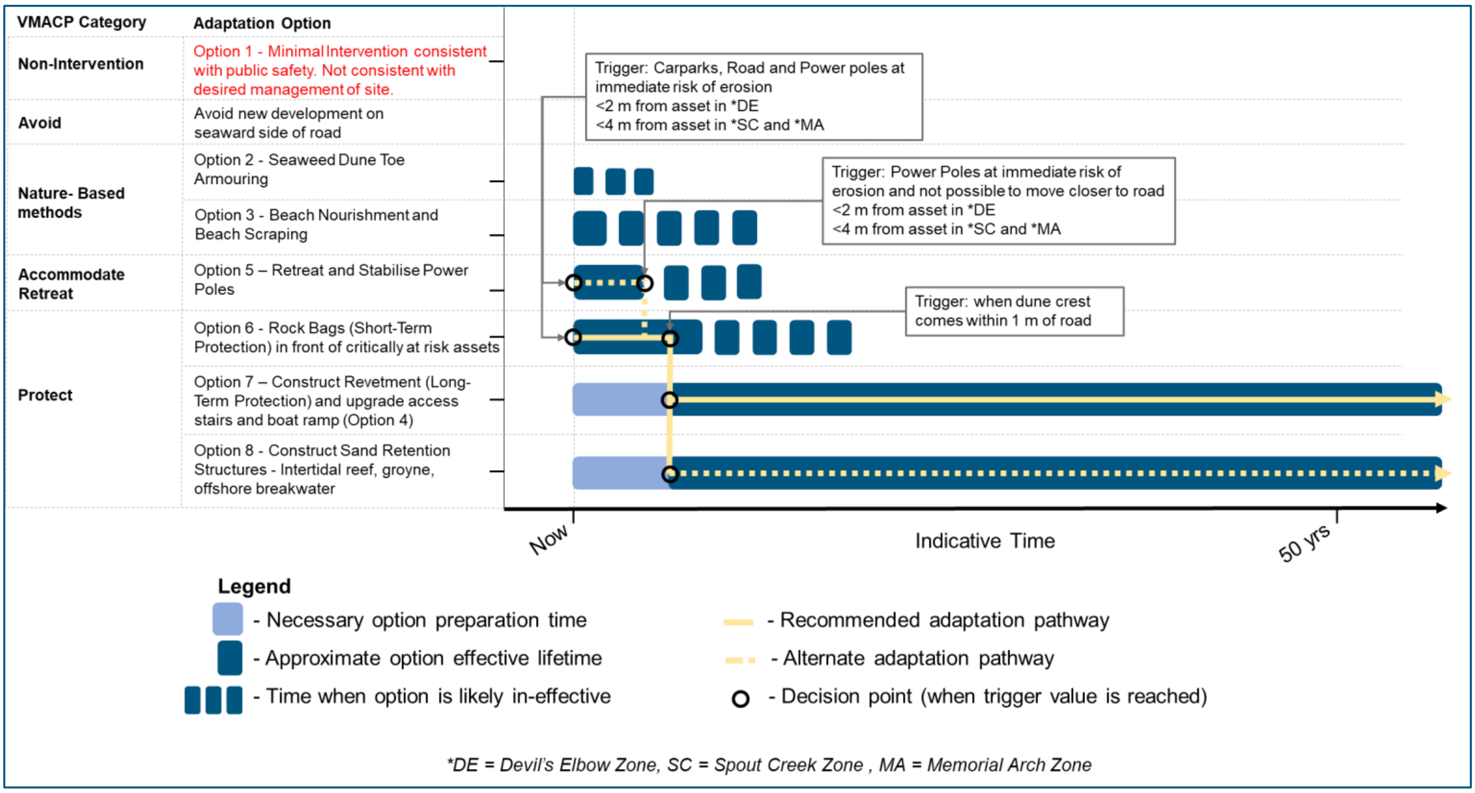

Figure 3 Recommended Adaptation Pathway

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1.1 Project Introduction

Eastern View is situated on the Surf Coast, approximately 1.5 hours SW of Melbourne. The Study site extends from the far SW corner of the Eastern View Beach (Devil's Elbow) to the Coalmine Creek Entrance (Figure 1-1). The area is currently managed by the Great Ocean Road Coast and Parks Authority (GOR Authority) (formerly GORCC), the committee of management in the area. This Authority is overseen by the Department of Land Water and Planning (DELWP).

In 2012, Eastern View and surrounds experienced significant erosion from a major storm causing multiple metres of foredune recession and loss of coastal vegetation, beach access structures and some carparking area. Retreat of assets (specifically car parks) has been underway since this time; however, successive erosion events have increased the risk posed to beach users and assets through continued carpark erosion, beach access structure instability and potential future power pole collapse.

DELWP have commissioned BMT to undertake this Coastal Adaptation Plan (CAP) for Eastern View to review available options/measures to manage erosion and respond to sea level rise within an 'Adaptation Pathways' framework in accordance with the Victorian Marine and Coastal Policy (VMACP) (DELWP 2020).

The CAP considers both short- and long-term measures and maps their interdependencies. Objectives of the CAP are to:

- Assess a range of management options/adaptation measures based on current understanding of coastal hazards and how these will change over time due to sea level rise,
- Recommend short term measures for the management of erosion that are consistent with the VMACP and do not constrain possible long-term options for the site,
- Map possible adaptation pathways for the long-term adaptation of the site to 2100 and beyond, to inform community consultation, further studies, and management decisions for the site.

1.2 Study Area

The Eastern View study area is situated on the lands of the Eastern Maar people. The site stretches from Devil's Elbow in the west to Coalmine Creek in the east (Figure 1-1), a distance of approximately 1.5 km. It is a high-energy ocean beach exposed to Southern Ocean swell and wind waves generated in Bass Strait which drive sediment transport processes on the shoreline. Consequently, the beach experiences fluctuations in width and episodic erosion of the back-shore area during storms.

The coast in this region consists of steep bluffs with the GOR cut into the toe. Seaward of the road is a narrow, vegetated area consisting of dune sand and/or colluvium/fill from the road construction over dune sand. The beach faces SSE and is characterised by fluctuating sand levels over rocky reef that is intermittently exposed in the intertidal and nearshore zones.

The site is dissected by Spout Creek and bordered on the east side by Coalmine Creek. The township of Eastern View is on the east side of coalmine creek and the Great Ocean Road Memorial Arch is situated over the road in the eastern end of the study site.

A high-level desktop review and discussions with stakeholders has identified key factors relating to coastal processes at the site:

- it is a high-energy surf beach (although somewhat sheltered in the SW end),
- there is a predominant south-west to north-east net sediment transport,
- there is a cyclical onshore – offshore sand movement resulting in fluctuating beach levels and erosion at dune toes,
- more than 10 m horizontal shoreline landward recession during the last 15 years at some sites, with more recession forecast due to sea level rise.

The key values/assets at the site are understood to be:

- Continued Beach Access
    - 4 carparks on the seaward side of the road. These carparks are essential for safe beach access as there are limited safe stopping locations along this stretch of the road
    - Pedestrian beach access via the Devil's Elbow Boat Ramp, a staircase from the Spout Creek carpark and various paths along the stretch
    - Boating access and emergency vehicle access to beach via informal boat ramp at Devil's Elbow Carpark
- Beach Amenity
    - Mostly used in summer for surfing, swimming, sunbathing
    - Used year round by walkers and fishers.
    - Carparks are often used for unplanned stops by tourist traffic travelling along the GOR
- Eastern Maar Indigenous Heritage Values
- Natural Values
    - Coastal dune vegetation strip
    - Inshore and intertidal reef habitat along much of the shoreline
- Power Cor Assets
    - 15 power poles on the beach side of the GOR
- Heritage Value
    - The GOR Memorial Arch and associated signage and carpark (eastern end of site).

Based on site inspections and discussions with stakeholders, the current coastal issues and associated risks and hazards are:

- Erosion of carparks

  - A combination of storm erosion of beach/dune, long-term coastal recession and overland flows during high rainfall events is causing the Devil's Elbow carpark, Spout Creek carpark and carpark 3 to erode onto the beach. These carparks have been retreated and reconfigured in the past but there is no longer sufficient room to for further retreat.
  - Beach access over the scarp seaward of the carparks causes hazards to beach users
- Erosion of dune
  - This is caused predominantly by storm erosion of the dunes, leaving steep dune scarps, highest at the eastern end of the site near the memorial arch.
  - Causes hazards to beach users trying to access the beach via steep/unstable access paths.
  - May cause hazards to beach users (predominantly children) who may climb on or burrow into the dune scarps.
- Erosion of informal boat ramp at Devil's Elbow Carpark
  - This is caused by storm erosion and overland storm water flows respectively causing undermining of the ramp toe and erosion ruts in the clay ramp surface. This creates a steep drop off at the base of the ramp, and a narrow and uneven ramp surface.
  - Causes hazards for community members launching boats.
  - Limits emergency vehicle access to the beach.
- Erosion threatening the stability of the Power Cor assets
  - Landward recession of the dune system has caused the dune scarp to be within several meters of multiple power poles along the study site. These poles are at most inserted 3 m into the ground (often 2 m) and are thus in danger of failing if dune erosion reaches them.
  - This could cause power lines to fall onto the beach/GOR/carpark and cause significant risks to the public safety.
- Threat of Erosion to the Great Ocean Road
  - Landward recession of the beach has narrowed the buffer of dune between the GOR and the beach, especially around Spout Creek and in an area between the Spout Creek carpark and carpark 3.
  - Storm erosion could impact the road in future, initially undermining the shoulder and safety barriers, causing a hazard to road users.

This background information provides relevant context for the ensuing Coastal Adaptation Plan and allows adaptation pathways to be specifically tailored to the needs of the Eastern View area.

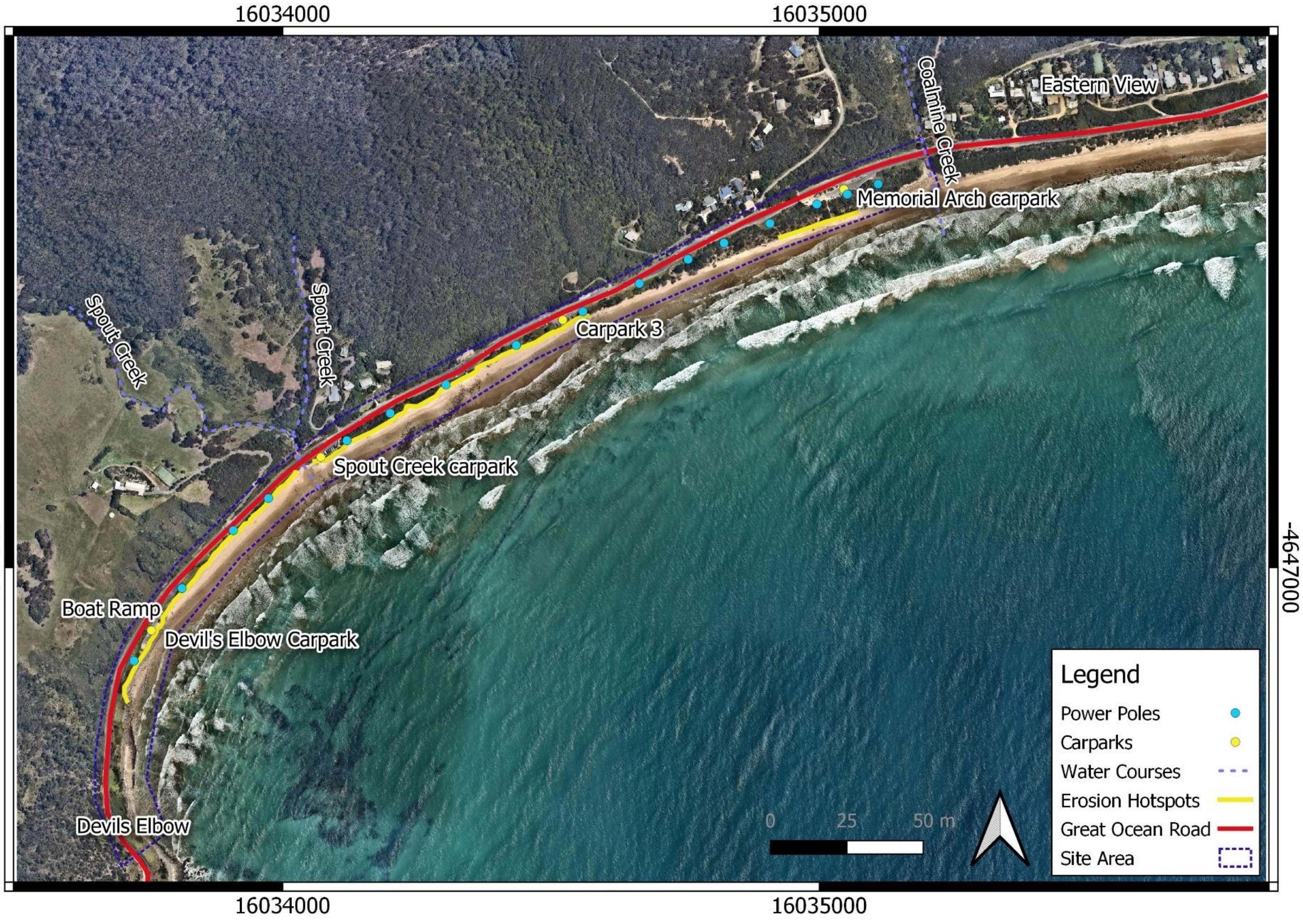

Figure 1-1 Study Area

1.3 Cultural Heritage

During the study period, DELWP also ran a parallel study into the cultural heritage of the study area performed by Christine Williams Heritage Consultants.

The study aimed to document the extent, nature and significance of Aboriginal cultural heritage within the site including oral history.

The report suggests predominantly nature-based solutions for protection of cultural heritage by revegetating the erosion escarpments and by placing large tree branches or geofabric logs at the toe of the escarpment to limit further erosion and encourage sand deposition.

DELWP conducted engagement with Eastern Maar throughout the study period and representatives attended the final draft presentation. Information on desired land management practices by Eastern Maar can be found in Section 1.6.

1.4 Previous Studies

Coastal Management at Fairhaven – E.C. Bird 1998

In this report, Eric Bird gives a summary of the geomorphological context of the beach between Fairhaven and Devi's Elbow, reviews the coastal processes impacting the area then focusses on management issues which were appearing. He notes that the bluffs landward of the Great Ocean Road are former sea cliffs, the terrace the road sits on is depositional and formed by the slumping of the former sea cliffs, and that there seemed to be the beginning of a net sediment deficit in the area (1998). The dominant net sediment transport is west to east along the beach with summer months potentially reversing the trend. Bird also reports that excavation with wheelbarrows and bags around 1922, of brown coal from an intertidal rocky reef seaward of coalmine creek caused the reef level to be lowered and the sandy beach to be eroded away. This reef outcrops along the entire stretch of the current site area and excavation of this may have resulted in the eroded profiles in the 1945 aerial images. Bird also suggests coastal management reforms for the area which revolve around dune fencing and sediment trapping.

Coastal Climate Change vulnerability and Adaptation Report – SKM 2012

This report outlined the key risks to assets and values on the Surf Coast LGA stemming from inundation, storm erosion and coastal recession. Informing this was a brief review of coastal processes impacting the Surf Coast which outlined the forecast increase in occurrence and size of short period swell waves from the South due to climate change. These are forecast to increase coastal storm erosion and long-term recession seen in the study area. The report also outlines the following key assets and values for the current study area: residential areas, boat ramp, carparks, beaches, surf breaks, the Great Ocean Road, intertidal habitats and their dependant flora and fauna. The combined risk from inundation, coastal erosion and coastal recession was estimated as 'high' for the current study area due to the low-lying nature of many of the built and natural assets. Sea level rise trigger values were estimated for coastal management decisions for the study area with 0.2 – 0.8 m sea level rise giving rise to material risks to assets from storm erosion and coastal recession. This relates to a 2030 – 2100 timeframe which is seemingly an underestimate in light of the continued impacts to assets since 2011 to present.

Coastal Process Study - CES 2012

This Coastal Process report for the Surf Coast summarizes all previous coastal process knowledge up until 2011 and focusses on highlighting potential foreshore management practice changes for future climate change and sea level rise scenarios. Eastern View is one of the key study areas and thus, the coastal process review is highly significant for the current study. The report undertakes coastal recession analysis from 1947 – 2007 for three transects over the current site area and shows net accretion over this time. CES also note that climate change is forecast to increase the occurrence and strength of winds from the SE quadrant resulting in larger storm waves at Surf Coast shores and hence, likely greater erosion potential in the future. At Eastern View, they suggested sustained and regular coastal survey monitoring to deduce how erosion was impacting the dunes on a semi-annual time scale.

Draft Coastal Management Master Plan – Fairhaven to Devil's Elbow – GORCC 2013

The Draft Master Management Plan document for the Devil's Elbow – Painkalac Creek coastal region created by the Great Ocean Road Coastal Committee (GORCC) outlines key objectives and actions for the management of the area between 2014 – 2020. This was informed by a previous study on the coastal processes in the area and outlined that there has been no net shoreline change in the last 60 years. Although this is true, it was reported that there was a recession trend from 2010 – 2013. The report also gives a good summary of issues relating to biodiversity, cultural heritage, land tenure, aesthetic character and recreation and tourism access/facilities.

Erosion advice letter to GORCC – Tomkinson Group 2017

This letter to GORCC from Tomkinson Group Pty Ltd outlines suggestions to limit the erosion of the exposed dune faces seaward of three of the four main carparks in the study area. This work was commissioned by GORCC after significant erosion in the beginning of 2017 led to undermining of some of the carpark areas. Suggestions were focussed on minimising overland flows coming from the Great Ocean Road during storm events and flow down the dune face, increasing erosion. They recommend, however, that further studies on the coastal processes at eastern view will likely be necessary to predict the future stability of these carparks and power infrastructure present in the area.

Eastern View Coastal Processes Technical Memorandum – GORCC 2017

This memorandum reviews coastal processes impacting Eastern View and outlines a proposal to batter the seaward margins of two carparks (Devil's Elbow Carpark and Carpark 3 in the current study) with a clay-rubble mixture from Anglesea quarry. This is an attempt to slow coastal recession in these areas. The review of coastal processes includes an approximate estimate of net sediment transport of 250,000 m^3/year adopted from a Water Technology (2019) report for Anglesea bay. The review also includes an analysis of coastal recession from aerial imagery which shows 2 – 20 m of landward recession between the years 2000 and 2020. Also included are the results of an extreme value analysis performed by Water Technology (2018) for storm tide levels, a brief review of the local wave climate (from Point Nepean Wave Buoy) and descriptions of both the long-shore and cross-shore sediment transport at the site. After reviewing the coastal processes impacting the site area, GORCC note that these works are only intended as temporary measures and that they expect the batter to wash away in time. Impacts of the batter on coastal processes were also identified and forecast to be negligible.

1.5 Methodology

This study has employed an outcome-centric methodology for rapid assessment of coastal hazards and selection of adaptation measures/strategies using a pathways approach consistent with the VMACP (2020).

- The first step was a rapid desktop-review of coastal processes and coastal hazards based on a site inspection and available literature.
- We then identified the values and assets associated with the site via consultation with all relevant stakeholders.
- This was followed by a first-pass options assessment conducted by BMT to identify a short list of coastal management strategies which may be applied to the site. This list was then taken to an options workshop with expert coastal engineers and representatives from DELWP and the GOR Authority to narrow the options shortlist into a limited set of technically feasible options that aligned with DELWP's strategic objectives.
- A tailored coastal hazard assessment was then undertaken to provide the information needed to support management decisions based on the agreed set of options, i.e. identified the most favourable options and trigger values for the implementation of each option.
- A full options assessment on the technically feasible management options previously identified was then undertaken to determine how effective they are now, and how effective they will be into the future.
- Finally, the favourable measures were assembled into a number of possible adaptation pathways that show how a series of measures can be implemented over time to manage the adaptation of the system to rising sea levels increasing coastal hazards.

The outcome-focused methodology made maximum use of previous studies and available data to inform a strong focus on identifying and developing practical solutions to complex coastal management issues. Stakeholder engagement was an important part of the process from the identification of values right through to the selection of pathways.

1.6 Stakeholder and Community Engagement

The outcome-centric methodology outlined above relies heavily on stakeholder engagement to produce the final adaptation pathways. This engagement was undertaken in the following ways:

- The stakeholder meeting on site.
  - Purpose was to identify infrastructure along the shoreline, understand the site usage and values, understand the history of erosion issues and their management, and identify options for erosion mitigation.
  - Attendees at this meeting included representatives from BMT, DELWP, GOR Authority, Rural Roads Victoria (RRV), Powercor and Better Boating Victoria (BBV).

- The First Pass Options Workshop
  - Purpose was to define the site-specific limited set of technically feasible options that aligned with DELWP's strategic objectives.
  - Attendees at this meeting included representatives from BMT, DELWP and the GOR Authority.
- Negotiables and Non-Negotiables Stakeholder meeting
  - Define negotiables and non-negotiable elements for inclusion in CAP.
  - Plan for community consultation during and after completion of this study
- Community 'Listening Post' conducted by DELWP and the GOR Authority
  - Aimed at gauging the community views on various options for coastal adaptation.
  - A tent set up in one of the Beach Carparks for a day containing posters of the coastal hazard assessment results from this study and posters describing potential options for erosion mitigation.
  - Very few people attended this opportunity (See Section 4 for more details).
- DELWP led consultation with the Eastern Maar Aboriginal Corporation
  - This was aimed at understanding the desires of Eastern Maar surrounding management of the site and cultural heritage values.
  - This consultation found,
    - Eastern Maar desire to be consulted as a first priority when any land management decisions are to be made.
    - Eastern maar request natural and natural looking coastal protection measures.
    - Permit requirements and Cultural Heritage Management Plans may need to be undertaken prior to any works being undertaken.

2 Coastal Hazards

2.1 First Pass Hazard and Risk Screening

Informed by site visits, stakeholder engagement meetings and background documents, we have undertaken a first-pass assessment of the coastal hazards which will drive adaptation planning at Eastern View. The long list of coastal hazards shown in Table 2-1 is a combination of those outlined in the Victorian Marine and Coastal Policy (DELWP 2020) and the prescriptive list given in the NSW Coastal Management Act (NSW State Government 2016). Combining these lists enables certainty that all potential coastal hazards for the site are assessed.

Table 2-1 First pass Hazard Assessment Summary

Coastal Hazard	Importance at Eastern View
(a) Beach erosion (short term storm erosion)	High
(b) Shoreline recession (long term shoreline retreat)	High
(c) Storm Inundation (short term storm effects including storm surge and wave runup)	High (may happen in the near future)
(d) Tidal Inundation (reoccurring high tide inundation, sea level rise)	Medium (sea level rise will likely cause overtopping of road/carparks in future)
(e) Catchment Inundation (catchment flooding in combination with storm surge/highwater level events)	Low (all water courses in site have steep valley sides)
(f) Coastal cliff or slope instability	Medium (Devil's Elbow has a high cliff/slope which has slipped and has a high scarp).
(g) Coastal Groundwater Changes	Low
(h) Coastal lake or watercourse entrance instability	Low (both creek entrance locations controlled by bridges and culverts part of the road infrastructure).

This study focusses on the following hazards which are considered most likely to drive adaptation decisions at Eastern View:

- Beach Erosion (short-term storm erosion),
- Shoreline Recession (long-term shoreline retreat),
- Coastal Inundation (due to short-term storm effects and sea level rise).

2.2 Coastal Processes

2.2.1 Geomorphology

2.2.1.1 Natural Processes

The geomorphology of the Eastern View region is predominantly comprised of various layers of Cretaceous and Tertiary sedimentary rock. These different geologies were laid down in order of age; the oldest being the Otway Formation (cretaceous), then the Eastern view Formation (lower tertiary), then the Demons Bluff Formation (Tertiary). The more recent Jan Juc formation (Oligocene) overlies the demons bluff formation at Aireys Inlet forming the calcareous intertidal shore platforms and cliffs common on the surf coast (Point Addis, Bells Beach).

After deposition of these cretaceous and tertiary sediments, the separation of Australia from the Antarctic continent and the subsequent northward drift of Australia caused uplift of the Otway Ranges (approximately 45 Ma) (Cochrane et al. 1991). Since this time, alluvial erosion processes via the various creeks and streams seen in the area (Figure 2-1) have caused the uplifted sediments to be formed into the valley and hills seen currently. It is highly likely that sediment found on shorelines in the region are derived from alluvial transfer from these uplifted cretaceous and tertiary sediments to the coast. This is seen clearly in the quaternary alluvial channel which the Painkalac Creek has cut into the much older underlying sedimentary layer.

Ocean ingression since the last ice age has raised the sea level by approximately 120 m (VRO 2020). This has caused coastal processes to erode the seaward toe edge of these risen sediments causing sea cliffs and shoreline intertidal platforms. These processes can clearly be seen at work in the current site area where erosion of the Eastern View Formation by waves and anthropogenic actions (see following section) has caused low, relatively flat intertidal reefs of soft sedimentary rock from Devil's Elbow to Coalmine Creek. When not covered by sand, these reefs clearly show the bedding planes of the Eastern View Formation dipping steeply to the SSE (Figure 2-1).

Coastal processes have also acted to form the sandy beach system with backing dunes which stretches from Devil's Elbow to Aireys Inlet, intersected by Spout Creek, Coalmine Creek, Moggs Creek and Painkalac Creek. The dunes have grown as sand has been carried onshore by persistent swell and is stabilised by vegetation. Recent years have seen the eroding of the dune system, possibly due to sea level rise and increased storm activity as a result of climate change.

Current geomorphological processes at the site include (Bird 1998):

- Continued coastal erosion of the dune system between Devil's Elbow and Aireys Inlet,
- Alluvial transfer of sediments from the hills to the beach via various creeks in the region.
- Fluvial transfer of sediment along the coast (predominantly west to east).

2.2.1.2 Anthropogenic Processes

Humans have also acted to shape the coastal geomorphology in recent times. Interestingly, during the early 1900's the Eastern View Formation intertidal reef was reportedly at significantly greater elevations than it is currently. E.C Bird (1998) reports that this reef had deposits of carbonaceous brown coal (hence Coalmine Creek) which was removed by people with bags and wheelbarrows for fuel. This anthropogenic action caused the lowering of the reef and may have acted to increase the wave energy impacting the shore and possibly lowering the beach level. This may have contributed to long-term erosion patterns in the area.

As well as this, the construction of the GOR (1918 – 1922) and carparks by placement of fill and road base on the Holocene dune material has impacted the natural dune processes. Erosion of the Devil's Elbow carpark, Spout Creek carpark and carpark 3 has contributed road base and fill to the beach sediments. The erosion scarp shows clearly how approximately 1 m of gravel has been placed over the dune sand to form the carpark (Figure 2-3).

Dune stability is also impacted by access tracks over the dunes. The sand under an access track is unprotected by vegetation and hence, more vulnerable to erosion by wind and waves.

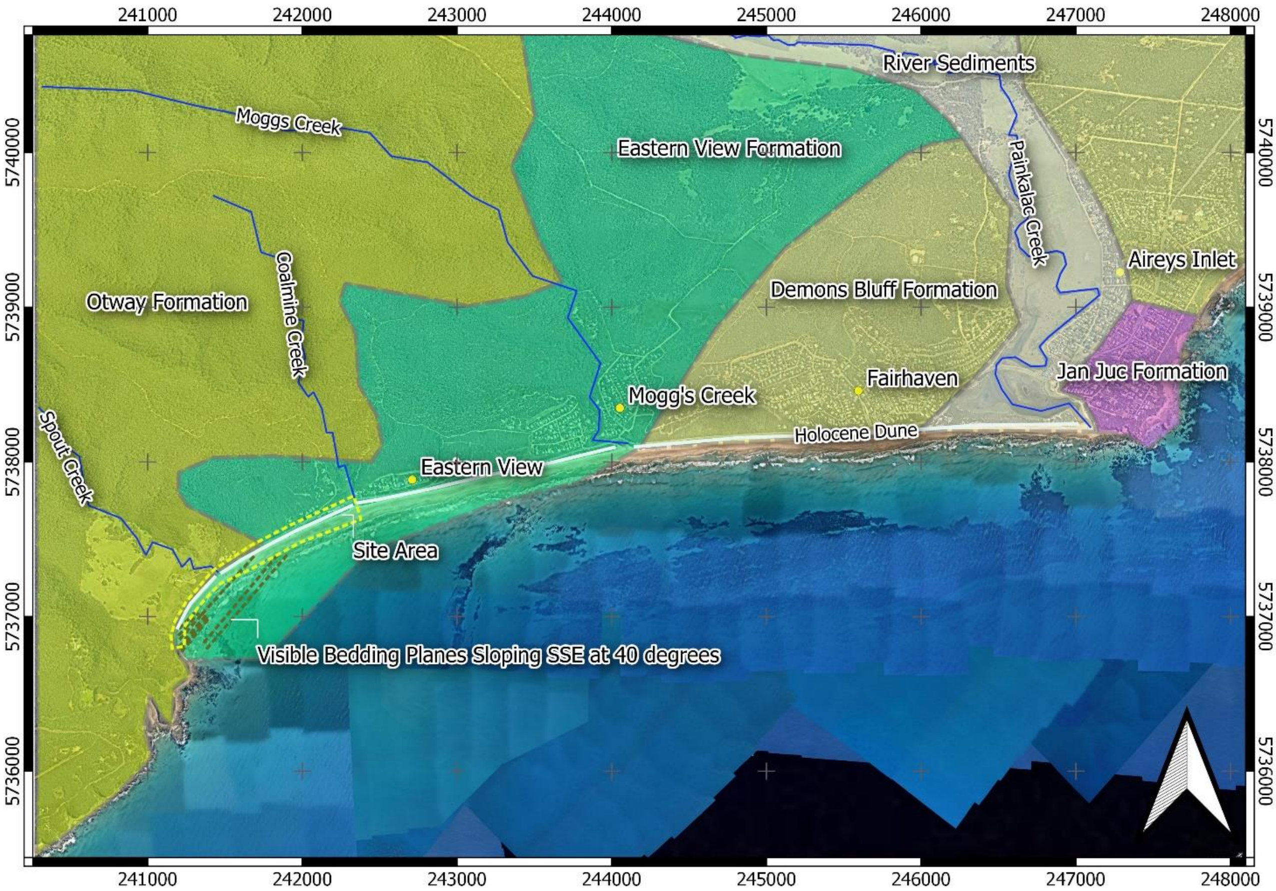

Figure 2-1 Eastern View Geomorphology Map

2.2.1.3 *Site Specific Geomorphology*

The study area in this project has many similar characteristics of the larger sediment compartment (Figure 2-1) with some interesting nuances. The site has a low sandy beach backed by actively eroding dunes (fill over dune sand in places). These dunes are up to 20 m wide in the east, adjacent to Coalmine Creek but gradually become narrower until a 5 m wide span of fill over dune sand sits between the road and beach along much of the stretch between Spout Creek and Devil's Elbow.

These Holocene dunes are backed by the GOR which sits immediately at the base of the cretaceous and tertiary sedimentary bluffs. As the GOR travels west around Devil's Elbow and gains elevation, the Holocene dunes give way to bluffs of colluvium from the erosion of the Otway Formation and the construction of the GOR. In areas, these bluffs have eroded into high (up to 5 m) scarps with boulders from historical landslides at the base (Figure 2-2).

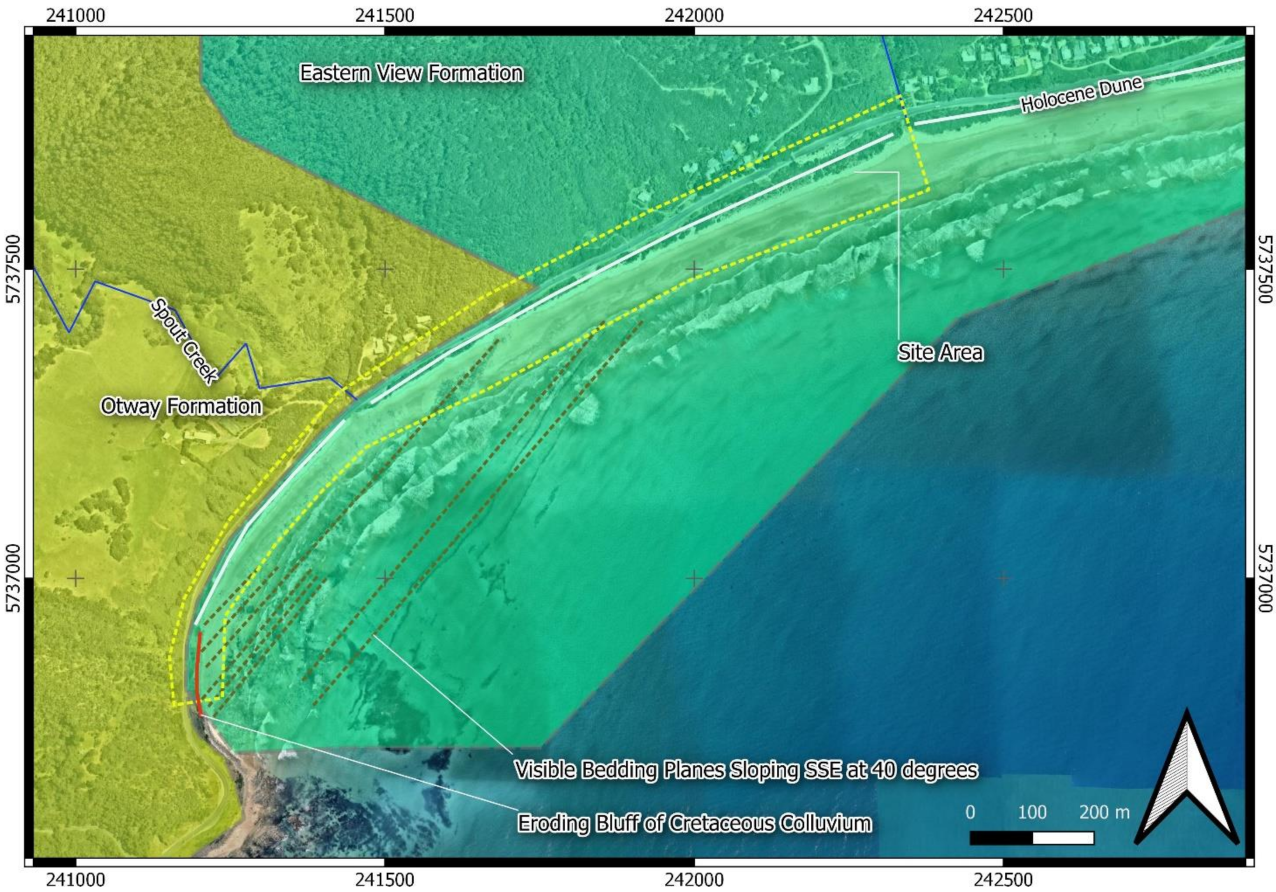

Figure 2-2 Site Specific Geomorphology Map

Especially relevant to this study is the fact that the GOR and the carparks are constructed on fill material (likely derived from the cutting of the GOR ledge) placed over dune sand, seaward of the base of the cretaceous and tertiary sedimentary hills (Figure 2-3). This makes these assets particularly vulnerable to erosion as the dune sand is easily eroded by wave action with the overlying fill then collapsing (Figure 2-3).

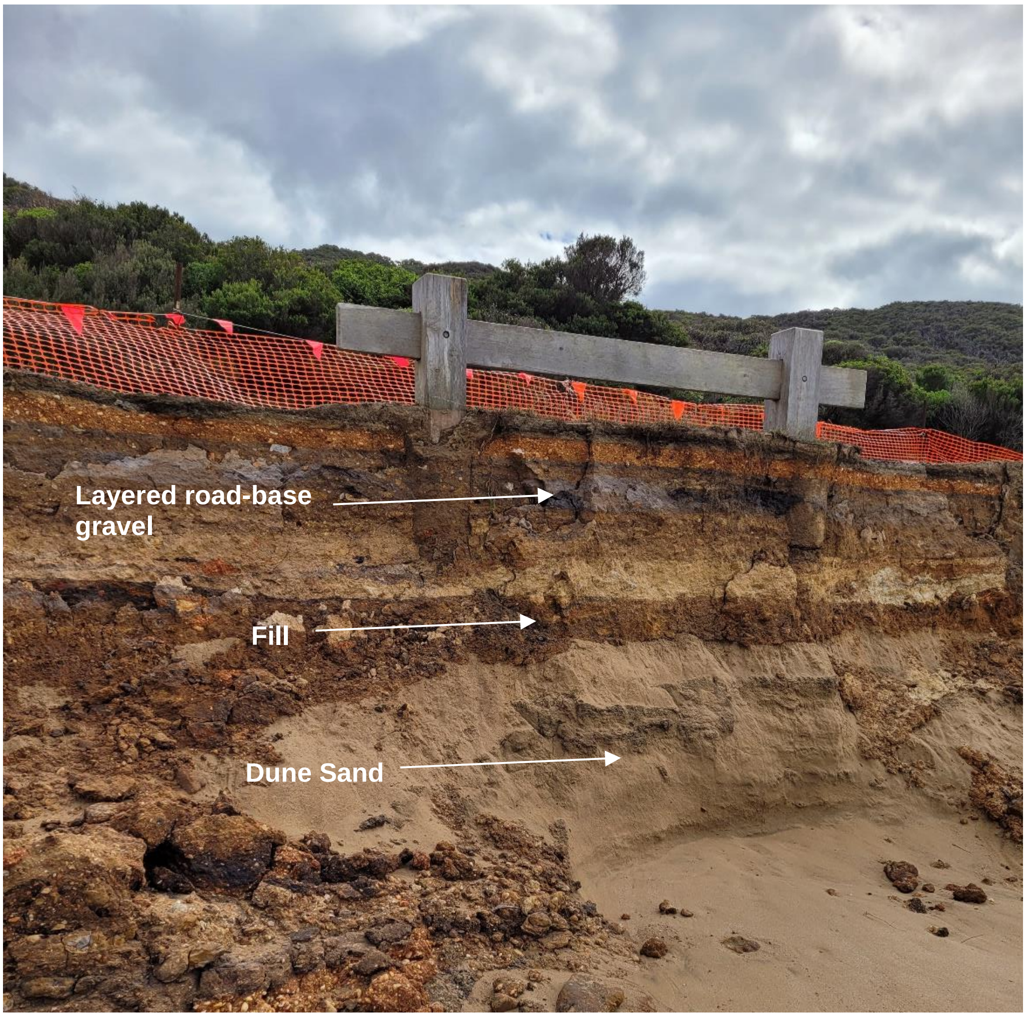

Figure 2-3 Road-base fill atop dune sand at carpark 3 (April 2021)

The presence of outcropping Eastern View Formation sedimentary rocks in the near shore zone and on the beach at Devil's Elbow (Figure 2-2) is also of interest to this study. Where these rocks outcrop in the near shore, they cause refraction and shoaling of the incoming waves, lessening the wave energy impacting the shoreline. Where these rocks outcrop on the beach, they limit the vertical erosion of the beach and reduce the wave energy reaching the dunes at the back of the beach.

2.2.2 Wave Climate

We used an existing BMT Bass Strait SWAN model to characterise the near shore wave climate at Eastern View (location as shown in Figure 2-5). This model incorporates swell waves entering Bass Strait from the east and west (from global wave models), wind wave generation, wave interaction, refraction and shoaling within Bass Strait. The model was used to hindcast 12 years of wave conditions between 1987 and 1999. An extreme value analysis of this data was also conducted for significant wave height to determine the magnitude of various return interval events. The model was previously calibrated using Apollo Bay wave measurements.

Note that modelled wave conditions were extracted at a nearshore location, seaward of the surf zone, with a mean depth of approximately 9 m. Long period swell waves will have undergone significant shoaling and refraction before they reach this point, which means that the reported waves are lower height and more shore-normal in direction than the deep-water wave climate further offshore.

Results from this model show that:

- The dominant waves at the site are swell waves from the Great Australian Bite and Southern Ocean with periods of 8 – 21 s which approach the site from 180 to 200 degrees (Figure 2-6).
- Wind waves formed in Bass Strait with periods of 1 – 8 s also approach the site from directions between 150 – 120 degrees (Figure 2-6).

These wave characteristics are summarized in visually in Figure 2-4 and Figure 2-9.

Extreme value analysis results for significant wave height is given in Table 2-2 for ARI 1, 10, 25, 50 and 100-year events.

Table 2-2 Inshore Wave Heights – Extreme Value Analysis Results

			Significant Wave Height (m)				
	LON	LAT	ARI-1	ARI-10	ARI-25	ARI-50	ARI-100
Eastern View	144.0445	-38.4797	2.64	2.95	3.08	3.18	3.27

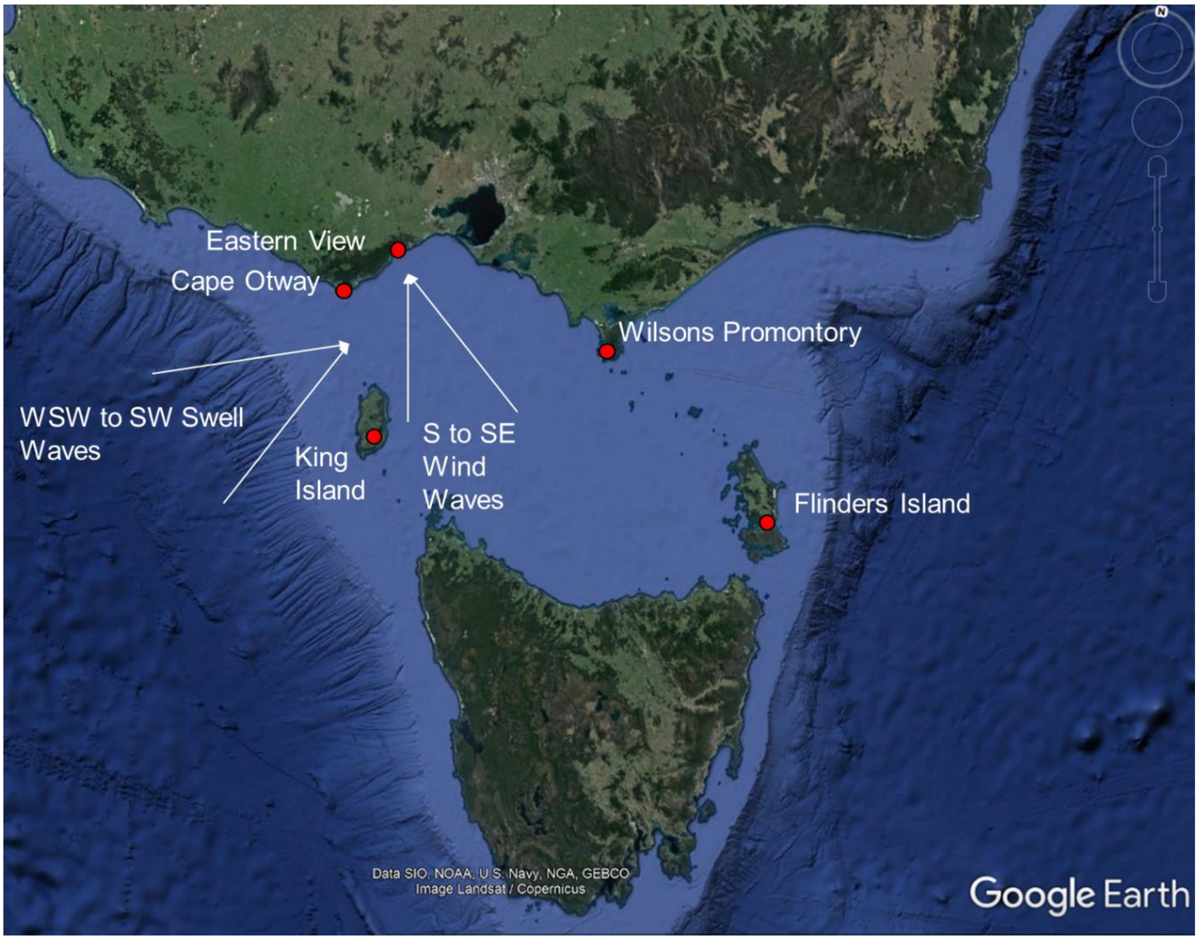

Figure 2-4 Eastern View Wave sources. Adapted from CES (2012)

Figure 2-5 SWAN model extraction point

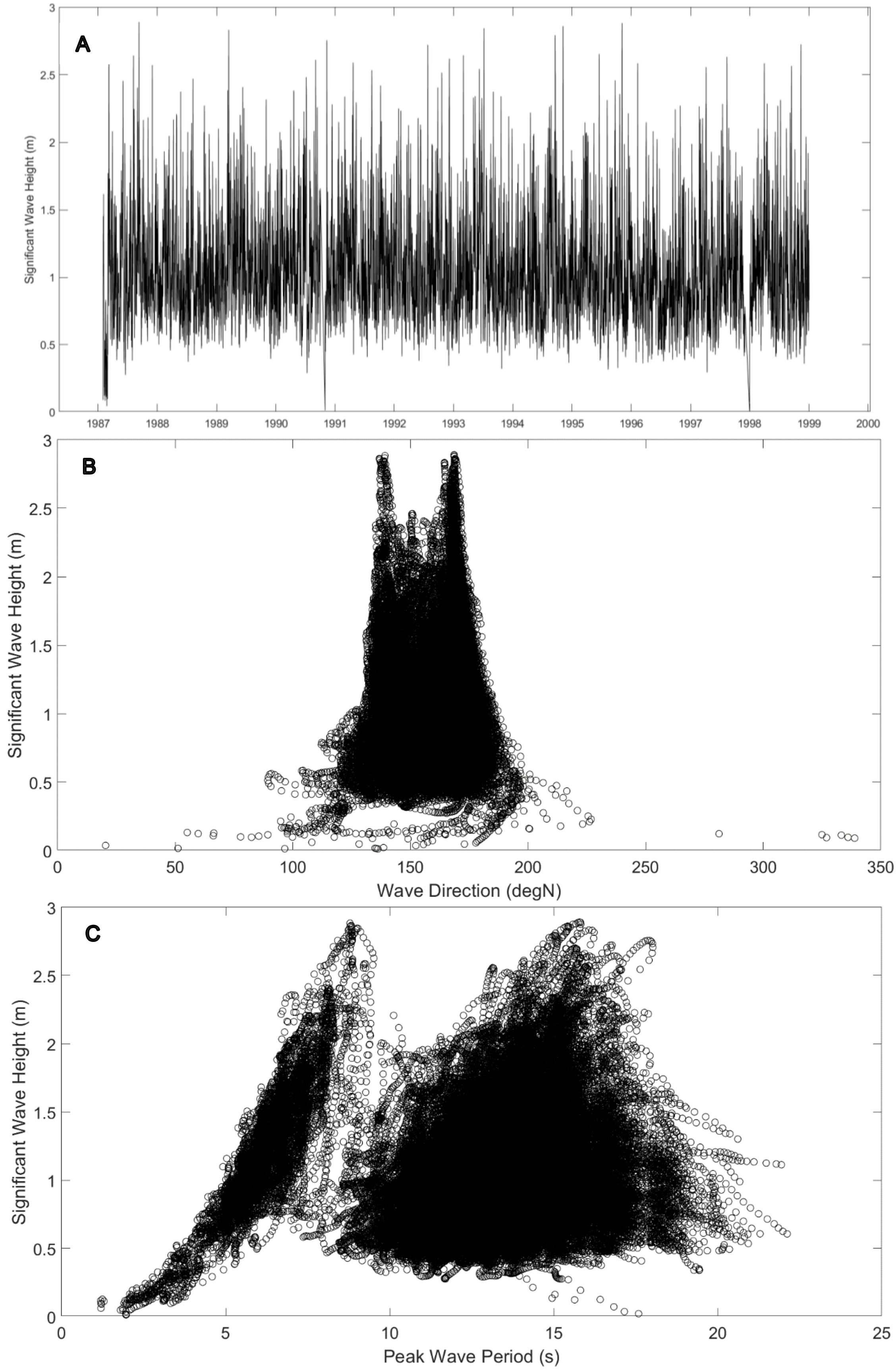

Figure 2-6 Bass Strait SWAN model results

2.2.3 Water levels

Water levels at a site at any given time are the combination of many fluctuating factors including astronomical tide, storm surge, wave set up and wave run up (Figure 2-7). Because each of these are constantly changing, extreme water levels at a site thus only occur when high water phases of the various constituents of water levels combine.

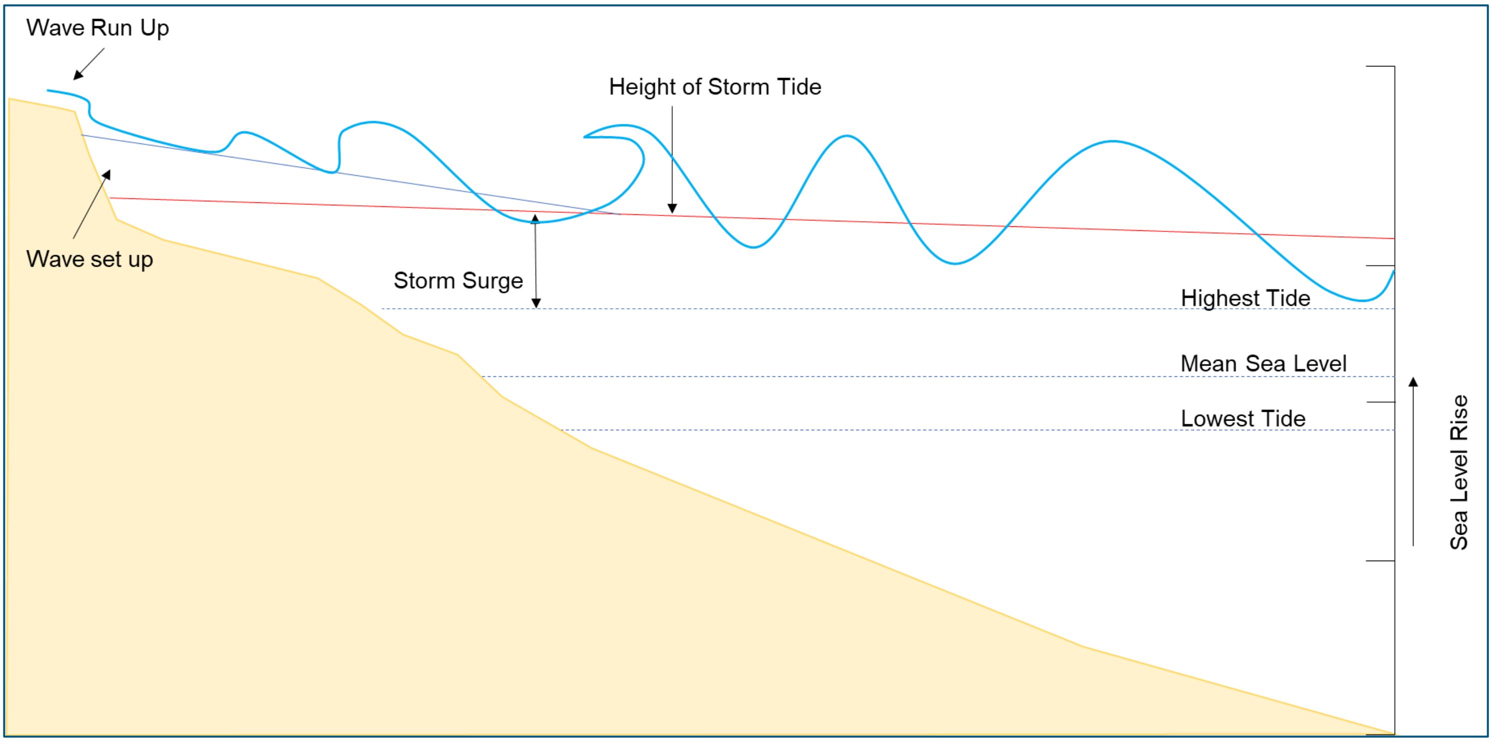

Figure 2-7 Diagram showing the constituents of water level at the coast.

The astronomical tide refers to fluctuations in local water level predominantly due to the gravitational pull of the sun and the moon. At Eastern View, the tidal signal is a combination of a smaller diurnal component (1 tidal cycle a day) and larger semi diurnal (2 tidal cycles a day) component yielding two tides per day with the amplitude fluctuating over a 28-day cycle. The tidal gauge at Lorne (8 km from the study site) is representative of the tides at Eastern View. Table 2-3 shows the tidal planes at Lorne in m AHD.

Table 2-3 Lorne Tidal Plane (ANTT 2019)

Tidal Plane	Water Level (m AHD)
Mean High Water Springs	0.8
Mean High Water Neaps	0.4
Mean Sea Level	0.0
Mean Low Water Neaps	-0.4
Mean Low Water Springs	-0.8

'Storm tide' refers to the combination of astronomical tide level, and storm surge which often occurs when low pressure systems with cold fronts cross Bass Strait causing sharp drops in atmospheric pressure, winds from the SW and high sea waves (McInnes et al. 2005) (Figure 2-7). Storm tide levels (exclusive of wave set up and wave runup) along the Victorian coastline have previously been calculated by McInnes et al. (2009) for ARI 10-, 20-, 50- and 100-year events under current conditions (late 20th Century climatic conditions) (Table 2-4).

Table 2-4 Estimated Current Storm Tide Levels at Lorne (McInnes et al. 2009)

Annual Recurrence Interval ARI (Years)	Average Exceedance Probability AEP (%)	Storm Tide Levels (m AHD)
10	10	1.32
20	5	1.46
50	2	1.59
100	1	1.69

As well as astronomical tides and storm surge, water levels at the coast are increased by wave set up and wave run up, both of which are locally dependant on the shore profile (Figure 2-7). Wave setup is caused by breaking waves pushing water towards the land. Wave run up is where broken waves flow up the local beach surface towards land. In storm conditions, these processes can cause overtopping of coastal protection structures and dunes.

Wave setup can be difficult to accurately calculate as its extent depends on both the continually changing local beach morphology and on the incoming waves. We used an SBEACH model to calculate wave set up for three locations (Figure 2-8) along the study site (Table 2-5). The model used:

- A pre-storm beach profile made from a combination of photogrammetry survey data (March 18th, 2021) and Future Coasts (2011) bathymetry survey data.
- Storm data as follows,
  - Significant Wave height (Hs), Wave Period (T_p) and Wave Angle (degrees) from the Apollo Bay Wave Buoy for the period March 18 – April 29, 2021.
  - Constant water level at MSL (0.8 m AHD)
  - Constant wind speed (25 m/sec)
  - Constant wind direction (30 degrees from shore normal to the south)

This resulted in the wave set up values summarized in Table 2-5.

Table 2-5 Modelled wave setup values

	Beach Zones		
	Devil's Elbow	Spout Creek	Memorial Archway
Wave Setup (m above still water level)	1.3	1.3	1.4

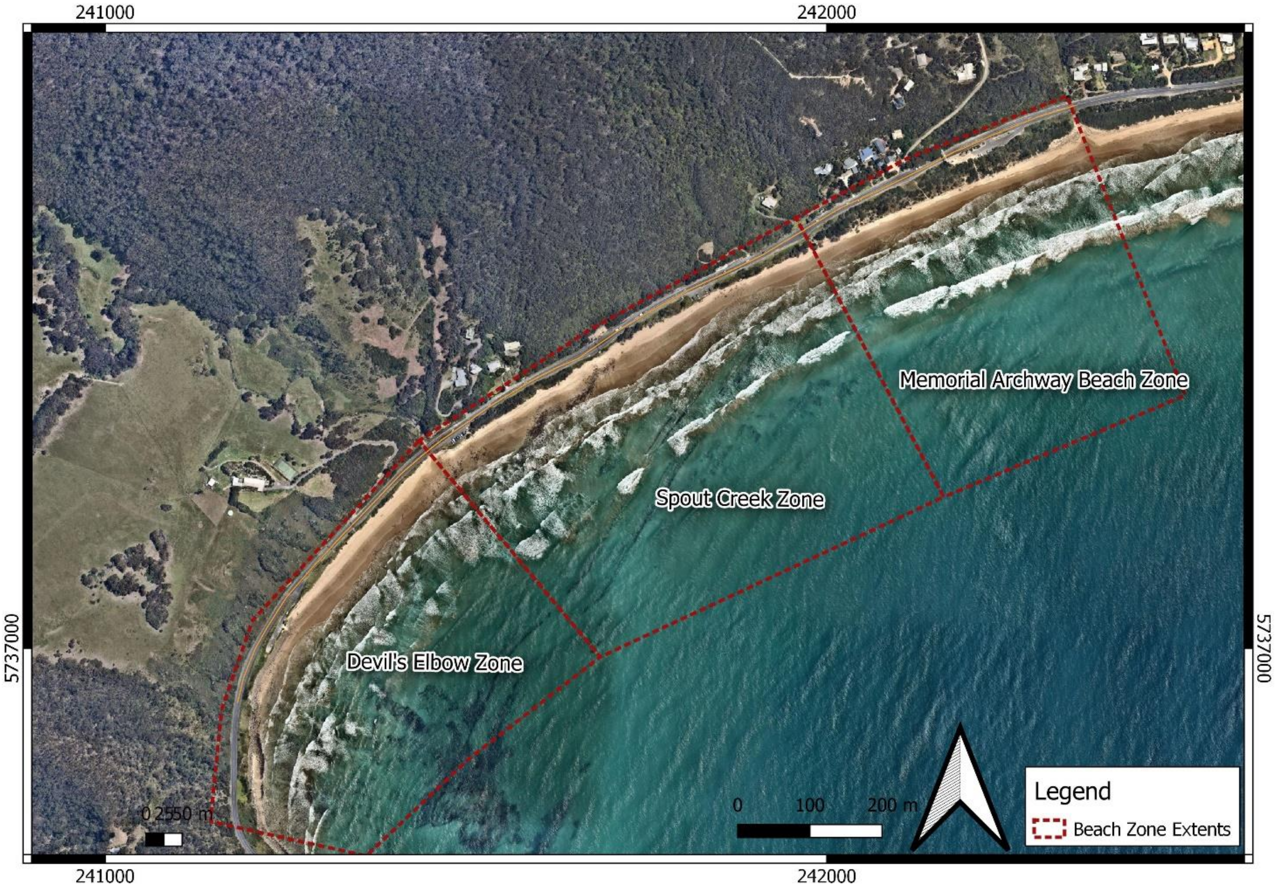

Figure 2-8 Inundation Beach Zones

Wave Runup is also inherently difficult to calculate due to the significant impact of beach slope, beach roughness and general beach morphology variability along a coast on the run-up extent. In this study, we estimate the wave runup extent (m) of the highest 2% of incoming waves ($R_{2\%}$) for the same three beach zones as for wave setup. This was done for ARI1, ARI10, ARI50 and ARI100-year events using the Nielsen and Hanslow (2000) equation [1] where,

$$R_{2\%} = 0.366 g^{\frac{1}{2}} \tan\beta \, H_o^{\frac{1}{2}} T \qquad [1]$$

- Gravity (g) = 9.81 m/s^2,
- The average shoreline gradient (tanβ) was calculated individually for each beach zone by averaging the gradient between the dune toe and the mean high water beach level (Doran et al. 2015),

- h_0 values were derived from a single, common modelled Hs value for each ARI event across all beach zones (Table 2-2) using a hs/h_0 ratio of 1.1 (steep waves) (Thompson and Vincent 1985),
- Modelled swell wave peak spectral period (Tp) values were used.

These calculations and results are generally consistent with previous estimations of wave runup on the surf coast (Water Technology 2012) with the resultant $R_{2\%}$ wave runup values summarized in Table 2-6.

Table 2-6 $R_{2\%}$ Wave Runup (m) Above Wave Setup Level

$R_{2\%}$ Wave Runup (m)	Beach Zones		
	Devil's Elbow	Spout Creek	Memorial Archway
ARI1	3.9	2.9	2.9
ARI10	4.4	3.2	3.2
ARI50	4.8	3.5	3.5
ARI100	4.9	3.5	3.6

The water level values in this section are used to assess the inundation hazard below in Section 2.3.

2.2.4 Climate Change and Sea Level Rise

Climate change currently affects and is forecast to increasingly affect many varying global processes (IPCC 2019). This is especially true for mean sea level and the various coastal processes which act to shape the coastline many of us inhabit (IPCC 2014).

McInnes et al. (2009) forecasted the climate change induced sea level rise in Bass Straight relative to mean sea level from 1995 – 2005 under the climatic conditions described in Table 2-7. Subtracting the baseline sea level rise value for 2021 of 0.07 m (above mean sea level from 1995 – 2005) calculated by the IPCC (2019), the McInnes et al. (2009) predictions are shown to be 0.05 m below the benchmark of 0.8 m of sea level rise by 2100 relative to 2020 MSL designated in the Victorian Marine and Coastal Policy (VMACP) (DELWP 2020). These values are thus scaled up by 0.5 m to align with the VMACP requirements (Table 2-8).

Table 2-7 Summary of the sea level rise estimations and climate change induced wind speed changes for Bass Strait (McInnes et al. 2009)

		2030	2070	2100
IPCC 2007 A1FI Scenario with high wind speed	Sea Level Rise Relative to 1995-2005 MSL (m)	0.15	0.47	0.82
	Wind Speed Increase (%)	4	13	19

Table 2-8 Adopted Sea Level Rise Values

	2030	2070	2100
Scaled Sea Level rise values relative to 2021 MSL (m)	0.13	0.45	0.8

As well as reporting sea level rise values, McInnes et al. also calculated storm tide levels under 2030, 2070 and 2100 future climate change model scenarios. These predictions include (notedly with significant uncertainty) the effects of predicted increases in average annual wind speeds in Bass Straight (CSIRO, Australian Bureau of Meteorology 2007). In previous work, McInnes et al. (2005) showed that such a localised 1% increases in wind speed linearly correlated to a 2% increase in storm surge height in Bass Strait. This rule allowed McInnes et al. (2009) to factor wind forcing on storm surge into storm tide calculations under different future climate change scenarios for Lorne, approximately 8 km from Eastern View. As outlined above, 0.05 m was added to these storm tide heights to align with the requirements of the VMACP (DELWP 2020). The adopted storm tide values are summarized in Table 2-9.

Table 2-9 Estimated Future ARI 10, 20, 50 and 100 year event storm tide elevations for the scenario outlined in Table 2-7 at Lorne (applicable to Eastern View).

	Future Storm tide height (m AHD)		
	2030 SL	**2070 SL**	**2100 SL**
ARI10	1.57	1.99	2.40
ARI20	1.72	2.11	2.55
ARI50	1.86	2.27	2.68
ARI100	1.96	2.38	2.79

2.2.5 Sediment Transport

2.2.5.1 Long Shore Transport

Longshore sediment transport occurs along a coast when waves impact the beach consistently from an oblique angle. As shown in Figure 2-6B, Eastern View has two dominant wave source directions, the SE and south, both of which impact the beach at Eastern View obliquely. Southerly swell waves occur approximately 50-70% of the time (McInnes et al. 2011 and Figure 2-9) at Eastern View and drives sediment transport west to east. Depending on the size of the swell event and the height of any ensuing storm surge, these waves can also cause significant storm erosion of the dunes.

SE wind waves push sediment transport east to west, filling into the corner at Devil's elbow. These wave events occur more often in summer months and depending on the storm intensity, may cause significant erosion of the dune.

The net sediment transport from west to east along the study site area (Figure 2-9). This means that erosion often occurs at the Devil's Elbow end of the beach, and that sand from this process travels along the coast towards Fairhaven. The strong net west to east sediment transport direction suggests that sediment is supplied to the study site compartment from around the devil's elbow headland and from the sea floor and is lost from the compartment once it rounds the Aireys Inlet headland (Split Point).

Net annual sediment transport for Eastern View has not been calculated in previous studies. Modelling by CES (2005) for Apollo Bay described a west - east net sediment transport of approximately 80,000 m^3/yr. Water Technology (2019) performed a similar assessment for Anglesea bay and calculated the annual west - east net sediment transport to be approximately 250,000 m^3/yr. GORCC (2017) assumed the net sediment transport at Eastern View to be similar to the conservative Anglesea value.

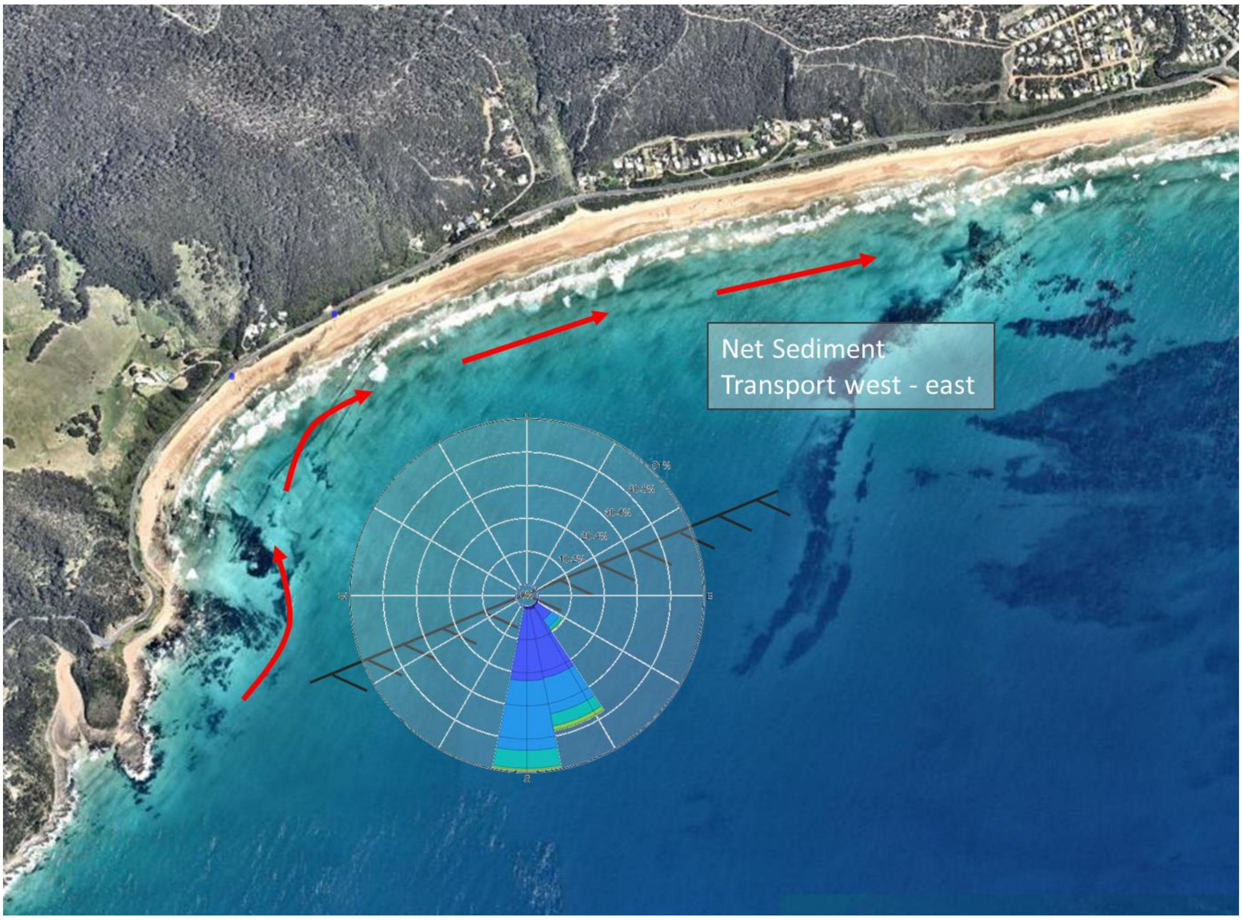

Figure 2-9 Wave rose with net sediment transport direction

2.2.5.2 Cross shore transport

Cross shore transport of sediment is a cyclical process whereby sand is moved between the beach and offshore sandbars. During a storm when large waves impact the beach, sediment is transported off the beach and formed into a sandbar some distance offshore. Under ambient conditions when small waves impact the site, this sand is usually transported back to the beach to re-fill eroded areas.

At Eastern View, storm cut of the beach can occur at any time of the year with either winter large S-SW swell wave events or predominantly summer SE wind wave events. Ambient conditions usually occur during the summer months thus (albeit with significant fluctuations), there is likely to be a lower beach level during winter months and higher beach levels during summer months.

Storms with elevated water levels and large waves typically erode sand from the beach and dune and deposit it in nearshore sandbars. 'Storm demand' is defined as the volume of sediment removed from a shore profile per meter of shoreline above 0 m AHD elevation (Mariani et al. 2012). Storm demand values can be calculated for individual beaches if survey is available pre- and post-storm. These can vary substantially both along a beach and between beaches with differing shoreline characteristics.

Mariani et al. (2012) calculated representative storm demand values for different coastal compartments around Australia using XBEACH and SBEACH models. The values calculated by Mariani et al. for the Lorne – Lonsdale coastal compartment are reported in Table 2-10. These values are used in the Erosion Hazard assessment for comparison to our beach specific calculated values (Section 2.4.1).

Table 2-10 Storm Demand Values, Lorne – Lonsdale Coast (Mariani et al. 2012)

Storm Return Interval	Storm Demand (m^3/m)
ARI1	37
ARI10	55
ARI100	85

2.3 Inundation Hazard

The inundation of sections of coastline occurs when coastal sea levels are elevated. This often occurs due to the combination of astronomical tide, storm surge, wave set up and wave run up. Because each of these are constantly changing, extreme water levels at a site only occur when the various constituents of water levels combine. These extreme water level events are also forecast to increase into the future as sea levels rise.

To predict current and future extreme water levels at Eastern View, we used the values summarized in Table 2-11 as calculated above in Section 2.2.2. For predictions of future extreme water levels (

Table 2-12), we use ARI10-year storm tides combined with ARI1-year wave runup. This represents a future scenario in which coastal assets below a certain elevation are predicted to be at risk of wave overtopping in an ARI10-year storm.

Table 2-11 Extreme Water Level Constituent Values Used in Hazard Mapping

Water Level Constituent	Devil's Elbow Beach Zone	Spout Creek Beach Zone	Memorial Arch Beach Zone
Mean High Water Spring Tide (MHWS) (m AHD)	0.8	0.8	0.8
Current Storm Tide (HAT + Storm Surge, ARI10-year) (m AHD) (McInnes et al. 2009)	1.32	1.32	1.32
2030 Storm Tide (HAT + Storm Surge, ARI10-year) (m AHD) (McInnes et al. 2009)	1.52	1.52	1.52
2100 Storm Tide (HAT + Storm Surge, ARI10-year) (m AHD) (McInnes et al. 2009)	2.35	2.35	2.35

Water Level Constituent	Devil's Elbow Beach Zone	Spout Creek Beach Zone	Memorial Arch Beach Zone
Wave Set Up (SBEACH model) (m AHD)	1.3	1.3	1.4
$R_{2\%}$ Wave Run-Up (ARI1-year event) (m)	3.9	2.9	2.9

Table 2-12 Predicted maximum wave run-up levels

Predicted Water Level (m AHD)	Devil's Elbow Beach Zone	Spout Creek Beach Zone	Memorial Arch Beach Zone
Current Coastal Runup Level	6.6	5.5	5.6
Predicted 2031 extreme runup level (m AHD)	6.8	5.7	5.8
Predicted 2101 extreme runup level (m AHD)	7.6	6.5	6.6

2.3.1 Storm Tide Inundation

Storm tides occur when coastal still-water levels are elevated due the combination of low atmospheric pressure (storm fronts), storm surges and high astronomical tides (Table 2-11). When shoreline assets are at low elevations, they may be inundated when storm tides occur.

The typical elevations of shoreline assets at Eastern View are:

- Dunes (and associated vegetation) – 4.5 to 7 m AHD
- Carparks – 4.25 to 7.25 m AHD
- Great Ocean Road – 5.25 -10 m AHD.

The lowest elevations of all shoreline assets are all higher than the current or future predicted storm tide levels (Table 2-11). Therefore, these areas are not predicted to be subject to submergence under storm surges.

2.3.2 Overtopping Inundation

Overtopping inundation is different to storm tide inundation. This is because wave runup is not an elevated still-water level, but rather individual waves running up the shore. These waves are slowed by rough terrain (e.g., erosion scarps, vegetation) and will infiltrate into sandy soils, reducing the volume of water in the wave.

Wave overtopping can cause scour of soil, damage to pavement and is a hazard to vehicles travelling at high speed. Hence, when assessing the risk from this type of inundation, a vegetated dune provides significant protection.

2.3.2.1 Current Hazard

Results of the analysis of current inundation risk shows that neither the Great Ocean Road nor the carparks are currently at risk of overtopping inundation due to the presence of the dunes and vertical erosion scarps along much of the site. These characteristics have the effect of minimising potential wave runup extents and protecting the carparks and road.

2.3.2.2 2031 Hazard

Inundation hazard was mapped across the site for 2031 by comparing the extreme water level predictions for each zone (Table 2-12) to the elevation of the Great Ocean Road. Where extreme water levels were mapped as greater than the road elevation, these zones were inspected for areas where the dune is either currently non-existent or is forecast to be completely eroded. The roads and carpark areas landward of these sections were deemed to be at risk from overtopping inundation by wave runup.

Four portions of the Great Ocean Road and carparks in the Devil's Elbow and Spout Creek Beach Zones are predicted to be at risk of overtopping inundation by 2031 (Figure 2-10 and Figure 2-11). The memorial arch zone is largely safe from overtopping in 2031 due to the high dunes and higher elevation of the road in this area (Figure 2-12).

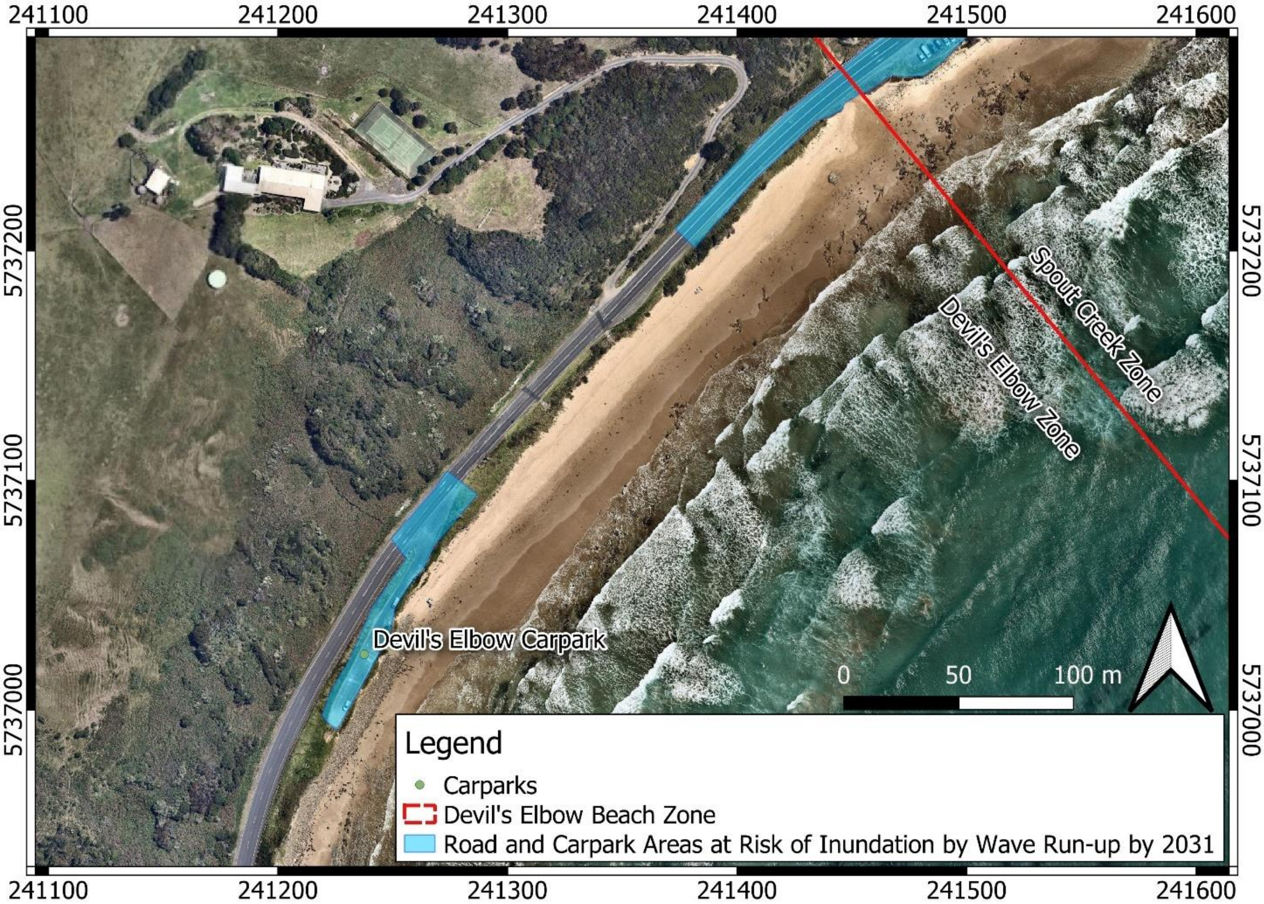

Figure 2-10 Road and Carpark areas at risk of inundation from wave runup in the Devil's Elbow beach zone by 2031.

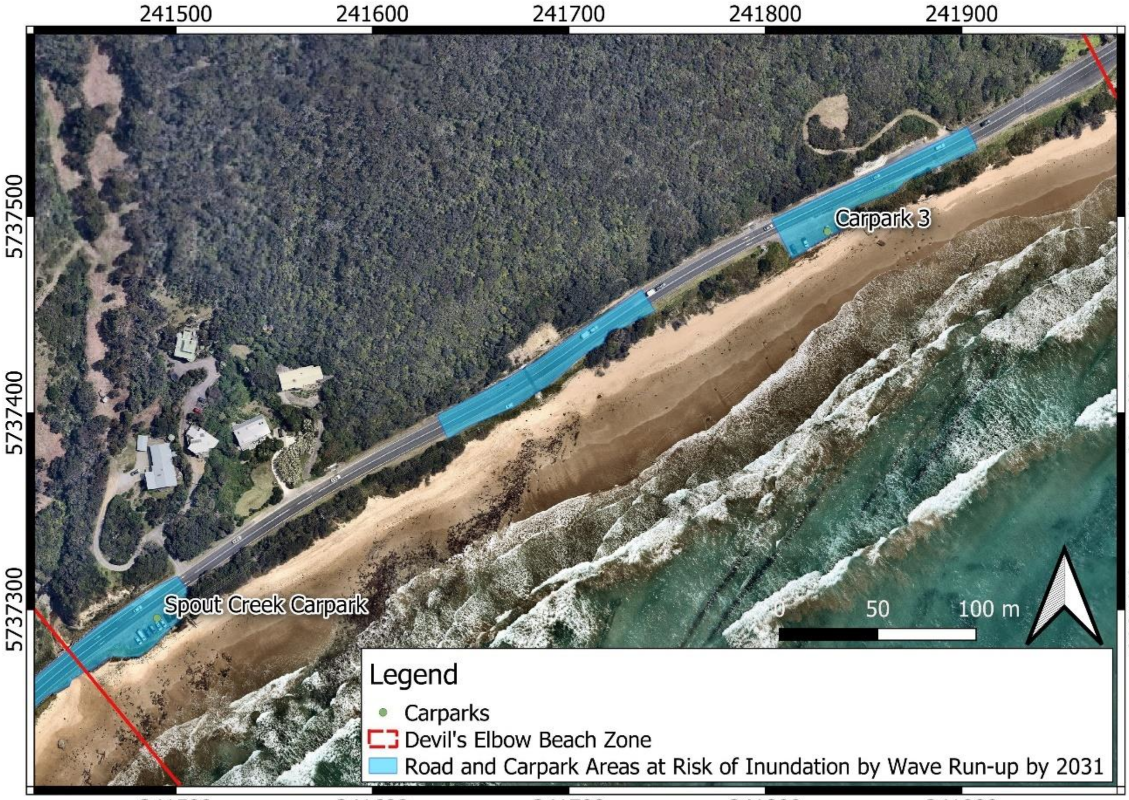

Figure 2-11 Road and Carpark areas at risk of inundation from wave runup in the Spout Creek beach zone by 2031.

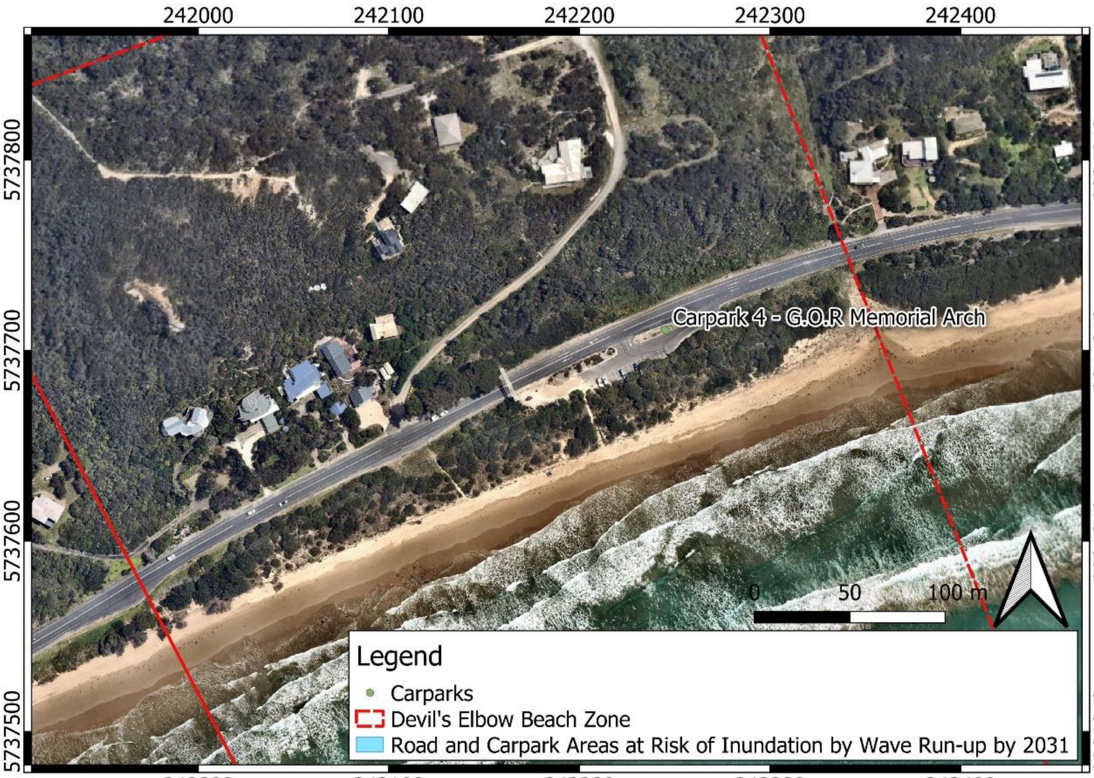

Figure 2-12 Inundation hazard – Memorial Archway Beach Zone

The process of determining areas at risk from wave overtopping in the future involves some conservative assumptions about how the dunes will erode and how dune scarps are likely to impact wave run up. As such, there is significant uncertainty in the inundation mapping shown in Figure 2-10, Figure 2-11 and Figure 2-12.

2.3.2.3 2101 Hazard

By 2100, all carparks are predicted to be at risk of overtopping, as well as approximately 850 m of the Great ocean Road between the Devil's Elbow carpark and 50 m east of Carpark 3.

By this time, however, it is likely that much of the Great Ocean Road will be protected by coastal structures (e.g., revetments) which will modify the wave run up and inundation hazard. With good design, these structures may minimise the risk of inundation to much of the area.

2.4 Erosion Hazard

Current and future erosion hazard has been predicted using three components,

- Storm erosion,
- Recession due to sediment loss, and
- Recession due to sea level rise.

Each of these constituents are calculated below in subsequent sections.

2.4.1 Storm Erosion

The extent of storm erosion along a beach under storm conditions shows considerable spatial variability depending on beach gradient, sediment size, the presence of single or multiple sand bars, rips, low tide beach terraces, deep troughs and a variety of other beach morphological features (Mariani et al. 2012).

The recent storm erosion for the Eastern View study area was analysed using photogrammetry data collected by the Victorian Coastal Monitoring Program (VCMP) between Devil's Elbow and Coalmine Creek before and after (18/3/2021 and 29/4/2021) two significant storm events which occurred during April 2021 (Figure 2-15). These events had maximum significant wave heights (h_s – measured at the Apollo Bay wave buoy) of 4.9 m and 3.9 m (10th April 2021 and 22nd April 2021 respectively), both with associated peak spectral periods (Tp) of over 20 s.

Using directional extreme value analysis (EVA) (Table 2-13) of the SWAN modelled wave height data for the Apollo Bay wave buoy location (See Figure 2-6 for modelled data time series and Section 2.2.2 for discussion of how the data was modelled) the larger 4.9 m Hs event on 10/4/21 had an estimated return interval of 50 years. Erosion from this event was seen during the on-site stakeholder meeting (20/04/2021), especially at Carpark 3 (Figure 2-13 and Figure 2-14).

The second storm on 22/4/21 has a much smaller maximum Hs of 3.9 m with an estimated ARI of 1 year.

Hence it is assumed that the vast majority of storm erosion which occurred between surveys occurred due to the initial ARI 50-year event.

Figure 2-13 Erosion at Carpark 3 seen on 20th April 2021

Figure 2-14 Erosion at Carpark 3 seen on 20th April 2021.

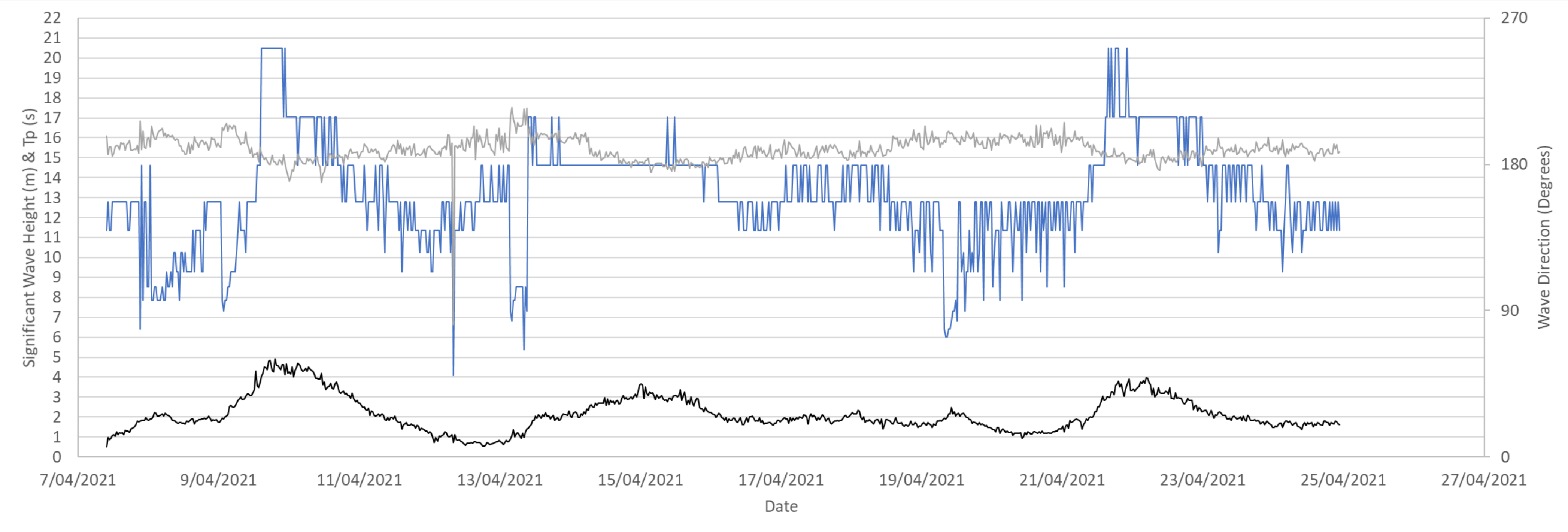

Figure 2-15 Significant wave heights and peak periods at Apollo Bay Wave Buoy Location from 18/3/21 – 29/4/21 (Between Surveys)

Table 2-13 Apollo Bay Wave Buoy Extreme Value Analysis – Significant Wave Height and Period for 180 degree swell wave events.

Hs (m)	ARI1	ARI10	ARI50	ARI100
180°	3.78	4.49	4.88	5.03

Tp (s)	ARI1	ARI10	ARI50	ARI100
180°	14.2	15.5	16.2	16.4

Analysis of the storm erosion occurring between 18th March 2021 and 29th April 2021 showed the presence of three distinct beach zones in which differing levels and patterns of erosion were seen (Figure 2-16). For the sake of this analysis, these zones are labelled Devil's Elbow Zone, Spout Creek Zone and Memorial Archway Zone, (the same zones used for the inundation hazard assessment).

Specific beach-zone erosion transects were then placed in the area within each zone where the maximum storm erosion was evident (Figure 2-17, Figure 2-18 and Figure 2-19). Profiles taken along these transects were then used to calculate representative values of storm cut (beach/dune volume reduction per lineal meter of dune (above MSL)), and dune crest vegetation line recession (analogous for dune crest recession) for each of the beach zones as outlined in subsequent sections.

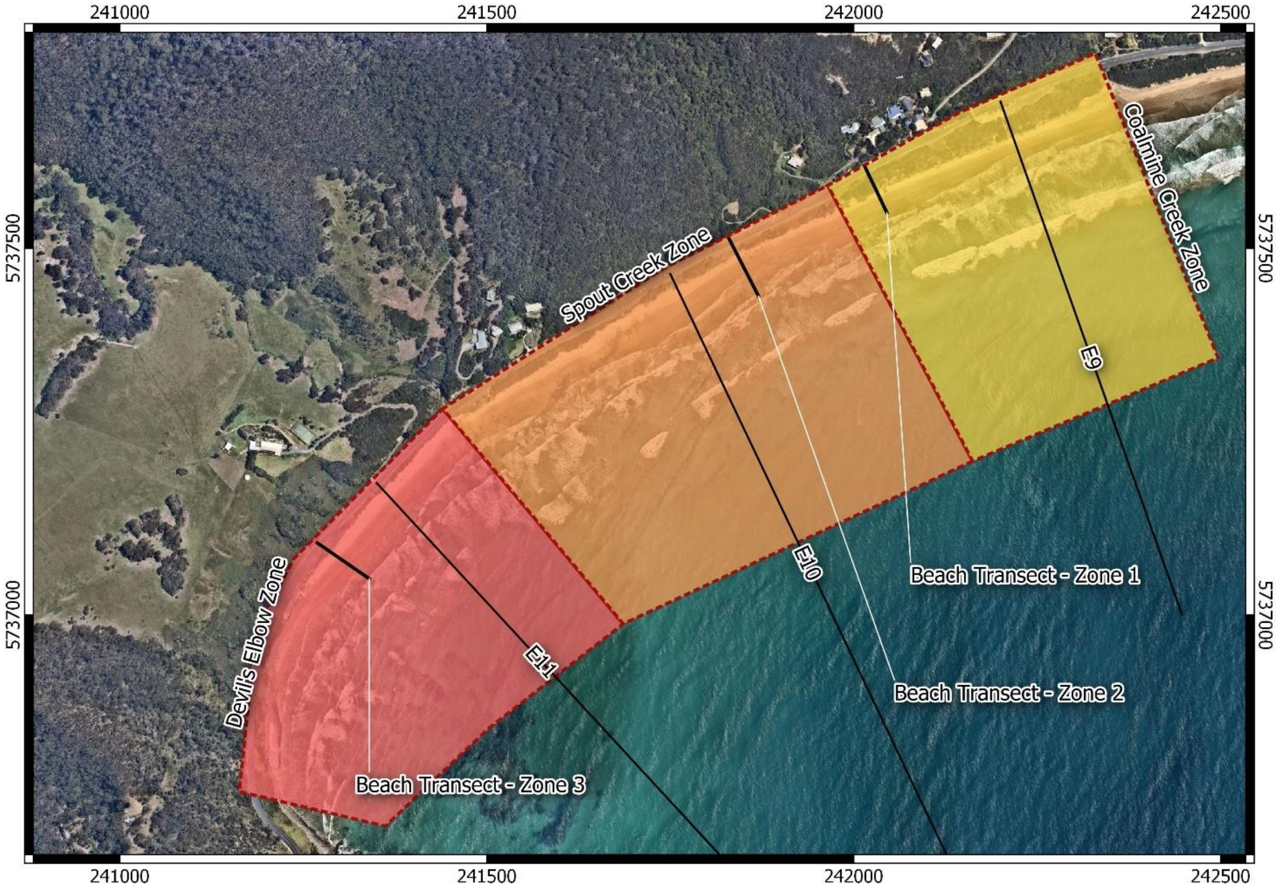

Figure 2-16 Storm Cut Calculation Beach Zone Map

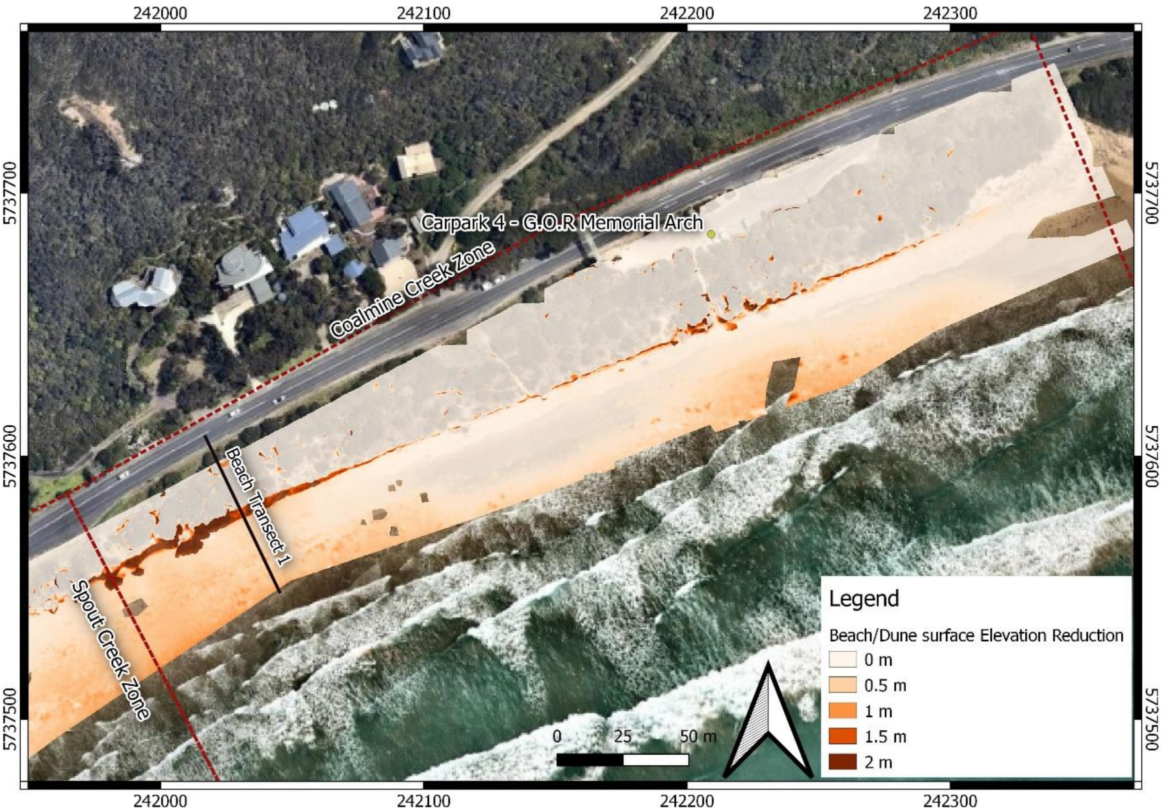

Figure 2-17 Memorial Archway zone surface elevation reduction map.

Figure 2-18 Spout Creek Beach Zone surface elevation reduction map

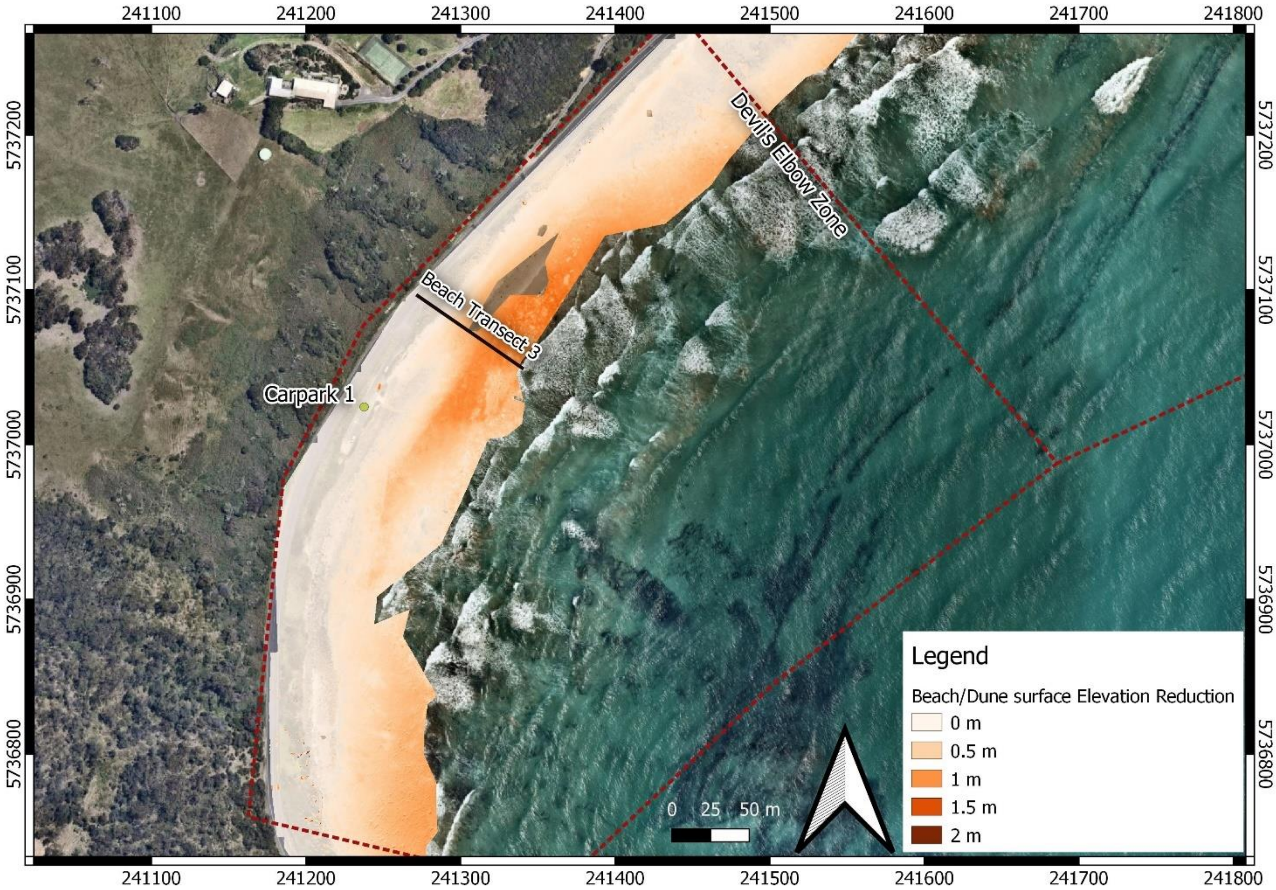

Figure 2-19 Devil's Elbow Beach zone surface elevation reduction map

2.4.1.1 Memorial Arch Beach Zone

Dune recession and storm cut were calculated on a representative profile shown in Figure 2-20 which was positioned to approximate the 90th percentile of vegetation line recession values in this zone. It was also positioned to avoid areas of dune crest where vegetation obscured ground levels in the pre-storm survey.

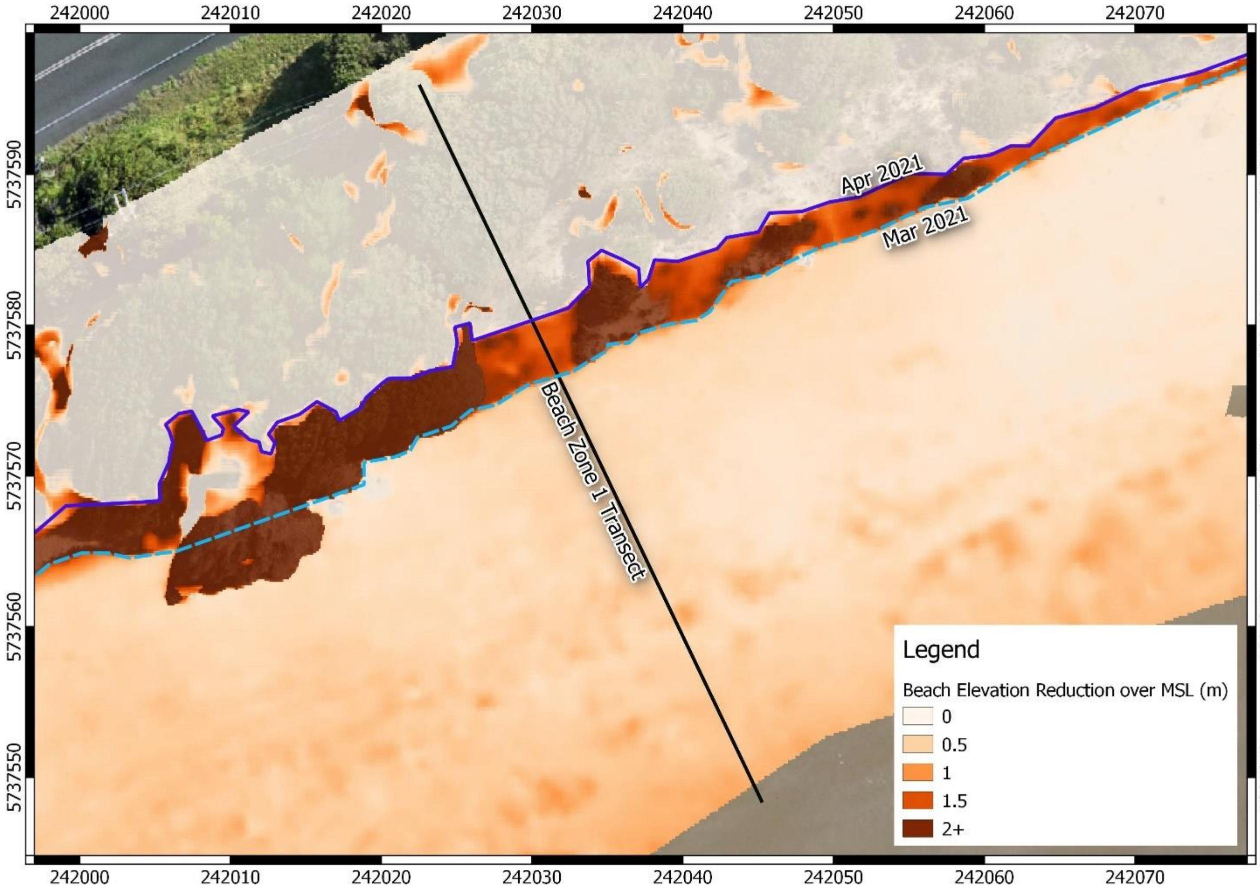

Figure 2-20 Transect placed over beach/dune surface elevation change (between surveys) and vegetation lines from pre- and post-survey.

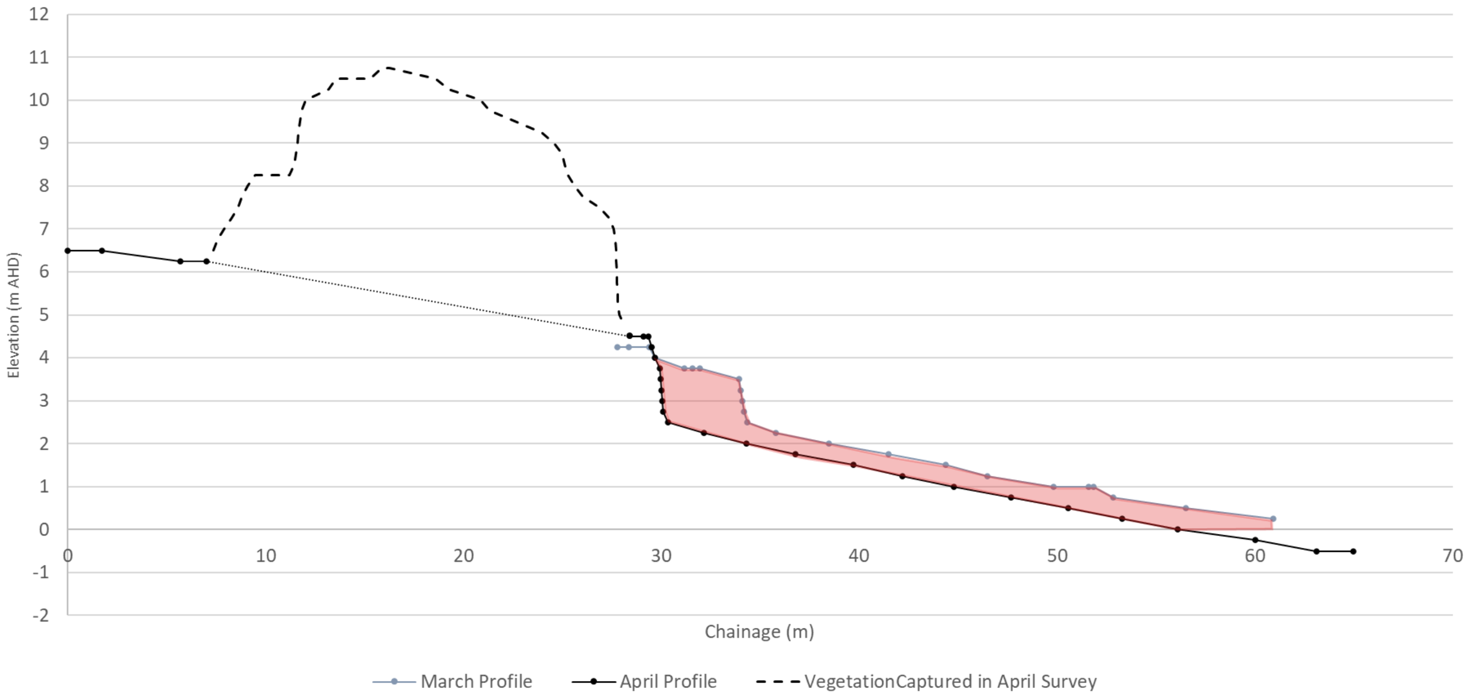

Figure 2-21 Beach profile comparison pre- and post-ARI 50-year Hs event. Shaded area represents volume of sand eroded.

Table 2-14 Storm Erosion from ARI 50-Year Hs event for Memorial Archway Zone.

	ARI 50-Year Wave Event Storm Erosion
Vegetation Line Recession (m)	4.1
Storm Cut above 0 m AHD (m^3)	18.7

2.4.1.2 Spout Creek Zone

The dune/vegetation line/carpark recession in this beach zone from an ARI 50-year storm is calculated to be 1.8 m (Figure 2-22) at Beach Transect 2 which was positioned to approximate the 90th percentile of vegetation line recession values in this area. It was also positioned to bisect carpark 3, one of the most at risk asset in the study area. This was done to enable accurate estimation of the risk to this asset for future adaptation pathways planning.

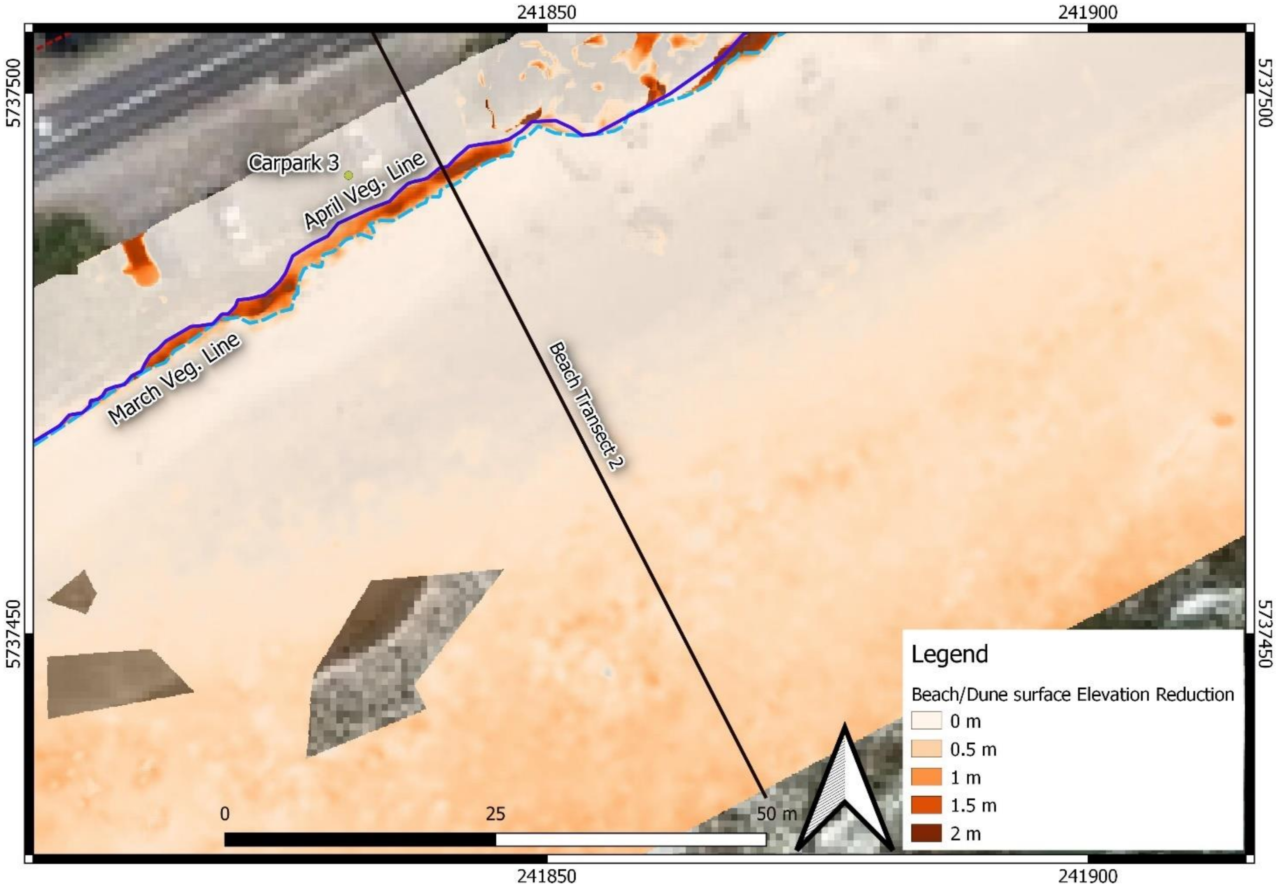

Figure 2-22 Beach Transect 2, Spout Creek Beach Zone – Difference Plot

The reduction in sand volume along Beach Transect 2 above MSL (0 m AHD) was identified by calculating the vertical area of sediment lost between the March and April surveys (Figure 2-23 and Table 2-15). Interestingly, it seems that this profile showed greater volumes of sub-MSL erosion than for the Coalmine creek zone profile.

Figure 2-23 Beach profile comparison pre- and post-ARI 50-year Hs event. Red shaded area represents volume of sand eroded per m of beach.

Table 2-15 Storm Erosion from ARI 50-Year Hs event for Spout Creek Beach Zone.

	ARI 50-Year Wave Event Storm Erosion
Vegetation Line Recession (m)	1.8
Storm Cut above 0 m AHD (m^3)	7.2

2.4.1.3 Devil's Elbow Zone

Interestingly, the Devil's Elbow Beach zone showed minimal vegetation line recession between the two surveys (Figure 2-25) with only 0.3 m seen at Beach Transect 3 (Figure 2-24). Contrasting the previous two beach transects (sections above), this transect was not situated to show the maximum vegetation recession value but was placed to demonstrate the significant erosion of the lower beach profile towards 0 m AHD (Figure 2-25).

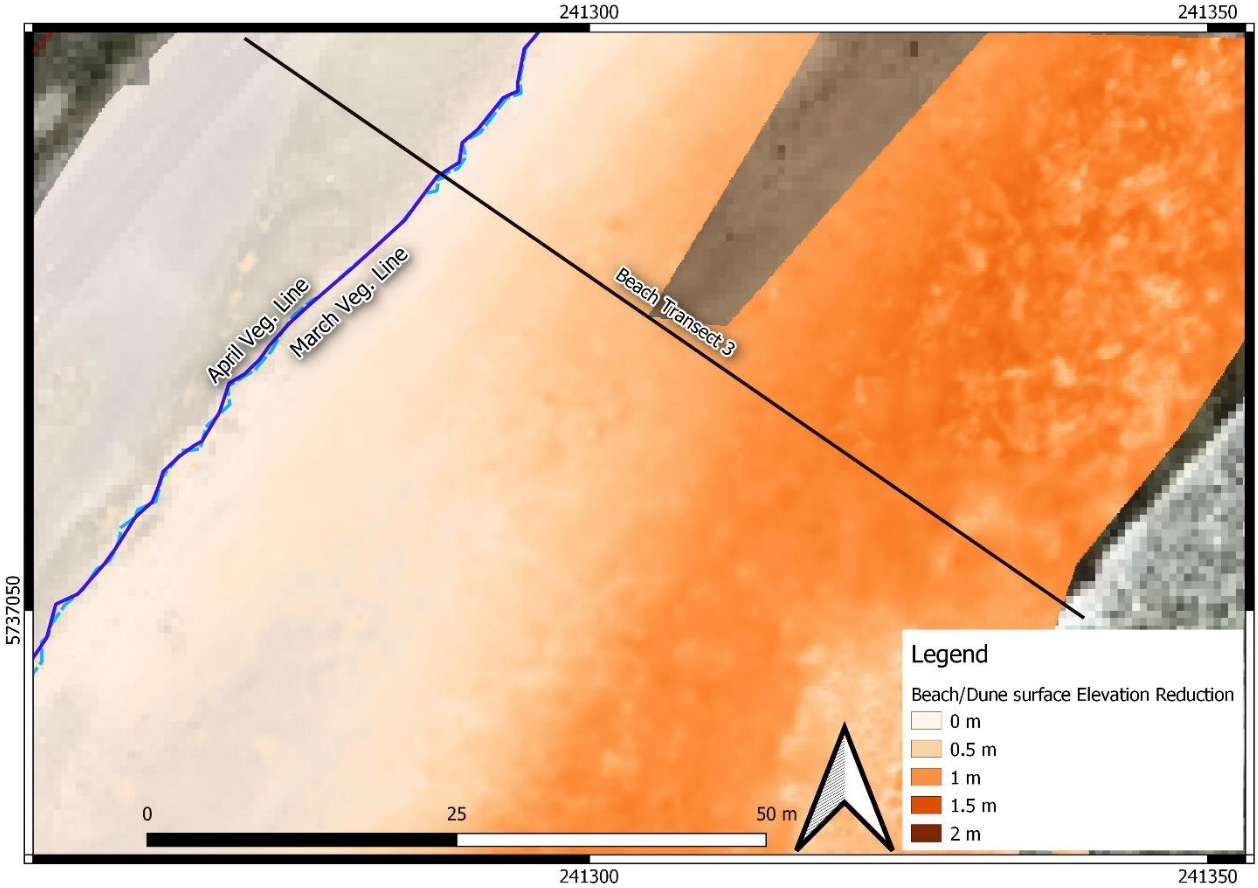

Figure 2-24 Beach Transect 3, Devil's Elbow Beach Zone – Difference Plot

The reduction in sand volume along Beach Transect 3 above MSL (0 m AHD) was identified by calculating the vertical area of sediment lost between the March and April surveys (Figure 2-25 and Table 2-16). Interestingly, although there was minimal dune erosion in this area, Beach Transect 3 showed the greatest volumes of sub-MSL erosion out of all transects measured.

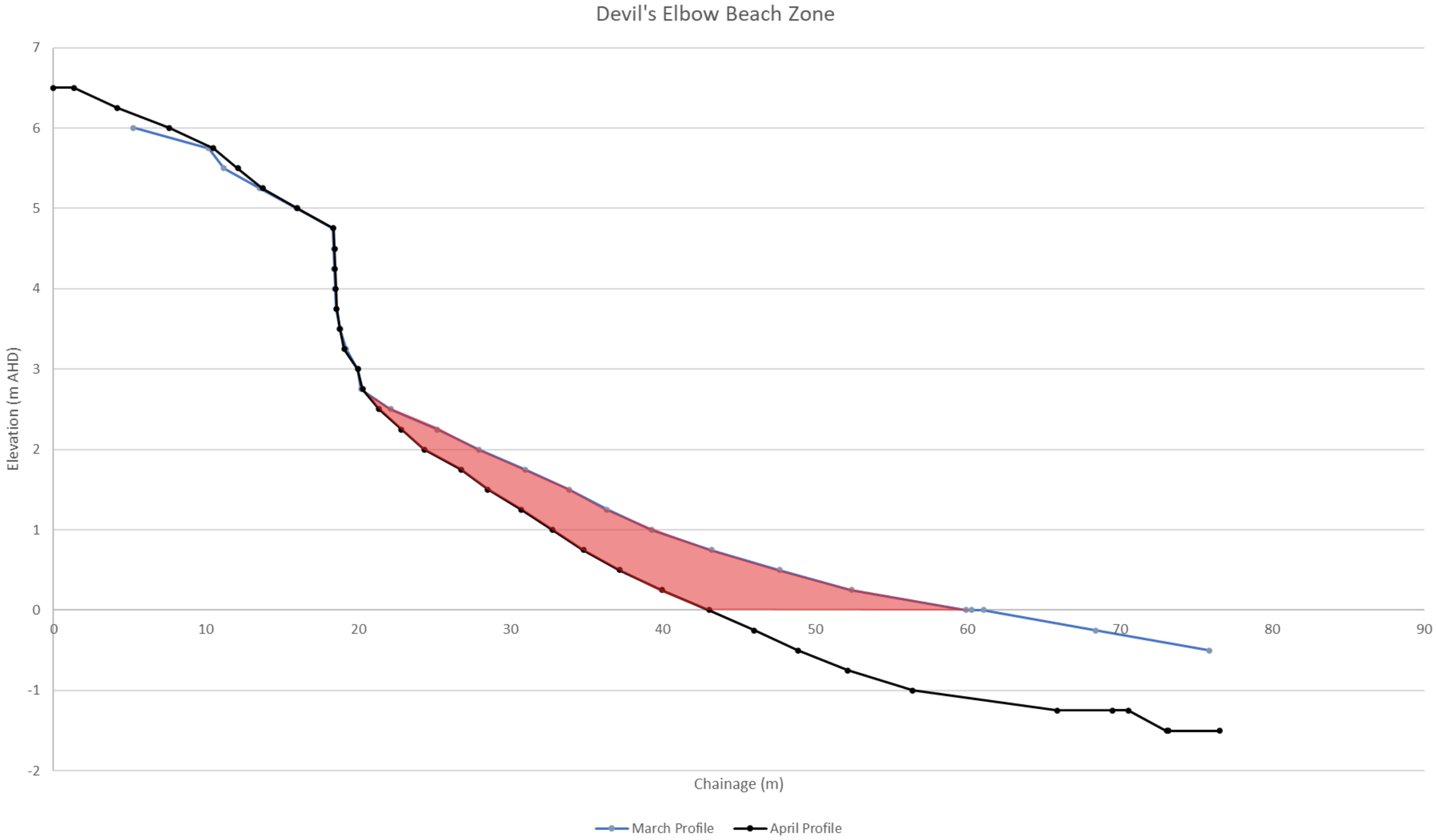

Figure 2-25 Beach profile comparison pre- and post-ARI 50-year Hs event. Red shaded area represents volume of sand eroded per m of beach.

Table 2-16 Storm Erosion from ARI 50-Year Hs event from Devil's Elbow.

	ARI 50-Year Wave Event Storm Erosion
Vegetation Line Recession (m)	0.3
Storm Cut above 0 m AHD (m^3)	16.9

2.4.1.4 Implications for Erosion Hazard

The extent of storm erosion occurring along a stretch of beach is highly dependent on a raft of morphological features (Mariani et al. 2012) which constantly change over time (eg. Beach steepness, presence of offshore sandbars, deep troughs etc.). As such, it is generally assumed that the section showing maximum storm erosion along a beach after a storm could potentially occur anywhere along the beach in future storms, depending on the beach morphology at the time.

At Eastern View after an ARI 50-year storm event, the maximum vegetation line recession was 4.1 m and the maximum sand erosion per m of beach above 0 m AHD was 18.7 m^3 (Table 2-14). These two values occurred coincidently at the Memorial Arch beach zone, however if the storm occurred when the beach had slightly different morphology, it may have occurred anywhere from Spout Creek to Coalmine creek. It is unlikely that the same level of dune recession would have occurred in Devil's Elbow as it is protected by the southern headland with SW swell waves required to refract into the beach (losing significant amounts of energy) before impacting shores. This is seen in the minimal dune recession at Devil's Elbow seen during the ARI 50-year event analysed. Therefore, as outlined in Table 2-17 smaller storm erosion dune recession values are adopted for the Devil's Elbow zone.

Generic storm demand values for coastlines around Australia have previously been calculated by Mariani et al. (2012) using X-Beach models (Table 2-10). These generic values (37, 55 and 85 m^3/m for ARI1, ARI10 and ARI100-year events respectively) are substantially greater than the maximum storm demand of 18.7 m^3/m measured in this study. This is suggested to be because these previous models did not take into account the presence of erosion-resistant rock layers under the beach or the presence of small-scale beach morphology (e.g., the presence of near shore reefs or sandbars) which would act to lessen the amount of wave energy impacting the shore and the potential amount of sand which could be transported away off from the shoreline. Although this is true, to maintain a conservative approach to coastal adaptation planning pathways, the adopted ARI50-year storm demand values are greater than our measured values (Table 2-17).

Table 2-17 Adopted ARI50-year Storm Demand and Erosion Values

Erosion Type	Devil's Elbow	Spout Creek	Memorial Archway
Storm Demand (m^3/m)	20	30	30
Dune Recession (m)	2	4	4

2.4.2 Coastal Recession Due to Sediment Loss

Long-term coastal recession can occur for a number of reasons including sea level rise and sediment deficit. A sediment deficit occurs on a beach when there is more sand being removed from the area than is being returned (e.g. through long-shore drift or cross shore transport). Although shoreline position often fluctuates on shorter time scales (e.g. seasonally), a sediment deficit can be identified through comparison of yearly aerial photographs from previous years. Coastal Recession due to sediment loss is here defined as the long-term recession rate (m/year) of the beach.

Coastal recession was calculated by CES (2012) for years 1947-2007 along transects E9, E10 and E11 in the current study area as shown in Figure 2-26. In this study we calculated the recession along the same transects for the years 2007-2021, additionally to the previous CES calculations Table 2-18.

Results showed that the beach along transects E9 and E10 accreted between 1947 and 2007, after which erosion occurred to the current level. Transect 11 showed sediment accretion between 1947 – 1991, after which erosion occurred to the present level. Transects E9 and E10 saw the highest levels of erosion since recording began from the decade between 2007 and 2017. Transect E11 saw the second greatest erosion magnitude on record in the same years.

Figure 2-26 Image Showing the position of the three transects measured by CES (2012).

Table 2-18 Landward coastal recession distances using 2007 dune crest position as a baseline. Data from 1947 – 2007 adapted from CES (2012).

	Shoreward Recession Distance (m)*												
	Easting	Northing	1947	1951	1962	1975	1977	1986	1991	2002	2007	2017	2020	2021
E9	242200	5737700	-26	-23	-21	-2	-8	-7	-5	-6	0	-8.3	-9.7	-9.8
E10	241750	5737465	-22	-21	-17	-2	-1		-1	-1	0	-9.6	-10.9	-10.5
E11	241350	5737180	1	1	-1	7	4		9	3	0	-5.0	-4.2	-4.6

**Note: negative values refer to shoreline position landward of 2007, positive values refer to seaward position*

Coastal recession due to sediment loss has only occurred at the study site since approximately 1991 Figure 2-27. As such, coastal recession rates due to sediment loss are here calculated as the average recession rate between the 30 years from 1991 and 2021. Adopted coastal recession rates for each beach zone are summarized in Table 2-19.

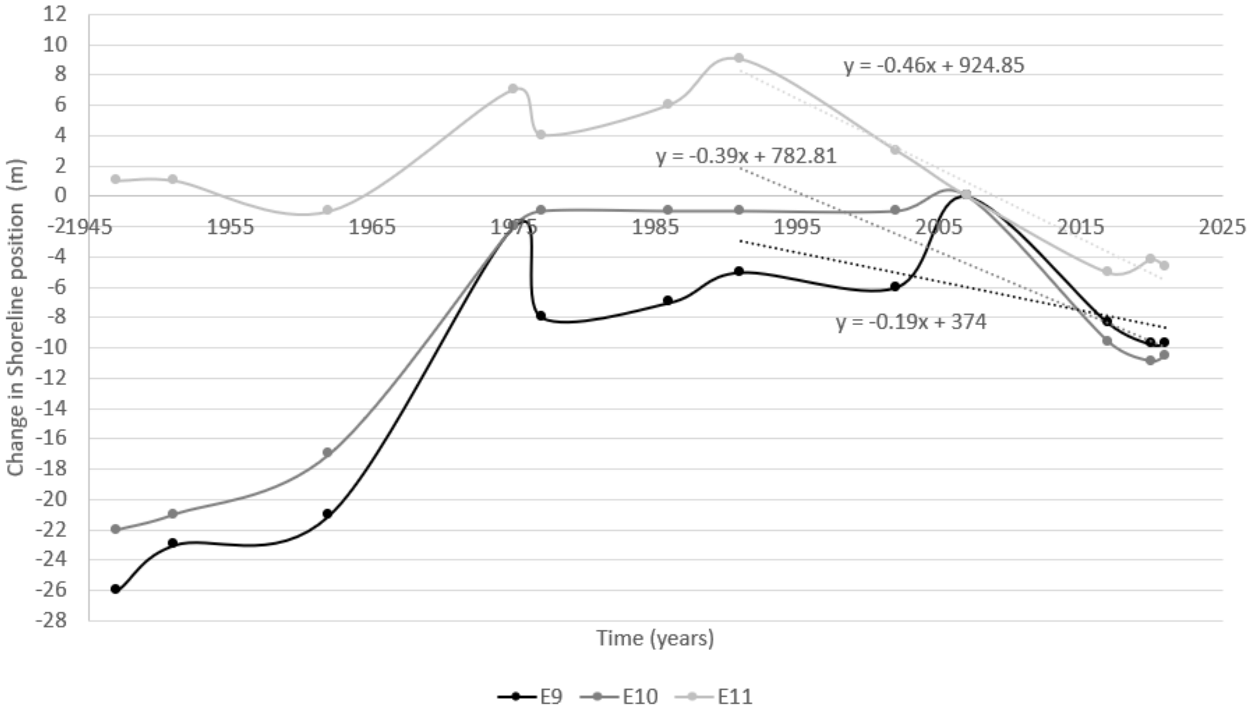

Figure 2-27 Shoreline position trends at Eastern View with 2007 shoreline position as a baseline.

Table 2-19 Adopted Coastal Recession Rates due to sediment loss.

	Devil's Elbow	Spout Creek	Memorial Archway
Coastal Recession Rate (1991 – 2021) (m/year)	0.5	0.4	0.2

2.4.3 Coastal Recession Due to Sea Level Rise

As mentioned previously, coastal recession can also occur due to sea level rise (SLR) as SLR increases the water depth near the beach and allows larger waves to reach the shore. This recession is inherently difficult to predict due to fine scale variability of beach structure, e.g., sediment type and the presence (or not) of underlying rock. As such, any prediction of shoreline retreat due to SLR has a high degree of uncertainty.

To assess the likely extent of shoreline, retreat due to SLR, we use the Brunn rule to calculate a recession rate (m recession/ m of SLR). The Brunn rule assumes the beach profile is in equilibrium with the water level and will rise as the sea level rises. For this to occur, the beach profile must also shift landward due to the finite volume of sediment available. The potential landward movement of the shoreline as sea levels rise in some cases is bounded by erosion resistant geology (e.g., a hill or rock outcrop) sitting landward of the shoreline. This is the case at Eastern View with both the Otway Formation and the Eastern View formation forming steep hills/cliffs immediately landward of the GOR shoulder along the entire study site.

The Brunn rule calculates recession as the product of SLR and the shoreline slope. In this study, this slope was calculated using the elevation of the landward edge of the GOR (the furthest possible distance the shoreline could retreat) as an approximation for top of the active beach profile at 7 m AHD and a depth of closure of -8 m AHD. Results of this analysis are given in Table 2-20.

As previously mentioned, there is a high level of uncertainty in these predictions. Regarding the following erosion options analysis, this uncertainty will have little impact on the use of any short-term measures. For long-term options, the time frame is indicative only and may differ from estimated values by years to decades.

Table 2-20 Adopted Coastal Recession Values due to Sea Level Rise.

Beach Zone	Shoreline Recession (m/m Sea Level Rise)
Devil’s Elbow	50
Spout Creek	40
Memorial Arch	40

2.4.4 Predicted Erosion Hazard Zones

The erosion hazard zones for Eastern View were calculated by combining the estimates of storm erosion, coastal recession due to sediment loss and recession due to sea level rise as summarized in Table 2-21. This enabled estimation and mapping of the possible location of the shoreline under various SLR scenarios.

Table 2-21 Recession components and theoretical recession hazards.

Erosion Type	Devil's Elbow	Spout Creek	Memorial Arch
Storm Dune Erosion for ARI50 year Hs event (m)	2	4	4
Long Term Coastal Recession due to sediment loss (m/year)	0.5	0.4	0.2
Coastal Recession due to SLR (m recession/m SLR)	50	40	40

Erosion hazard lines have been calculated and mapped in terms of the worst-case erosion escarpment position after a theoretical occurrence of an ARI50-year storm in the relevant year. Further slumping of this dune scarp as described by Nielsen et al. (1992) is difficult to quantify in this site as the considerable fill overlying the dune sand has the effect of somewhat stabilising the scarp. As such, we have not attempted to include this possible further slumping in the erosion hazard line calculations.

Shoreline position setback distances behind the current dune crest are calculated for the years 2031 and 2051 and summarized in Table 2-22. These are also mapped across the study site area in (Figure 2-28, Figure 2-29 and Figure 2-30).

In the Devil's Elbow beach zone, much of the seaward edge of the Devil's Elbow Carpark is within the immediate hazard zone. Three of the four power poles in this zone are also within the immediate hazard zone (Figure 2-28). By 2031, all of the Devil's Elbow Carpark and much of the GOR nearer to Spout Creek are within the hazard zone. The remaining power pole will also be at risk of erosion by 2031 (Figure 2-28).

In the Spout Creek Beach Zone, considerable portions of both the Spout Creek carpark and carpark 3 are within the immediate hazard zone. There is also one area approximately 250 m east of the Spout Creek carpark where the shoulder of the GOR is within the immediate hazard zone. The only power pole in immediate risk from erosion in this zone is immediately east of the Spout Creek carpark. By 2031, most of both the Spout Creek carpark and carpark 3 are at risk of erosion and the GOR and much of the road shoulder is at risk in the section east of the Spout Creek carpark and landward of carpark 3. At this point, all 6 of the power poles in this beach zone are predicted to be at risk from erosion (Figure 2-29).

The memorial archway beach zone has substantially wider dunes than the other zones and no assets within the immediate hazard zone (not mapped in Figure 2-30 for simplicity). This is similar for erosion hazard in 2031 in this zone with no assets in immediate danger. By 2051, a portion of the GOR in the SW end of the zone near carpark 3 is at risk from erosion as well as four of the 6 power poles in the beach zone (Figure 2-30).

Table 2-22 Erosion Hazard Line Setback Distances Behind April 29th, 2021 Dune Crest

Erosion Hazard Line	Setback Behind 2021 Dune Crest (m)		
	Devil's Elbow	Spout Creek	Memorial Arch
Immediate Hazard Zone (ARI50-year storm erosion)	2	4	4
2031 Erosion Hazard (0.13 m SLR)	12	13	11
2051 Erosion Hazard (0.45 m SLR)	32	28	20

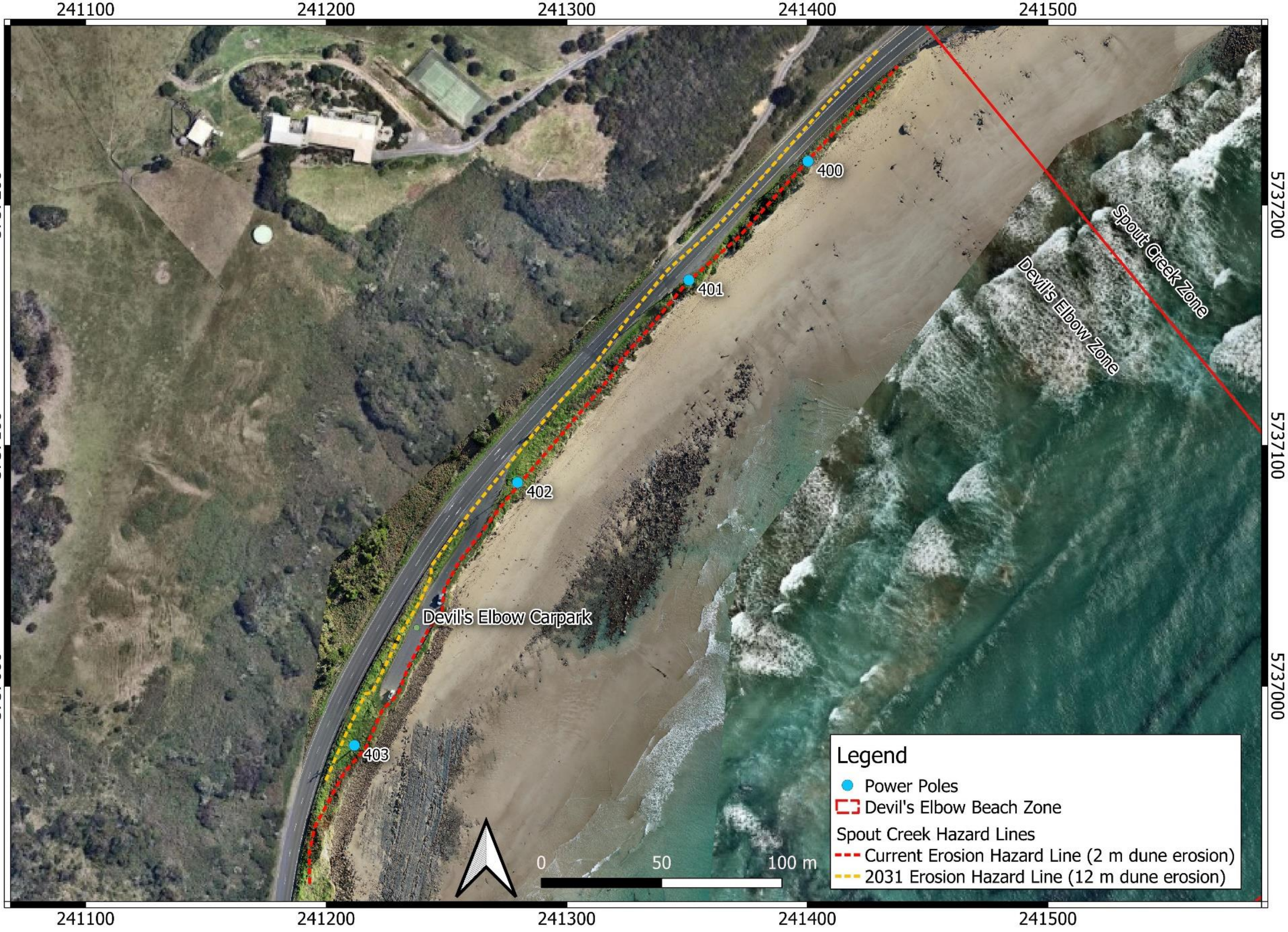

Figure 2-28 Erosion Hazard Map – Devil's Elbow

Figure 2-29 Erosion Hazard Map – Spout Creek Beach Zone

Figure 2-30 Erosion Hazard Map – Memorial Archway Beach Zone

3 Asset Vulnerability

The assets possibly at risk from inundation and/or coastal erosion/recession hazards at the Eastern View study site are:

- The Great Ocean Road and associated drainage infrastructure
- Beach Carparks
  - Devil's Elbow Carpark and Boat Ramp
  - Spout Creek Carpark
  - Carpark 3
  - Memorial Archway Carpark
- Beach Access Structures
- Power Poles.

The vulnerability of these assets is discussed below in subsequent sections.

3.1 The Great Ocean Road

The Great Ocean Road is the key asset at risk from both erosion/recession and inundation hazards and is impacted differently along its length, largely dependent on the elevation of the road and the width of the dune buffer.

3.1.1 Devil's Elbow Beach Zone

In the Devil's Elbow Beach zone, the road drops from 11.25 m AHD where it rounds the Devil's Elbow Headland to 5 m AHD where it crosses Spout Creek. Where the road is at higher elevations, it sits on a bench cut into the Otway Formation geology when the road was formed. As it descends, the road bends off this bench and onto a bench of fill material placed over the sand. These areas have no dune system to protect the road and from the entrance to the Devil's Elbow carpark to Spout Creek, the road is predicted to be at risk from erosion by 2031 (Figure 2-28).

The Great ocean Road is predicted to be at risk of inundation by wave runup and overtopping in the Devil's elbow zone at the entrance to the Devil's Elbow Carpark and in a zone within 100 m of the Spout Creek mouth by 2031. This could cause sheet flow across the road, pooling in low areas, scour of the road shoulder and present a hazard to vehicles.

3.1.2 Spout Creek Beach Zone

From Spout Creek eastward through the Spout Creek Beach zone, the road remains between 5 m AHD and 6 m AHD (rising slowly as it moves eastward). The dune system is mostly wider in this region than in Devil's Elbow, providing the road with some protection from erosion and inundation. In spite of this, a small section of the road shoulder is within the current erosion hazard zone approximately halfway between the Spout Creek Carpark and Carpark 3 where there are no dunes, and the road is at a low point (Figure 2-29 and 3.1). By 2031, the road is predicted to be at risk of being eroded onto the beach in a 50 m section of road shoulder near Spout Creek, a 100 m section between the Spout Creek carpark and carpark 3, and a small area of shoulder behind carpark 3 (Figure 2-29).

The road is predicted to be at risk of inundation by wave runup in the Spout Creek zone in 3 areas by 2031. These areas are (1) immediately behind the Spout Creek carpark, (2) a 120 m long section situated between the Spout Creek Carpark and carpark 3 and (3), immediately behind carpark 3 and extending approximately 75 m NE along the road. Memorial Archway Beach Zone

In the memorial archway beach zone, the road rises from 6 m AHD to 7 m AHD and the dune system again widens. Thus, the road in this section is not predicted to be at risk from erosion in the next 10 years. By 2051, a small area of road is at risk from erosion in western end of the zone near Carpark 3 (Figure 2-30). Other than this area, the road is predicted to be largely safe from erosion by 2051.

Only a small portion of the Great Ocean Road is predicted to be at risk of inundation by wave runup by 2101 in the Memorial Archway beach zone (westernmost 50 m of road). No road in this section is predicted to be at risk of erosion before this time.

Table 3-1 Great Ocean Road Vulnerability

	Coastal Erosion/Recession Predicted Impact Time (years)	Inundation Predicted Impact Time (years)
Devil's Elbow Beach Zone	0 – 10	10 - 15
Spout Creek Beach Zone	0 – 10	10 - 15
Memorial Arch Beach Zone	10 – 30	50 - 80

Figure 3-1 Great Ocean Road shoulder at Risk of erosion immediately behind the small fence.

3.2 Beach Carparks

Each of the carparks in the study area are forecasted to be impacted differently by erosion and inundation (Erosion: Figure 2-28, Figure 2-29 and Figure 2-30; Inundation: Figure 2-10, Figure 2-11 and Figure 2-12).

The Devil's Elbow carpark and its associated boat ramp are at immediate risk as they are within the predicted extent of storm cut from an ARI50-year storm (as was experience on 10th April 2021). If a storm of this severity occurred again, much of the edge of the asphalt carpark may be eroded from the scarp. This would necessitate the closure of the carpark (and hence the boat ramp) to maintain public safety. This extent of erosion may also occur if multiple smaller storms occur consecutively. This gives the carpark an effective lifetime of 0 – 10 years. The informal clay boat ramp at the Devil's Elbow Carpark is also currently vulnerable to erosion and is repaired every year with clay to maintain its usability. In future as sea levels rise, this continued repair will be unsustainable.

The entire Devil's Elbow carpark and boat ramp is forecast to be at risk of inundation by wave runup by 2031 which could cause sheet flow across the road, pooling in low areas, scour of the road shoulder and present a hazard to vehicles.

The Spout Creek Carpark is also at immediate risk from erosion. This has been seen recently with chunks of the carpark eroding from the scarp in recent storms. Further storm erosion in the coming months to years will see more of this material eroded away. The erosion seen from the most recent large storms on April 10th, 2021 has resulted in a vertical erosion scarp at the edge of the carpark. Due to the instability of the basement material of this carpark (fill over sand clearly visible in the scarp), this carpark should be closed to maintain public safety. Because the carpark is already in its furthest landward orientation (Tomkinson Group 2017), further retreat of the carpark is not an option.

The entire Spout Creek Carpark is also forecast to be at risk of inundation by wave runup and overtopping by 2031.

Carpark 3 is again at immediate risk from erosion. This carpark has seen the most erosion of the seaward edge by waves of any carpark along the stretch in recent times (Figure 2-13 and Figure 2-14). This carpark has also been retreated to its furthest landward orientation (Tomkinson Group 2017) with erosion impacting the parking spaces. Carpark 3 has the same basement material (fill over sand) as the Spout Creek Carpark. As such carpark 3 should also be closed in its current condition to maintain public safety.

Carpark 3 is predicted to be at risk of inundation by wave runup and overtopping by the year 2031.

The Memorial Archway carpark is the only carpark in the study area not in immediate risk owing to the wide dunes in the area. This carpark is not predicted to be at risk until later than 2051 and thus, has a predicted effective lifetime of 30 – 50 years (Figure 2-30).

The Memorial Archway carpark is also not forecast to be at risk from inundation by wave runup and overtopping until after 2071.

Table 3-2 Beach Carpark Vulnerability Summary

	Coastal Erosion/Recession Predicted Impact Time (years)	Inundation Predicted Impact Time (years)
Devil's Elbow Carpark	0 – 10	5 – 10
Spout Creek Carpark	Immediate Risk	5 – 10
Carpark 3	Immediate Risk	5 – 10
Memorial Archway Carpark	30 – 50	50 - 80

Figure 3-2 Carpark 3 erosion seen on 20th April.

3.3 Beach Access Structures

The boat ramp in Devil's Elbow and the beach access stairs from the Spout Creek carpark are the only current formal beach access structures in the study site. Formerly, there were beach access stairs from carpark 3, however, erosion and wave action caused their failure. The GOR Authority intend to rebuild these stairs when appropriate. The current beach access stairs are designed for stability under certain levels of inundation with the bottom steps inundated often at high tide. As such, these structures are not deemed vulnerable to inundation alone. The boat ramp is designed to be a temporary structure effective for the summer months. In winter, the ramp is currently inundated more often by large waves making it dangerous to use for both pedestrian beach access and boat launching. As such, the boat ramp is currently vulnerable to inundation. As sea levels rise, both structures will become more vulnerable to increasingly common inundation and will require some form of adaptation to maintain their usability.

Figure 3-3 Beach access stairs with Spout Creek carpark erosion

Both beach access stair structures and the boat ramp are also currently in the immediate erosion hazard zone and are vulnerable to undermining. At the Spout Creek carpark, the seaward edge of the carpark and adjacent dunes are actively receding. This is progressively weakening the upper platform and will eventually cause the stairs to collapse. This could occur after a single storm at any time. The boat ramp annually requires closure due to erosion of the toe and ramp surface. As climate change causes increases to the size of waves impacting the ramp area, this erosion will occur more often and more severely, increasing the vulnerability of the ramp to failure during a storm. This will make the current management strategy unfeasible with maintenance required more and more often.

Figure 3-4 Devil’s Elbow Boat Ramp Erosion

3.4 Power Poles

There are 16 power poles spread along the study site (Table 3-3), at varying distances from the current dune crest. Coastal erosion/recession is forecast to be the key hazard which may put these assets at risk in the future. Inundation of the base of a power pole is unlikely to impact the pole's stability or function.

Table 3-3 Power Poles and Locations – Eastern View

Equipment Identifier	Pole Number	Coordinates	Predicted time before pole is within erosion hazard zone (years)	Pole Oversunk* (Y/N)	Available Distance for Retreat (m)	Predicted time before retreated pole is within erosion hazard zone (years)
32074957	390	-38.471767, 144.045828	10 - 30	N	10.5	30+
30268333	390A	-38.471902, 144.045306	30+	N	0	30+
33042967	391	-38.472030, 144.044795	30+	N	0	30+
32074942	392	-38.472290, 144.044007	10 - 30	N	7.6	30+
32074937	393	-38.472541, 144.043252	10 - 30	N	8.9	10 - 30
32074924	393A	-38.472749, 144.042643	10 - 30	N	6	10 - 30
32074913	394	-38.473072, 144.041827	0 – 10	N	2.4	10 - 30
32074905	395	-38.473436, 144.040880	0 – 10	N	4.5	0 – 10
30064680	396	-38.473873, 144.039759	Now	N	7.5	0 – 10
32074889	397	-38.474395, 144.038590	Now	N	2.6	0 – 10
33042946	398	-38.474771, 144.037656	0 – 10	N	5.5	10 - 30
30064663	399	-38.475127, 144.036929	Now	N	5.5	0 – 10
30242128	400	-38.475882, 144.035627	Now	Y	3	0 – 10
30343435	401	-38.476317, 144.035036	Now	Y	1.2	0 – 10
31011751	402	-38.477073, 144.034185	Now	N	5.2	0 – 10
30064638	403	-38.478016, 144.033382	0 – 10	N	6.7	0 – 10

**Oversinking poles refers to the process of inserting a pole deeper into the soil for extra stability.*

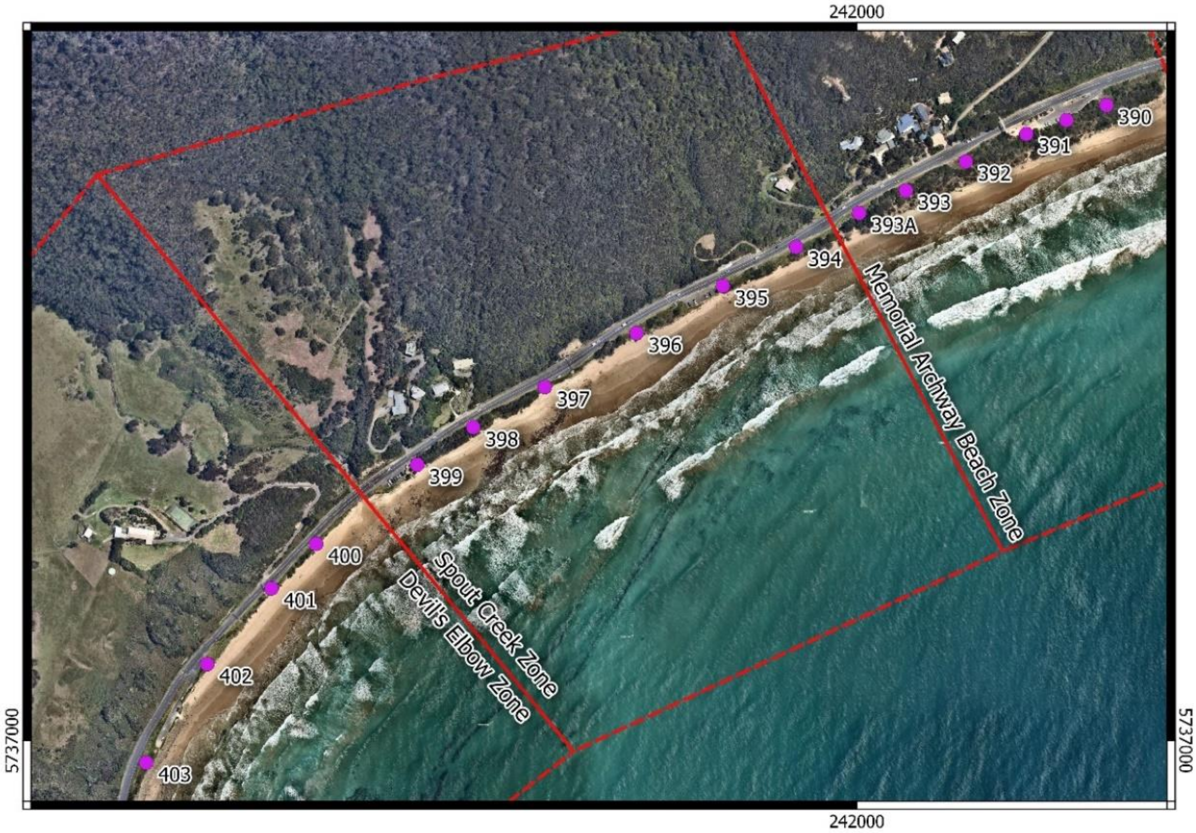

Figure 3-5 Map of Power Pole Locations

3.5 Cultural Heritage Sites

All cultural heritage material identified is currently vulnerable to and being impacted by coastal erosion. These sites are forecast to be impacted more severely as sea levels rise.

4 DELWP Community Listening Post

A community listening post was conducted by DELWP to gauge community response to the various available future adaptation options for Eastern View. This was done under a tent in a carpark along the study site with posters of the above hazard maps (Figure 2-28, Figure 2-29 and Figure 2-30) and posters describing all relevant adaptation options.

Very few people showed up to the listening post, with those present predominantly concerned with maintaining boat ramp access to the beach from the Devil's Elbow carpark (Figure 4-1). Minimal comments were made on the various options for coastal adaptation beyond these concerns.

As such, this community consultation does not factor heavily in the option assessment in the following section. Further planning for adaptation of assets to coastal hazards into the future should attempt to undertake more community consultation. This is especially salient in light of the findings in Section 3 which show considerable erosion risk to carparks and the GOR along much of the study site.

Figure 4-1 Informal Boat Ramp at Devil's Elbow Carpark.

5 Adaptation Measures Assessment

5.1 First Pass Adaptation Assessment

The first pass options assessment was undertaken collaboratively between coastal engineers at BMT, representatives from DELWP and members of the Great Ocean Road Coasts and Parks Authority (GOR Authority). It was undertaken to short list the adaptation measures/options to be investigated further and rule out those which are not feasible/desirable at the site.

Table 5-1 below, outlines a long list of potential coastal adaptation measures considered. These are arranged according to the Marine and Coastal Policy hierarchy (DELWP 2020) in order of:

(1) Non – Intervention,

(2) Avoid,

(3) Nature-Based Methods,

(4) Accommodation,

(5) Retreat,

(6) Protect.

A short comment on each option is also given describing the adaptation measure and giving reasons why, or why not, the measure is recommended for further assessment. Following this are assessments of the possible options of individual (utilising one adaptation option) and hybrid (utilising multiple adaptation options) coastal adaptation strategies available for Hodgson Street.

Table 5-1 First Pass Options Assessment

Coastal Adaptation Measure	Comment	Shortlist for Further Consideration (Y/N)
1.0 Non – Intervention		
Minimum intervention consistent with public safety	E.g. If beach accesses are undermined, remove them; if the carpark erodes, fence then close it. This option will be assed further as a baseline from which to compare the outcomes of other adaptation measures.	Y (Base Case)
2.0 Avoid		
Not Applicable	This type of action relates to planning for new uses, development and re-development seeking to avoid placing them in at-risk areas. This project focusses on beach access (cannot be moved landward) and other pre-existing infrastructure, thus this type of action is not relevant.	N

Coastal Adaptation Measure	Comment	Shortlist for Further Consideration (Y/N)
3.0 Nature Based Methods		
Beach Nourishment or Scraping	Beach/dune nourishment at the Eastern view site would be difficult due to uncertainty surrounding sand sources. Local on beach sources are limited due to the shallow rock underlying the sand while on beach sources from Fairhaven are also problematic due to erosion issues impacting that end beach as well. On-land sources are problematic due to cost. Beach Scraping involves moving sand from low on the beach to higher up towards the dune base for short term protection. This may be difficult due to the shallow underlying rock mentioned. These options may also be problematic due to limited access and rocky shorelines making access along the beach difficult.	Y
Wet Sand Fencing	Wet Sand fencing has been used recently at Eastern View in 2013-2014 and was of limited effectiveness. This is because Eastern View has a relatively high wave climate which easily damaged the fence and still easily caused erosion behind the fence.	N
Dune Management	E.g. Safety fencing at toe of dune and re-vegetation of foredune for stability. This measure may be used in concert with other measures such as beach nourishment. Due to the high scarps and continued erosion, this measure on its own however, it would not likely be sufficiently effective to manage dune erosion at Eastern View.	Y
Seaweed Dune Toe Armouring	This method has been practiced in the past at Point Roadknight using the naturally occurring piles of seaweed (usually kelp species) found on the beach. This seaweed is pushed up to the base of the dune/cliff toe and	Y

Coastal Adaptation Measure	Comment	Shortlist for Further Consideration (Y/N)
	partially covered with sand to create a small protective berm along trouble erosion areas. This is likely only a very short-term protective solution (weeks to months) depending on the severity of local storms.	
4.0 Accommodate		
Construct or modify beach access structures for increased footing stability.	E.g. Construct fiberglass reinforced polymer (FRP) access structures or pile the access footings deeper and use more stable footing technology (e.g. screw piles). This measure would allow access stairs and ramps to withstand shoreline erosion cycles and still be present when returning sand again increases beach level. This measure would also increase the boat ramp functionality and safety year-round.	Y
Countersinking Power Poles to greater depth.	Power Cor have the option to embed poles deeper into the ground for extra stability. It is reported that can only occur to a maximum depth of 3 m. Because the dune is often 2-3 m high, dune recession could still cause poles to fail which are countersunk to 3 m. As such, this adaptation measure would be of limited effectiveness.	Y
5.0 Retreat		
Reconfigure carpark	This measure has been used to date at Eastern View. There is currently limited area to continue to retreat without pushing parking out onto the GOR and causing traffic hazards.	N
Re-route Great Ocean Road Behind Fairhaven, Moggs Creek and Eastern View	This measure would re-route the Great Ocean road away from the at-risk coastal areas near the dune system. As there is limited room between the current road and the steep slope landward of the road, the only option for this re-routing would be behind the towns of Fairhaven, Moggs	N

Coastal Adaptation Measure	Comment	Shortlist for Further Consideration (Y/N)
	Creek and Eastern View. This option would have extremely high costs and negatively impact the natural forest ecosystem behind the towns and the scenic and heritage value of the GOR.	
6.0 Protect **Short Term Protection**		
Rock Bags	This measure would use rock bags to temporarily armour the to of the dune scarp/carpark while more long-term options are investigated. These could be used for all trouble areas along the stretch.	Y
Geo Bag Revetment	Geotextile sand containers have been used in diverse erosion situations along many Australia beaches as temporary revetment protection structures. Although this is the case, the cost associated with a stable wall on such a high energy coast compounded with the relatively short lifetime make this option not viable at eastern view.	N
Clay Armouring	This option is the current management practice at Eastern View and involves the construction of a wedge of clay fill material abutting the face of the dune/carpark scarp and extending out onto the sand. This is intended as a temporary protective structure and reportedly lasts approximately 1 year. This option will be included for comparison of the effectiveness of current management options to other short-term protection options.	Y

Longer Term Protection			
Engineered Revetment/seawall		Long term engineered coastal protection could take the form of a revetment or seawall. This would protect the coast for a period of time from storm erosion and shoreline recession under future sea level rise scenarios.	Y
Engineered Wave Reduction and Sand Retention Techniques	Groynes and Beach Nourishment	Groynes work by interrupting longshore transport and retaining sand on the beach. Combining this with beach nourishment could protect the carparks and GOR by maintaining a wider beach at Eastern View. This option would likely be very expensive and would have a large impact on the local coastal processes.	Y
	Intertidal reef breakwater	E.C Bird (Fairhaven Coastal Management pg. 7) describes reports of the human removal of an intertidal reef for fuel due to brown coal inclusions at the low water mark seaward of Coalmine creek. This was of high enough elevation to make a ‘swimming’ pool at low tide. Re-introduction of this reef and other such reefs along the stretch of coast could act to protect the sandy shore by lowering wave energy and could have co-benefits for beach amenity and intertidal habitat.	Y
	Offshore Breakwaters	This option would create offshore rock breakwaters to attenuate wave energy before it impacts the Eastern View site. This option would be extremely expensive and would have a large impact on the local coastal processes, potentially causing significant erosion in other areas.	Y

5.2 Coastal Adaptation Options Assessment

5.2.1 Option 1 – Minimal Intervention Consistent with Public Safety (Non – Intervention)

This option is essentially the ‘Do Nothing’ approach and is included as a point of comparison to the other options. This approach uses a risk management approach and would involve decommissioning assets when they present a hazard to public safety.

The Devil’s Elbow carpark, Spout Creek carpark and Carpark 3 are all being impacted by erosion with the seaward edge currently eroding onto the beach. All three are closed or will need to be closed in the near future, as they continue to erode. The boat ramp at Devil’s Elbow is also eroding and will need to remain closed if it is not rebuilt. Power poles 396, 397, 399, 400, 401, 402 are currently at risk from erosion and this line should be decommissioned if it is not relocated or protected, to avoid poles falling onto beach or road.

Within the next 10 years the Great Ocean Road is predicted to be at risk of coastal erosion. If erosion reaches the road the seaward lane would need to be closed for safety. This would be followed by frequent maintenance of the eroding edge to keep the road open.

Figure 5-1 Fencing and collapse of Carpark 3 after April 10th storm.

This option is not recommended for Eastern View because it would fail to maintain key assets and values surrounding beach access and amenity. It would likely lead to unmanageable safety risks with power poles and the Great Ocean Road.

Table 5-2 Option 1 - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Negative: Minimal Intervention is technically very feasible; however, it would not be effective at maintaining assets or values.
Timeframe	Strongly Negative: this option would not be effective and may cause erosion to impact the Great Ocean Road in the next 0 – 5 years.
Relative cost	Strongly Positive: Minimal cost
Social/economic impact	Strongly Negative: Loss of the beach carparks, boat ramp and beach access would diminish the beach amenity at Eastern View. Closure of the GOR would have a negative regional and state-wide impact on tourism and visitation.
Impact on coastal processes and environment	Neutral: This would have low impact on local coastal processes.
Governance, alignment with VMACP	Strongly Negative: Closure of the road would be unacceptable from a governance and political perspective.

Because this option is not recommended for Eastern View, a detailed cost analysis is not undertaken here. Nominally however, this option would include regular (e.g., monthly) evaluations of the site by workers to identify at-risk areas and/or asset failure. Where necessary, fencing should also be installed. This could cost approximately $10,000 - $20,000 per year.

5.2.2 Option 2 – Seaweed Dune Toe Armouring (Nature-Based)

Seaweed wrack (dead seaweed washed up on the beach), sand and cobbles on the beach can be pushed up to the toe of the dune/erosion escarpment to form a semi-wave resistant berm at the base and limit further erosion. This no-regret approach is only intended for immediate-term protection of a dune escarpment. Large waves impacting the seaweed will rapidly transport it away, although net erosion may be diminished.

Seaweed armouring has been trialled at Eastern View recently (May 2021) in front of the Devil's Elbow carpark after large amounts of predominantly kelp washed ashore. All seaweed placed in these areas had completely washed away in the 2 months after placement, but there was little overall retreat of the erosion scarp in this time.

This option involves seaweed dune toe armouring to all areas where assets are currently at risk, a length of 590 m of dune between Devil's Elbow and carpark 3, as shown in Figure 5-2. If sufficient seaweed is available, this should be repeated approximately 6-times each year for maximum effect.

A key limitation of this option is what it can only be utilised when sufficient seaweed wrack is naturally available on the shoreline.

Figure 5-2 Option 2 – Seaweed Dune Toe Armouring.

Table 5-3 Option 2 – Seaweed Dune Toe Armouring - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Negative: This has been done previously at Devil's Elbow but was not very effective
Timeframe	Strongly Negative: This option is only effective for a very limited time (days – months)
Relative cost	Strongly Positive: Minimal cost
Social/economic impact	Neutral: Minimal impact
Impact on coastal processes and environment	Positive: No impact on coastal processes
Governance, alignment with VMACP	Positive: Nature Based Methods are in line with the VMACP.

Table 5-4 Option 2 – Seaweed Dune Toe Armouring - Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Equipment Hire**				
	Bobcat	day	4	$500 - $1,000	$2,000 - $4,000
2.0	**Annual Recurrence**	days/year	6		
	Total Costs per year (excluding GST)				$12,000 - $24,000
	Total Cost ($/m/year)				$20 - $40

Trigger Value – This option should be considered when there is dislodged seaweed wrack available on the beach and when a dune erosion scarp crest is within 4 m of a built asset in the Spout Creek and Memorial Arch beach zones and within 2 m in the Devil's Elbow Zone. This trigger value has already been reached/exceeded for the Devil's Elbow carpark, Spout Creek carpark, carpark 3 and power poles 396, 397, 399, 400, 401, 402.

5.2.3 Option 3 – Beach Nourishment and Beach Scraping (Nature-based)

This option involves placing sand on the upper beach and dune in areas where assets are at risk of erosion (Figure 5-3) to build a buffer against further erosion. The sand may be scraped from lower on the profile, around the low tide line (termed 'beach scraping') or brought in from elsewhere (termed 'beach nourishment'). The presence of shallow rock under the beach means that beach scaping may not be feasible when the beach is in an eroded state. For beach nourishment, sand may be sourced from further east along the beach towards Fairhaven if a suitable area with significant sand build up can be identified (no suitable areas have been identified to date) or quarried sand could be imported (this is much more expensive).

By itself, sand nourishment may only provide protection for weeks – months, depending on prevailing weather patterns and would need to be repeated regularly (assumed annually for cost estimate in Table 5-6) to remain effective.

Dune management, such as fencing, planting and matting, is often used to increase the stability/longevity of nourished material against wave attack. This would not likely be effective at Eastern View due to the high wave climate (Morris et al. 2021), thus it is not suggested in this option. Structures to retain sand, such as groynes, can also be used to increase the longevity of the nourishment, and this is considered separately in Option 8.

This option involves beach nourishment of 27 m^3/m to all areas where assets are currently at risk, a length of 750 m between Devil's Elbow and carpark 3, as shown in Figure 5-3.

Figure 5-3 Option 3 – Beach Nourishment and Scraping.

Table 5-5 Option 3 – Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Neutral: This option is technically feasible but would likely require quarried sand to be trucked in due to lack of supply on the beach. This would not be very effective for coastal defence.
Timeframe	Strongly negative: This option may have a very short effective timeframe (weeks – months) due to the high energy waves.
Relative cost	Negative: Nourishment on the scale needed at Eastern View may be very expensive and would need to be repeated often
Social/economic impact	Positive: This would create a temporarily wider beach for beachgoers to enjoy and may increase tourism to the area.
Impact on coastal processes and environment	Positive: This option mimics natural coastal processes.
Governance, alignment with VMACP	Positive: Nature Based Methods are in line with the VMACP.

Table 5-6 Option 3 Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Nourishment**				
	Supply Sand	m^3	20000	\$10 - \$75	\$200,000 - \$1,500,000
	Spreading Sand on Beach	m^3	20000	\$5 - \$10	\$100,000 - \$200,000
3.0	**Allowances**				
	Approvals and permits	%	5%	-	\$15,000 - \$45,000
	Design fees	%	5%	-	\$15,000 - \$45,000
	Engineering and supervision	%	3%	-	\$9,000 - \$51,000
	Contractor overhead	%	5%	-	\$15,000 - \$85,000
	Contingency	%	15%	-	\$45,000 - \$255,000
	Total Costs (excluding GST)				**\$399,000 - \$2,181,000**
	Cost Per m (excluding GST)				**\$532 - \$2,908**

Trigger Value – This option should be considered when a dune erosion scarp crest comes within 4 m of a built asset in the Spout Creek and Memorial Arch beach zones and within 2 m in the Devil's Elbow Zone. This value has been exceeded/reached for the Devil's Elbow carpark, Spout Creek carpark, carpark 3 and power poles 396, 397, 399, 400, 401, 402.

5.2.4 Option 4 – Upgrade Beach Access Structures (Accommodate)

Beach access stairs and the boat ramp could be modified/rebuilt to better withstand wave impact and accommodate erosion, thus preserving access to the beach. This would involve deeper foundations, extending the structures landward (so they remain accessible if the dune retreats) and using more resilient materials such as timber piles and fiberglass mesh decks.

While upgraded access structures should be effective for 10 or more years, it does not make much sense to implement this option in isolation as the carparks they connect to are closed or under immediate threat from erosion. This option should be implemented in combination with another option to address the erosion risk to the carparks.

This option includes construction of three beach access staircases from each of the Devil's Elbow carpark, Spout Creek carpark and carpark 3 (Figure 5-4, Table 5-7 and Table 5-8). The boat ramp from the Devil's Elbow carpark would also be reconstructed using similar construction material as the stairs to produce a raised boat ramp deck on piles. This would allow year-round access to the beach for boaters and emergency vehicles with minimal maintenance costs.

No access structures are currently proposed for the Memorial Arch beach zone. Beach access paths in this area could be re-graded if they become overly steep, and/or fitted with board-and-chain treads to prevent erosion by pedestrian traffic, for minimal cost if required.

Figure 5-4 Option 4 – Upgrade Beach Access Structures

Table 5-7 Option 4 – Upgrade Beach Access Structures - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Positive: This option is technically feasible and has been used at various other places on the surf coast to maintain beach access.
Timeframe	Positive: Structures reconstructed for greater stability may have long effective lifetimes.
Relative cost	Strongly Positive: Beach access structures are relatively cheap to construct.
Social/economic impact	Positive: This would maintain beach access and allow community members and tourists to enjoy the beach.
Impact on coastal processes and environment	Neutral: No impact
Governance, alignment with VMACP	Positive: Accommodate Methods are in line with the VMACP.

Table 5-8 Option 4 – Upgrade Beach Access Structures - Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Access Construction**				
	Access Stairs	Item	3	$5,000 - $10,000	$15,000 - $30,000
	Boat Ramp	Item	1	$20,000 - $30,000	$20,000 - $30,000
3.0	**Allowances**				
	Approvals and permits			-	$10,000 - $30,000
	Design fees			-	$10,000 - $30,000
	Engineering and supervision	%	3%	-	$1,050 - $1,800
	Contractor overhead	%	5%	-	$1,750 - $3,000
	Contingency	%	15%	-	$5,250 - $9,000
	Total Costs (excluding GST)				**$63,000 - $134,000**

Trigger Value – This option should be considered when the carparks are protected using either short- or long-term protection measures.

5.2.5 Option 5 – Retreat & Stabilise Power Poles (Retreat & Accommodate)

Power poles currently risk from coastal erosion (poles 396, 397, 399, 400, 401 and 402) could be moved landward (closer to the road) to reduce level of risk.

At the same time the poles could be 'over-sunk' to increase their stability. Of the poles at Eastern View, 14 are sunk to 2.2 m depth and 2 (poles 400 and 401) are over-sunk to 3 m, which is understood to be the maximum practical embedment (Figure 3-5 and Table 3-3). Note that over-sinking alone is not sufficient to mitigate the erosion risk. The dune area where the poles are located is typically 5 to 7m AHD. The expected eroded beach level after a major storm is 2m AHD or lower, so a pole sunk 3m from the dune level would be undermined if the dune erosion scarp reached the pole.

It is preferred to keep the poles on the seaward side of the road because there is limited room on the landward side of the road and placing poles on private property is not preferred by Powercor or residents. The available retreat distance of at-risk poles is limited, ranging between 1 – 7.5 m, assuming a minimum distance of 3 m from the traffic lane (Table 3-3). Even if they were moved as close as possible to the road, some of the poles would still be at risk form erosion within the next few years, and most of them within 10 years.

This option proposes to retreat and over-sink poles 396, 397, 399, 400, 401 and 402, moving them as close as possible to the road. This would be a sort term measure to reduce the immediate risk. Protection of the poles or retreat to the landward side of the road will likely be needed in the medium to long term.

Figure 5-5 Option 5 – Retreat & Stabilise Power Poles

Table 5-9 Option 5 - Retreat & Stabilise Power Poles - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Neutral: This option has already been used at Eastern View on 2 power poles. Will reduce but not eliminate risk.
Timeframe	Negative: This option likely to be effective for <10 years
Relative cost	Positive: relatively low cost
Social/economic impact	Neutral: This would have little social or economic impact on the area
Impact on coastal processes and environment	Positive: No Impact on local coastal processes.
Governance, alignment with VMACP	Positive: Accommodation/Retreat is in line with the VMACP.

Table 5-10 Option 5 - Retreat & Stabilise Power Poles - Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Site establishment**				
	Site establishment	Item	1	\$5,000 - \$10,000	\$5,000 - \$10,000
2.0	**Works**				
	Over-sink Power Poles	item	6	\$7,500 - \$10,000	\$45,000 - \$60,000
3.0	**Allowances**				
	Approvals and permits	%	10%	-	\$5,000 - \$7,000
	Design fees	%	10%	-	\$5,000 - \$7,000
	Engineering and supervision	%	3%	-	\$1,500 - \$2,100
	Contractor overhead	%	5%	-	\$2,500 - \$3,500
	Contingency	%	15%	-	\$7,500 - \$10,500
	Total Costs (excluding GST)				**\$71,500 - \$100,000**

Trigger Values – This option should be considered when the dune crest comes within 4 m of any power pole in the Spout Creek and memorial Archway beach zones and within 2 m of a power pole in the Devil's Elbow zone. This trigger value has already been reached/exceeded for poles 396, 397, 399, 400, 401 and 402.

5.2.6 Option 6 – Rock Bags (Short-Term Protection)

This option would use short term protection methods (geotextile sandbags, clay armouring or rock bags) along sections of the dune where assets are deemed at-risk. This is an immediate option to minimise erosion of the dune and protect assets in critically at-risk areas. These protection options are only intended to be short term, intermediate measures before longer term solutions (e.g., protection or retreat) can be designed and implemented.

Geotextile sandbag walls are not preferred because they are relatively very expensive to implement. Clay armouring (as described in Table 5-1) is generally a technically viable option for short term protection of assets but is not currently preferred by DELWP because it allows clay material to wash into the ocean.

Rock Bags are a relatively new technology in Australia made from polyester mesh with a deployed lifetime of up to 30 years (Kyowa 2019). They are filled on site then placed on the beach using a crane. Benefits of rock bags include (1) that they are easily and quickly filled on site, (2) they are easily deployed, (3) they can be easily removed. Due to these benefits and DELWP preference, rock bags are advised for Eastern View over geotextile bags for short term protection.

This option proposes to use a 4-bag high rock bag revetment using 4-tonne bags as temporary protection for assets at immediate risk of erosion. As shown in Figure 5-6, this would include approximately 450 m of revetment shoreward of the Devil's Elbow carpark, Spout Creek carpark, carpark 3 and the 100 m section between the Spout Creek carpark and carpark 3 where power poles and the GOR are or may soon be at risk from erosion.

Further assessment of this option against key criteria is outlined in Table 5-11 and Table 5-12 below.

Figure 5-6 Option 6 – Rock Bag Protection.

Table 5-11 Option 6 – Assessment - Rock Bags

Assessment Criteria	Comment
Technical feasibility/effectiveness	Positive: Rock bags have been used to effectively limit erosion in high-risk area on multiple beaches on the east coast of Australia.
Timeframe	Neutral: This option may be effective for 5-10 years.
Relative cost	Negative: Relatively expensive
Social/economic impact	Positive: This option would maintain the beach carpark usability, beach access structures and the Great Ocean Road.
Impact on coastal processes and environment	Negative: This option would cause sediment lock up and end scour at the sides of each rock bag wall. This may shift the erosion issues to different places on the beach.
Governance, alignment with VMACP	Positive: Short Term Protection of structures at critical risk is in line with the VMACP.

Table 5-12 Option 6 – Cost Estimate – Rock Bags

	Item	Unit	Qty	Rate	Total
1.0	**Site establishment**				
	Site establishment	Item	1	$5,000 - $10,000	$5,000 - $10,000
2.0	**Works**				
	Rock Bag Installation	m	450	$2,000 - $2,500	$900,000 - $1,125,000
3.0	**Allowances**				
	Approvals and permits	%	4%	-	$36,200 - $45,400
	Design fees	%	4%	-	$36,200 - $45,400
	Engineering and supervision	%	3%	-	$27,150 - $34,050
	Contractor overhead	%	5%	-	$45,250 - $56,750
	Contingency	%	15%	-	$135,750 - $170,250
	Total Costs (excluding GST)				**$1,185,500 - $1,487,000**
	Cost per m (excluding GST)				**$2,500 - $3,500**

Trigger Value – This option should be considered when the dune crest erodes to within 4 m of a built asset in the Spout Creek and Memorial Archway beach zones and within 2 m of a built asset in the Devil's Elbow zone. This trigger value has already been reached for the Devil's Elbow carpark, Spout Creek carpark, carpark 3 and power poles 396, 397, 399, 400, 401 and 402.

5.2.7 Option 7 – Revetment (Long-Term Protection)

Rock revetment structures have been used previously along much of the Great Ocean Road with great success (e.g., Apollo bay and Skenes Creek). When well designed, revetments can protect assets for many years into the future. Typical design life is 50 years, and it is possible to modify the revetment in future to extend the design life. Revetment construction could also include nourishment of the dunes protected by the structures, the planting of native vegetation for dune stability and re-instatement of beach access ramps and stairs and the reinstatement of the boat ramp.

This sort of protection strategy is designated as an 'option of last resort' in the Victorian Marine and Coastal Policy (DELWP 2020) because it is inherently expensive, may shift the erosion issue to other areas and would have considerable impact on coastal processes. It also may have negative impacts on coastal processes with lowering of the beach level in front of the revetment and end scour.

At Eastern View erosion already impacts three of the four carparks in the study area and is predicted to impact six power poles and the Great Ocean Road by 2031 (Section 2.4.4). In the study area nature based methods have been tried and failed (Section 5.2.2), assets retreated to maximum safe distances are currently being impacted by erosion (Section 5.1) and adaptation options are either not predicted to be effective or not feasible (Sections 5.2.5 and 5.1). As such, long-term protection of the Great Ocean Road is recommended to be considered.

This option involves construction of approximately 1.1 km of revetment as shown in Figure 5-7 to protect all assets long-term. This could be staged, beginning at Devil's Elbow if required, however this would create more potential end scour locations to be managed. Modification of beach access stairs and the boat ramp (Option 4) could be combined with this option.

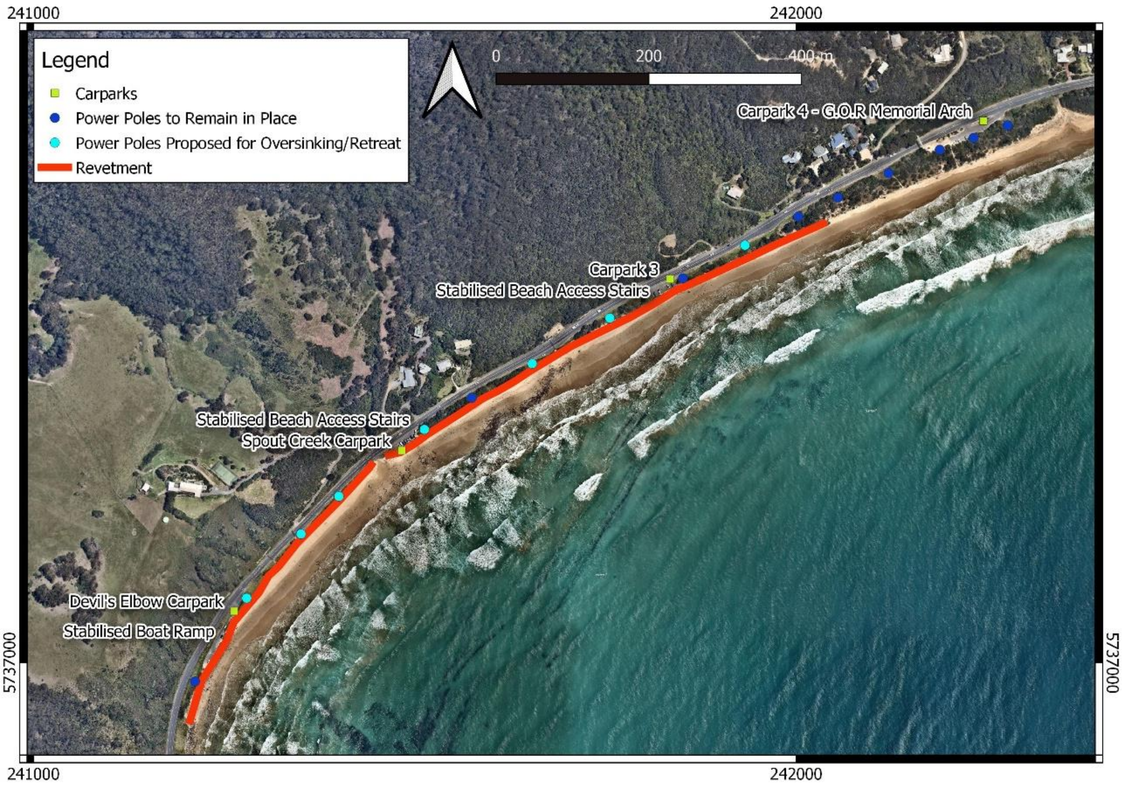

Figure 5-7 Option 7 – Revetment

Table 5-13 Option 7 – Revetment - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Strongly Positive: Revetment structures have been implemented at various places along the Great Ocean Road to protect assets from coastal erosion which are effective.
Timeframe	Strongly Positive: With good design, this option may be effective for 50+ years.
Relative cost	Strongly Negative: Highly Expensive
Social/economic impact	Negative: This may cause the loss of the high tide beach at Eastern View completely through beach lowering in front of the revetment.
Impact on coastal processes and environment	Strongly Negative: Revetments have large impacts on coastal processes and may shift the issue to other locations along the beach.
Governance, alignment with VMACP	Positive: Long Term Protection of assets is in line with the VMACP only when other, lower impact options are not viable.

Table 5-14 Option 7 – Revetment - Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Site establishment**				
	Site establishment	Item	1	\$5,000 - \$10,000	\$5,000 - \$10,000
2.0	**Works**				
	Revetment	m	1100	\$6,000 - \$10,000	\$6,600,000 - \$11,000,000
3.0	**Dune Management**				
	Plants	m2	9000	\$1 - \$2	\$9,000 - \$18,000
3.0	**Allowances**				
	Approvals and permits	%	3%	-	\$198,420 - \$330,840
	Design fees	%	3%	-	\$198,420 - \$330,840
	Engineering and supervision	%	3%	-	\$198,420 - \$330,840
	Contractor overhead	%	5%	-	\$330,700 - \$551,400
	Contingency	%	15%	-	\$992,100 - \$1,654,200
	Total Costs (excluding GST)				**\$8,532,000 - \$14,226,000**
	Cost Per m				**\$8,000 - \$13,000**

Trigger Value – Design of this option should be considered immediately. This option should begin to be progressively implemented when the dune crest comes within 4 m of the Great Ocean Road. This trigger has already been reached immediately adjacent to Spout Creek, and at a small section around a stormwater outlet pipe between the Spout Creek carpark and Carpark 3.

5.2.8 Option 8 – Sand Retention Structures (Long Term Protection)

This option would use rock structures such as groynes, intertidal reefs or offshore breakwaters to lower wave energy impacting the shore and trap sand on the beach, thus reducing the erosion hazard to assets.

Groyne work by intercepting longshore transport to create a locally wider beach and have been used previously along the Great Ocean Road (e.g., Apollo bay and Lorne). Intertidal reef breakwater structures have been implemented experimentally in various areas globally with some success (Morris et al. 2021, Chowdhury et al. 2019). This option is a novel approach, as such, design and approval costs, as well as lead time are expected to be higher than for a conventional structure.

The concept shown in Figure 5-8 involves two 180 m long intertidal rock groyne/reef structures placed along the outcropping bedding planes of the Eastern View Formation, forming a wider beach and protecting approximately 350 m of shoreline. Similar intertidal reefs historically existed in the study area with reports of outcropping Eastern View Formation at the low tide line forming a 'swimming pool' at low tide and higher beach levels (Bird 1998). This approach may also include nourishment of the dunes protected by the structures, planting of native vegetation for dune stability and re-instatement of beach access stairs and the boat ramp. With good design, this option could be effective for 50+ years. The groynes in Figure 5-8 are placed to reflect where the historic reefs are reported to have been. If more of the shoreline is to be protected, more groynes may be feasible.

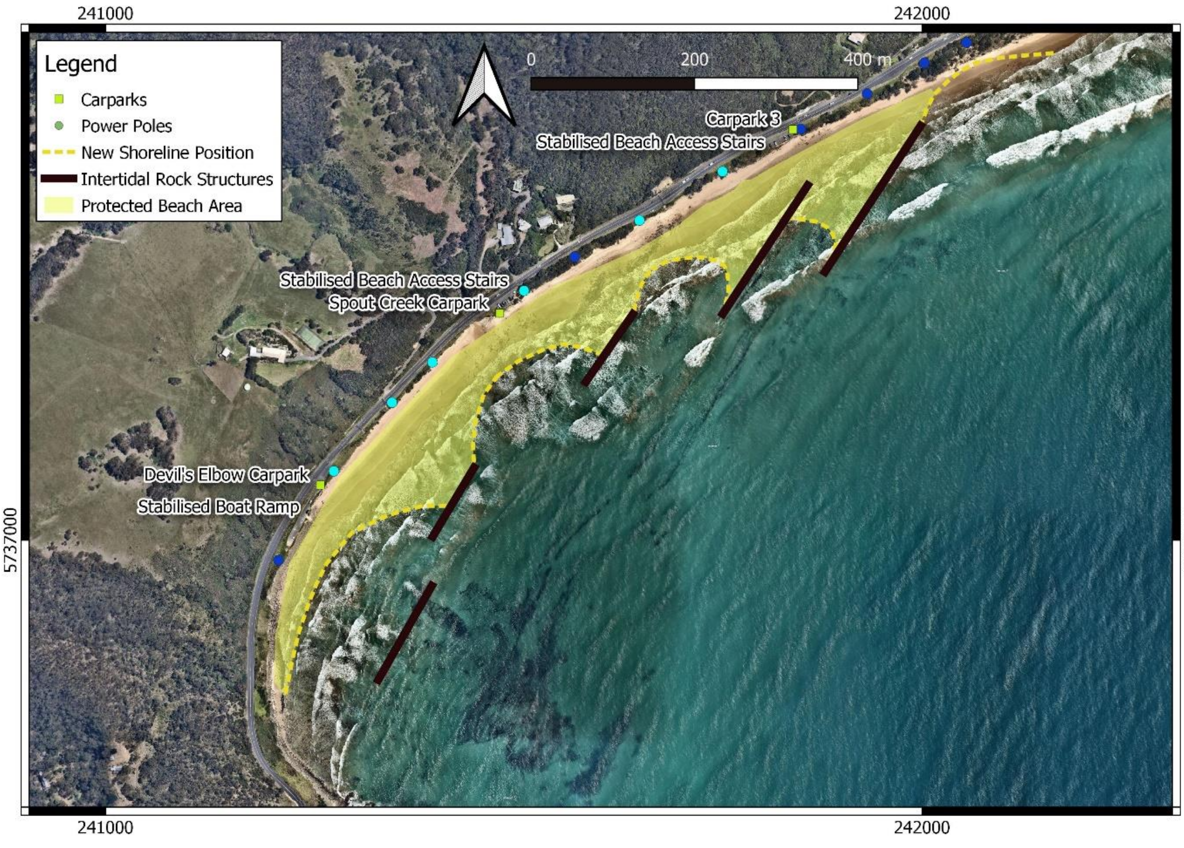

Figure 5-8 Option 8 – Sand Retention Structures

Protection is designated an 'option of last resort' in the Victorian Marine and Coastal Policy (DELWP 2020) because of its expense, and tendency to shift erosion issues along the coast. As outlined in Option 7 above, erosion at Eastern View is such that long-term protection of assets should be considered.

Table 5-15 Option 8 - Sand Retention Structures - Assessment

Assessment Criteria	Comment
Technical feasibility/effectiveness	Neutral Groynes have been implemented at various locations along the Great Ocean Road (e.g., Lorne and Apollo Bay), however this has more complexity and more risk.
Timeframe	Positive: With good design, this option may be effective for many years, however there is less certainty with the novel approach and may require occasional nourishment.
Relative cost	Strongly Negative: Highly Expensive
Social/economic impact	Positive: This option would protect assets along the coast and maintain or improve beach amenity.
Impact on coastal processes and environment	Negative: Groynes/breakwaters have large impacts on coastal processes and may shift the issue to other locations along the beach. Build up of sand could improve beach amenity
Governance, alignment with VMACP	Positive: Long Term Protection of assets is in line with the VMACP only when other, lower impact options are not viable.

Table 5-16 Option 8 – Sand Retention Structures - Cost Estimate

	Item	Unit	Qty	Rate	Total
1.0	**Site establishment**				
	Site establishment	Item	1	$5,000 - $10,000	$5,000 - $10,000
2.0	**Works**				
	Intertidal Reef/Groyne	m^3	4950	$150 - $300	$742,500 - $1,485,000
3.0	**Allowances**				
	Approvals and permits	%	10%	-	$74,750 - $149,500
	Design fees	%	10%	-	$74,750 - $149,500
	Engineering and supervision	%	3%	-	$22,425 - $44,850
	Contractor overhead	%	5%	-	$37,375 - $74,750
	Contingency	%	15%	-	$112,125 - $224,250
	Total Costs (excluding GST)				$1,069,000 - $2,138,000
	Cost per m (excluding GST)				$3,000 - $6,000

Trigger Value – Design of this option should be considered immediately. This option should begin to be progressively implemented when the dune crest comes within 1 m of the Great Ocean Road.

6 Adaptation Pathways and Recommendations

6.1 Pathways

The VMACP (DELWP 2020) defines a pathways approach as a decision-making strategy made up of a sequence of manageable steps or decision points over time. According to the policy, a pathway approach also includes:

- Consideration of the impacts of climate change on the marine environment using best available and conservative coastal process understanding,
- A comprehensive list of all available and relevant management options,
- Identification of relevant coastal hazards and prediction of how hazards will change over time,
- A list of thresholds or triggers for when new decisions need to be made,
- Recommendations of future decision points in light of the above information and considering costs, effectiveness, benefits, impacts and path dependency of adaptation actions.

After identification of these, different possible pathways of management action can be mapped over time. These pathways are defined by certain decision points when land managers will need to change the management strategies they employ because of increased risk from coastal hazards. These points are defined by the identified trigger values.

As outlined above, there are 8 short-listed options/measures identified to manage coastal hazards at Eastern View, all with relevant trigger values for their implementation. These are,

- Option 1 – Non-Intervention (Not Recommended)
- Option 2 – Seaweed Dune Toe Armouring (Nature Based)
  - Trigger Point – *when there is seaweed wrack in the intertidal zone of the beach and when a dune erosion scarp crest is within 4 m (Spout Creek and Memorial Arch zones) or 2 m (Devil's Elbow zone) of a built asset.*
- Option 3 – Beach Nourishment and Beach Scraping (Nature-based)
  - Trigger Point – *when a dune erosion scarp crest is within 4 m (Spout Creek and Memorial Arch zones) or 2 m (Devil's Elbow zone) of a built asset.*
- Option 4 – Upgrade Beach Access Structures (Accommodate)
  - Trigger point – *when* the carparks are protected using either short- or long-term protection measures.
- Option 5 – Retreat & Stabilize Power Poles (Retreat/Accommodate)
  - Trigger Point – *when a dune erosion scarp crest is within 4 m (Spout Creek and Memorial Arch zones) or 2 m (Devil's Elbow zone) of a built asset.*
- Option 6 – Rock Bags – Short-Term Protection

- *Trigger Point – when a dune erosion scarp crest is within 4 m (Spout Creek and Memorial Arch zones) or 2 m (Devil's Elbow zone) of a built asset.*

- Option 7 – Rock Revetment – Long-term protection
  - Trigger Value – *Design of this option should be considered immediately. This option should begin to be progressively implemented when the dune crest comes within 1 m of the Great Ocean Road.*
- Option 8 – Sand Retention Structures – Long-term protection
  - Trigger Value – *Design of this option should be considered immediately. This option should begin to be progressively implemented when the dune crest comes within 1 m of the Great Ocean Road.*

It is important to note that there are many assets currently at imminent risk and that trigger values for all Adaptation Options have been reached/exceeded. This means that decision points on adaptation action have been reached.

Utilising these options and trigger values, some possible pathways for coastal adaptation at Eastern View have been constructed. These are described in full below and summarized in Figure 6-1.

6.1.1.1 Adaptation Pathway – Eastern View

(1) Because erosion is currently impacting the Devil's Elbow carpark, Spout Creek carpark, Carpark 3, and the Great Ocean Road in one area, all of which can be retreated no further, immediate short-term protection in the form of rock bags should be installed. Where power poles are at risk (poles 396, 397, 399, 400, 401 and 402), they should be protected by short term protection or retreated and over-sunk to maximum depth. Dune toe armouring with seaweed can occur if desired when seaweed supplies wash up between the current time and when rock-bags can be implemented.

(2) When rock bags are installed, design of long-term protection should begin. This protection may be a rock revetment, intertidal reefs or groynes, offshore breakwaters, or a combination of any of the above.

(3) When design of the desired form of long-term protection is completed, staged construction should begin replacing the short-term protection then moving onto other areas as trigger values are reached. Practically it may be more efficient to build a large section of revetment in one stage rather than several smaller stages.

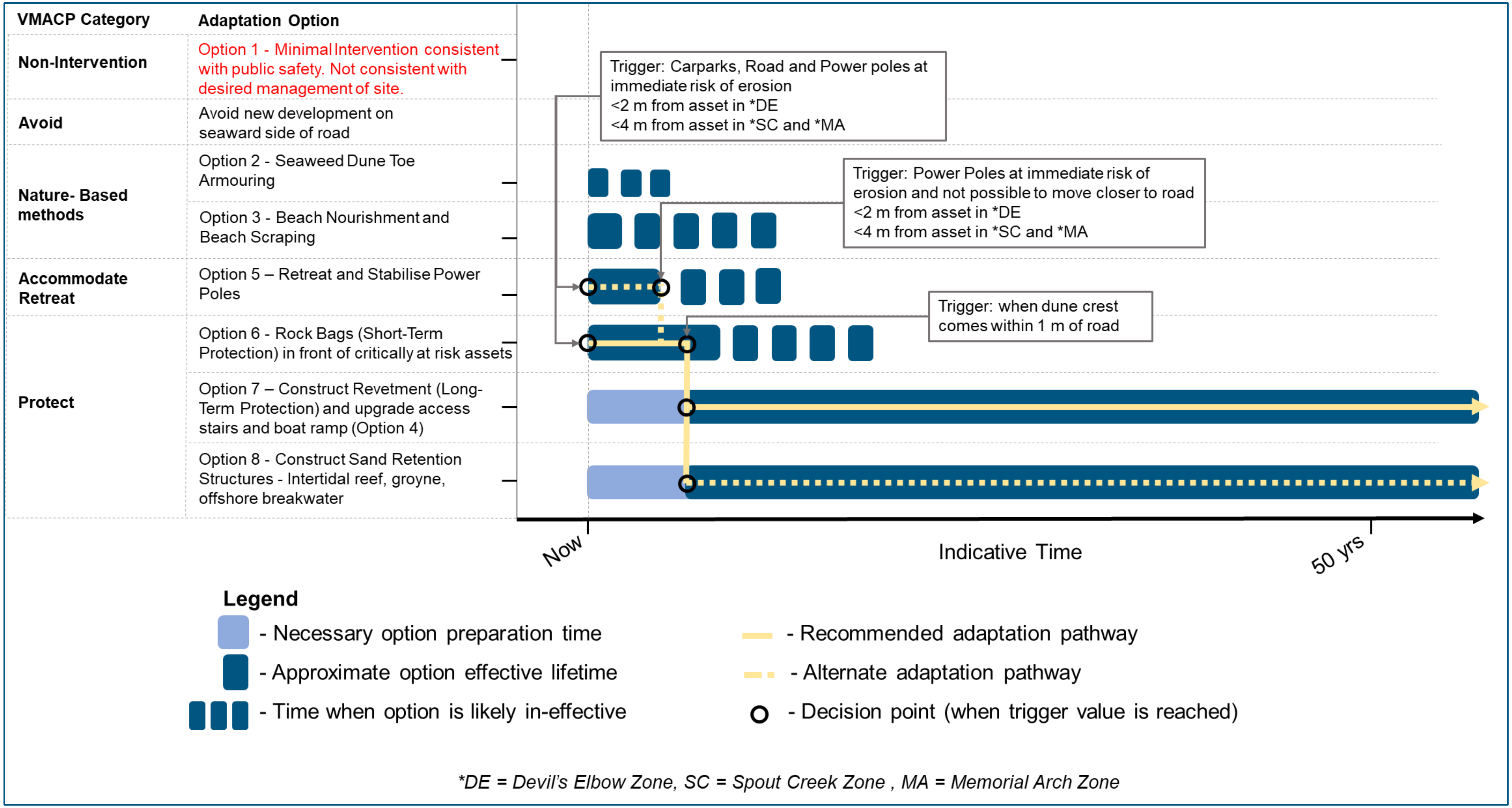

Figure 6-1 Recommended Adaptation Pathway – Eastern View

6.2 Recommendations

It is recommended that the management pathway outlined above in Section 6.1 should be utilised at Eastern View. This involves the following actions for coastal assets.

6.2.1 Carparks

It is recommended that short term rock bag revetment protection be implemented along the dune toe shoreward of the Devil's Elbow Carpark, Spout Creek carpark and Carpark 3 as soon as possible to halt ongoing erosion. Clay armouring of carpark edges may be an interim option at the digression and permittance of DELWP where the risk of carpark erosion is high and the required time to receive permits for, design and construct a rock bag revetment is too long.

After immediate short-term protection is in place, planning and design of long-term protection should commence. This may include revetment only or use a combination of revetment and novel sand retention structures. When the planning and design of these structures are complete, implementation should begin as soon as is practical.

Both these adaptation options will require consultation with Eastern Maar and may require permits and Cultural Heritage Management Plans.

6.2.2 Road

It is recommended that the 100 m stretch of road between the Spout Creek carpark and Carpark 3 (Figure 5-6) be immediately protected with an interim rock bag revetment. As above, planning for long-term protection of this section should also commence for implementation as soon as practical. Clay armouring of the GOR edge may be an interim option at the digression and permittance of DELWP where the risk of GOR erosion is high and the required time to receive permits for, design and construct a rock bag revetment is too long.

The GOR in the rest of the study area is not currently at risk from erosion, however, much of the road is predicted to be at risk by 2031. As such, planning for long-term protection of the road along the coast 1 km from Devil's Elbow to the East should commence immediately. This should include provision for construction of beach access stairs and a boat ramp.

All these adaptation options will require consultation with Eastern Maar and may require permits and Cultural Heritage Management Plans.

6.2.3 Power Poles

It is recommended that power poles 396, 397, 399, 400, 401 and 402 be retreated as far as possible on the seaward side of the road or protected with rock bags immediately. All other power poles are not at immediate risk from erosion and hence, can be left in place.

As above, planning for long-term protection of this section should also commence for implementation as soon as practical. This could involve protection with a rock revetment or moving the power line to the landward side of the road.

If erosion begins to impact a pole before long-term protection can be implemented, the pole should be temporarily protected with rock bags.

Each of these adaptation options will require consultation with Eastern Maar and may require permits and Cultural Heritage Management Plans.

6.2.4 Boat Ramp

It is recommended that the clay boat ramp be maintained annually as currently occurs while the carpark remains open and until long term protection is designed for the area. Once protection is in place upgrading the ramp to a more resilient piled structure should be considered.

This will require consultation with Eastern Maar and may require permits and Cultural Heritage Management Plans.

6.2.5 Cultural Heritage Sites

Representatives from Eastern Maar attended the draft presentation of this report where coastal adaptation regarding cultural heritage sites was discussed. We heard the following:

- Consultation with Eastern maar on coastal management/adaptation is a priority.
- Eastern Maar want to preserve and protect cultural heritage.
- Natural and natural looking adaptation options are preferred.
- Permits and Cultural Heritage Management Plans may be required for any works which may impact sites.

In line with this, it is recommended that prior to any adaptation/management decision regarding the study area, representatives of Eastern Maar are consulted as a first priority. Representatives should also be consulted continually through the implementation process of any coastal adaptation structure (e.g., revetment) to ensure the product is culturally appropriate and that Cultural heritage management plans and permits are prepared where necessary.

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