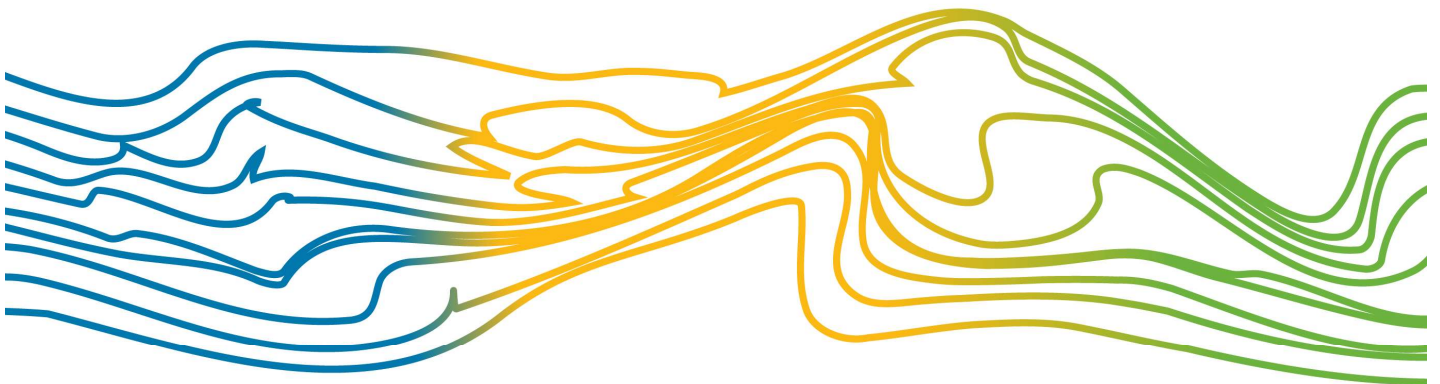


# Coastal Hazard Vulnerability Assessment

The Beach, Apollo Bay

Australian Tourism Investments No. 5 Pty Ltd

27 March 2019



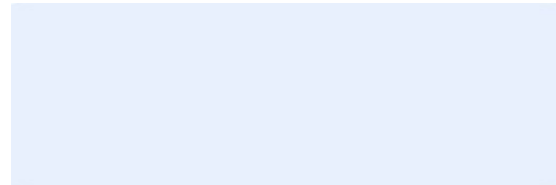


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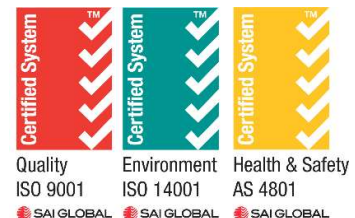


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## GLOSSARY AND DEFINITIONS

AHD	Australian Height Datum. 0m AHD approximately corresponds to mean sea level
AEP	Annual Exceedance Probability: The measure of the likelihood (expressed as a probability) of an event equalling or exceeding a given magnitude in any given year
Astronomical tide	Water level variations due to the combined effects of the Earth's rotation, the Moon's orbit around the Earth and the Earth's orbit around the Sun.
Exceedance probability	The probability of an extreme event occurring at least once during a prescribed period of assessment is given by the exceedance probability. The probability of a 1 in 100 year event (1% AEP) occurring during the first 25 years is 22%, during the first 50 years the probability is 39% and over a 100 year asset life the probability is 63%.
HAT	Highest Astronomical Tide: the highest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects.
Holocene	Geological epoch beginning approximately 12,000 years ago. It is characterised by warming of the climate following the last glacial period and rapid increase in global sea levels to approximately present day levels.
MHHW	Mean Higher High Water: the mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day this is taken as the higher high water.
MSL	Mean Sea Level: the long-term average level of the sea surface.
Significant wave height	The average of the highest one third of all waves.
Storm surge	The meteorological component of the coastal water level variations associated with atmospheric pressure fluctuations and wind setup.
Storm tide	Coastal water level produced by the combination of astronomical and meteorological (storm surge) ocean water level forcing.



## 1 INTRODUCTION

Water Technology was engaged by the owner of the property at The Beach Development, Apollo Bay, Victoria to undertake a Coastal Hazard Vulnerability Assessment (CHVA) to define the extent of existing coastal hazards and potential future coastal hazards associated with climate change and sea level rise at the proposed new development site.

The assessment has been undertaken in accordance with the following advisory documentation and information:

- *The Marine and Coastal Act 2018*
- *Victoria's Marine and Coastal Reforms Final Transition Plan (DELWP, 2018)*
- *The Victorian Coastal Strategy (VCC, 2014)*
- *Derivation of Revised Victorian Sea-Level Planning Allowances Using the Projections of the Fifth Assessment Report of the IPCC (Hunter, 2014)*
- *How to consider sea level rise along the Victorian Coast (DSE, 2008)*
- *The Effect of Climate Change on Extreme Sea Levels along Victoria's Coast (CSIRO, 2009)*
- *State Planning Policy Framework, Amendment VC148 Clause 13.01*
- *The Victorian Coastal Hazards Guide (DSE, 2012)*
- *Practice Note 53: Managing Coastal hazards and the Coastal Impacts of Climate Change (DPCD, 2012)*
- *Guidelines for Coastal Management Authorities: Assessing Development in Relation to Sea Level Rise (DSE, 2012)*
- *Coastal Hazards Management Plan for Marengo to Skenes Creek (Water Technology, 2012)*
- *Marengo to Wild Dog Creek Sand Management Plan (Water Technology, 2017)*
- *Apollo Bay – Coastal Protection Study (GHD, 2018)*

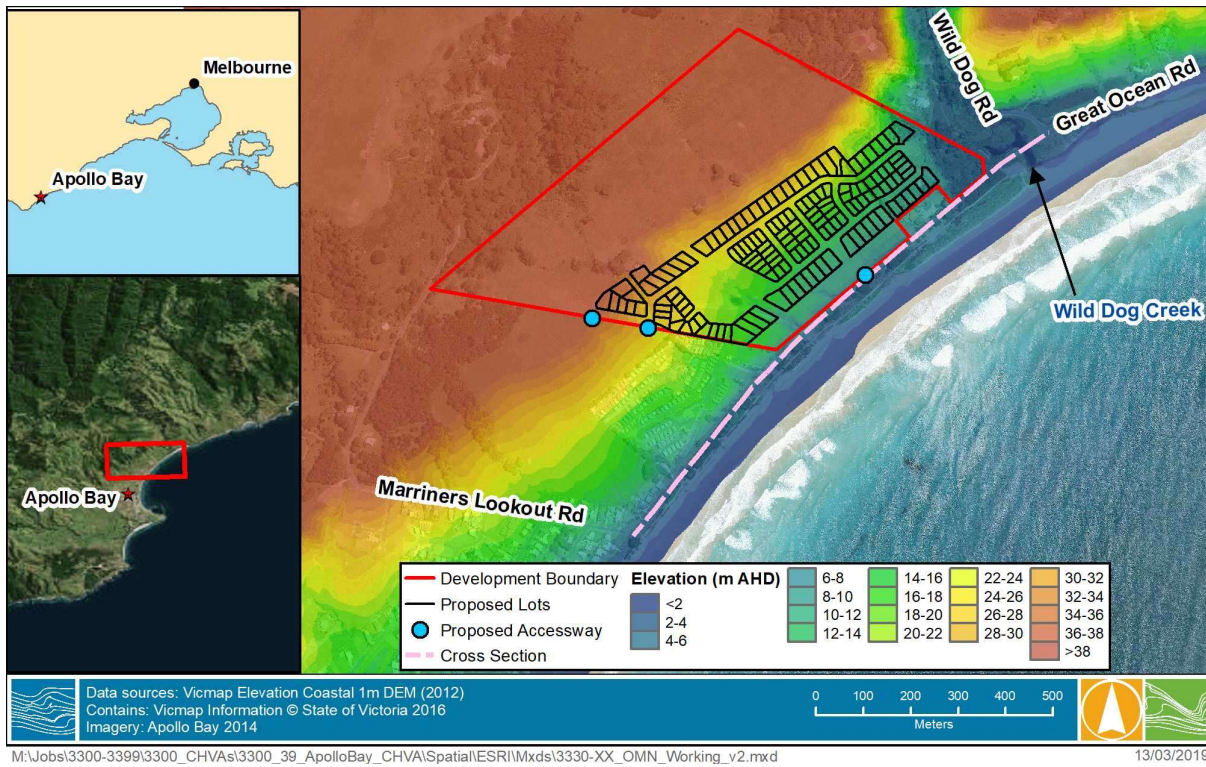
### 1.1 Site Details

The proposed development (site) is located in Apollo Bay on Victoria's western coastline as illustrated in Figure 1-1. The development comprises a series of residential building lots, open spaces, drainage ways and roads as detailed in Figure 1-4.

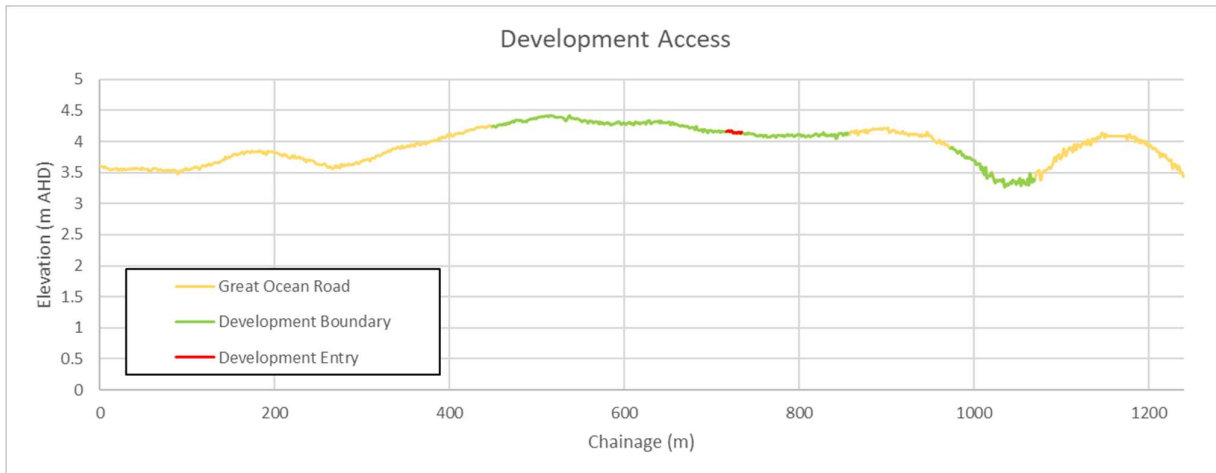
The site is situated immediately landward of the Great Ocean Road (GOR) and is bounded by Wild Dog Creek to the north and an existing developed holiday park to the south. Along the sites seaward boundary the development contains a 50m wide buffer zone of open grassed space and undeveloped drainage reserve that rises from an elevation of around 4 – 5m AHD to an elevation of around 7m AHD or higher. It should be noted that the north-eastern corner of the site contains a drainage reserve that is intended to provide a buffer to the low lying flood plain of Wild Dog Creek. The development site is situated beneath Mariners Lookout and slopes upwards in a landwards direction to 158m AHD on the sites north western boundary. The residential lots within the proposed development are to be situated between elevations of 6.5 – 40m AHD.

The proposed buildings are to be constructed on land which is no lower than 6.5m AHD, resulting in Finished Floor Levels (FFL) greater than this elevation as a minimum. The main access way to the site is from the Great Ocean Road as shown in Figure 1-1, the pink dotted line represents the cross section presented Figure 1-2. To the west of the site the elevation of the Great Ocean Road to Marriners Lookout Road is 3.5 – 4.4 m AHD whilst to the east of the site the elevation of the Great Ocean Road to Wild Dog Road is 3.3m AHD to 4.1m AHD (see Figure 1-2). Two new roads/accessways are proposed on the southern site boundary at elevations of 25m AHD and 40m AHD respectively (see Figure 1-1).





**FIGURE 1-1 SITE LOCATION**



**FIGURE 1-2 GREAT OCEAN ROAD CROSS SECTION: MARRINERS LOOKOUT RD CHAINAGE 0 TO WILD DOG CREEK ROAD CHAINAGE 1240**

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**FIGURE 1-3 VIEW OF SITE LOOKING NORTH-EAST ALONG GREAT OCEAN ROAD (IMAGE COURTESY OF GOOGLE STREETVIEW (15/03/2019) ©**

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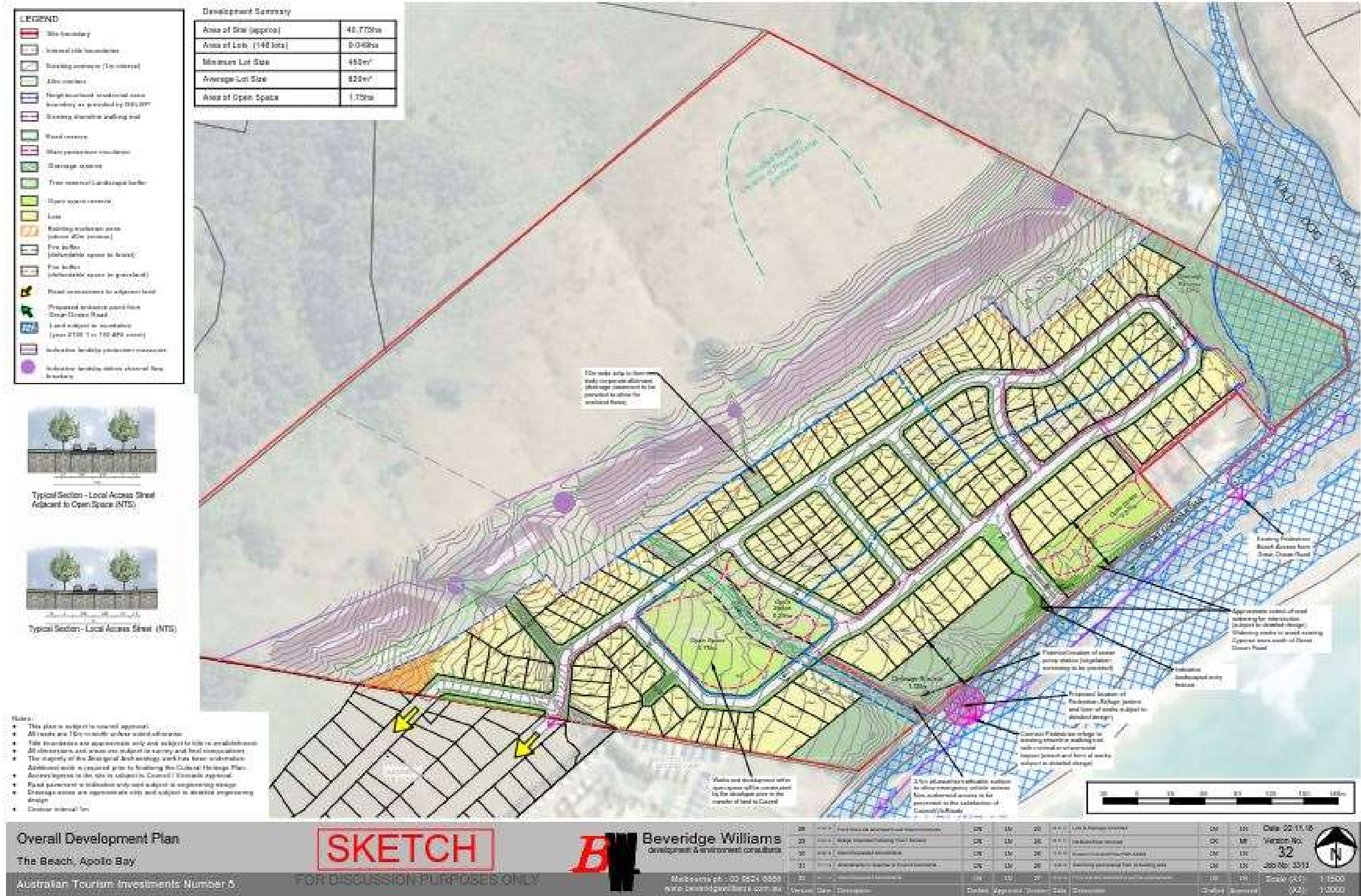


FIGURE 1-4 SITE LAYOUT (BEVERIDGE WILLIAMS, 2018)

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## 2 GEOMORPHOLOGY AND COASTAL PROCESSES

### 2.1 Geomorphology

To provide context to the coastal vulnerability assessment the underlying geomorphology of the area has been reviewed in conjunction with the coastal and riverine processes impacting the development site.

Apollo Bay is located at the foot of the Otway Ranges which are comprised of uplifted Cretaceous sedimentary formations that sit at an elevation of roughly 300m above sea level. The Cretaceous sediments contain a large concentration of feldspar, the eroded sediments of which do not supply large quantities of sand sized sediments to the coastline. As such, the sediments found within the littoral zone of the sand bars, beaches and dune system in the region are predominately comprised of marine sediment that has drifted shoreward from the floor of Bass Strait following the end of the last glacial phase and subsequent marine transgression.

Between Apollo Bay and Wild Dog Creek, a crenulate shaped bluff exists behind the present-day shoreline which was likely formed during the relatively higher sea level conditions of the mid Holocene (6,000-7,000 years before present). The fall in mean sea level which occurred after the mid Holocene has birthed the present-day dune and beach system located seaward of this earlier shoreline this is shown in Figure 2-1. The net sediment transport along the present-day coastline is in a north east direction, predominantly driven by south westerly swell waves.

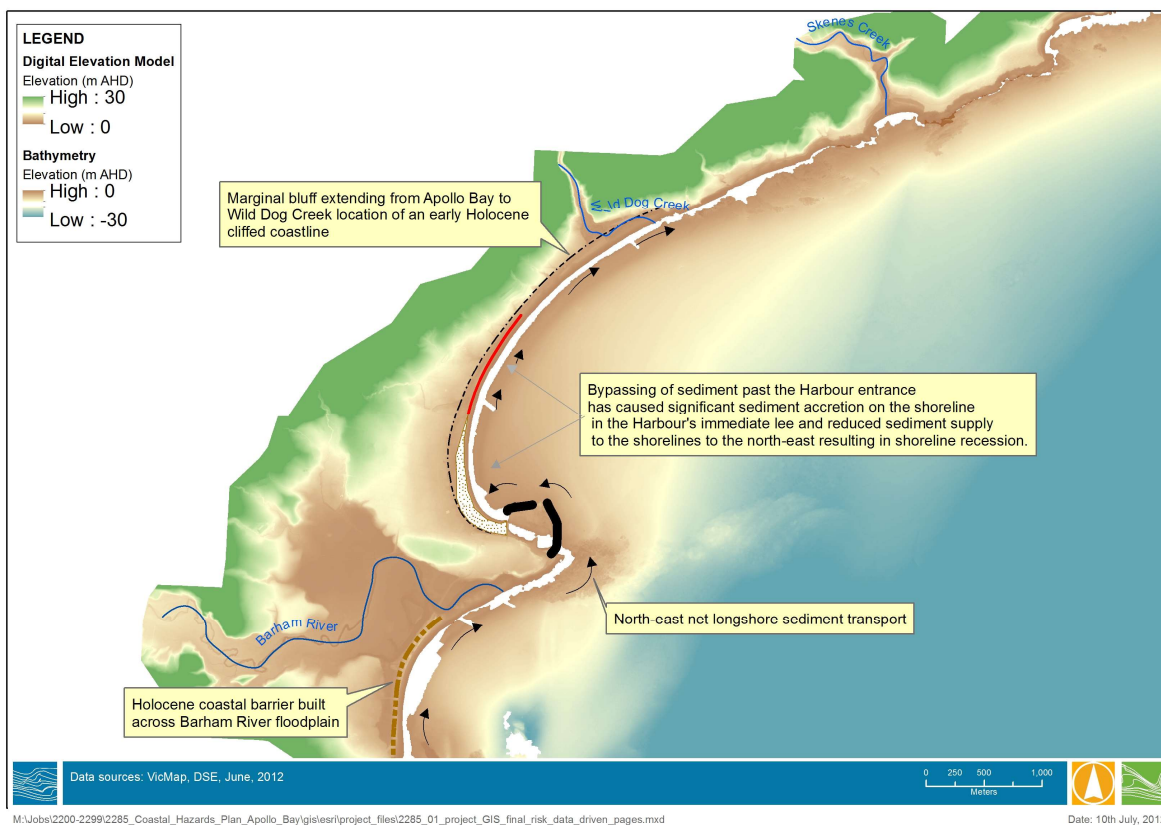


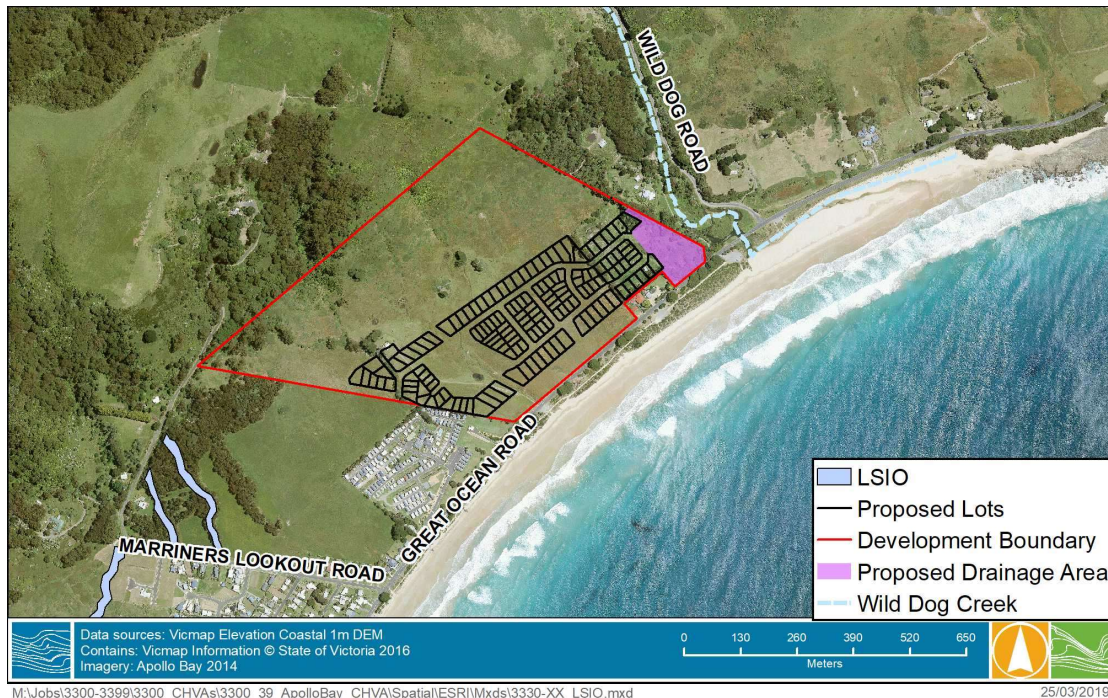
FIGURE 2-1 OVERVIEW OF COASTAL GEOMORPHOLOGY (WATER TECHNOLOGY, 2012)

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## 2.2 Land Subject to Inundation Overlay

An overview of the Colac Otway Planning Scheme (2018) indicates that the property is situated outside of the Land Subject to Inundation Overlay (LSIO) (Victorian State Government, Planning Maps Online). A portion of land to the south west of the site within the vicinity of Mariners Lookout Road is covered by the overlay as shown within Figure 2-2. The absence of the LSIO near Wild Dog Creek may indicate that there has been no flood study completed for this area. However, given the close proximity of the development to the creek entrance, it is likely that creek flood levels in the vicinity of the development would be dictated by the downstream (storm tide) flood levels. The area of the development adjacent to the creek entrance has been reserved as a drainage basin, with elevations up to 6.5 m AHD. Consequently, the development is not expected to be adversely affected by ocean flooding via Wild Dog Creek.



**FIGURE 2-2 LAND SUBJECT TO INUNDATION OVERLAY FOR THE REGION SURROUNDING THE SITE**

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### 3 REGIONAL EXPOSURE ASSESSMENT

The following assessment identifies the magnitude and frequency of the main oceanographic processes impacting the coastline in the region under existing conditions and under the 2040, 2070 and 2100 climate change predictions.

#### 3.1 Mean Sea Level

Table 3-1 provides a summary of relevant sea level rise scenarios for planning. Estimates of sea level rise by Hunter (2014), incorporating the IPCC 2014 A1F1 climate change scenario, predict an increase in the mean sea level of 0.8 m by 2100. This scenario is considered to meet the minimum sea level rise scenario for planning as per the Victorian Coastal Strategy (VCC, 2014).

Practice Note 53 from the Department of Environment, Land, Water and Planning (DELWP, 2015) also notes the following amendment to the State Planning Policy Framework:

“In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill)”.

**TABLE 3-1 SEA LEVEL RISE SCENARIOS (VCC, 2014; DPCD, 2012)**

	Scenario and Year		
	2040 High	2070 High	2100 High
Global Mean Sea Level Rise (m)	0.2	0.47	0.82

#### 3.1.1 Shoreline Response to Sea Level Rise

To investigate potential future coastal recession due to sea level rise, the Bruun Rule (Bruun, 1962), Equation 3-1, has been used. This equation considers the active beach profile to be in equilibrium; with sea level rise  $S$  (m) accompanied by an equal rise in the bed elevation. The Bruun Rule and resulting setback distances should be used with caution and considering the limitations listed below. The setback is indicative and approximate only and is calculated for an idealised undisturbed beach profile.

The active profile is defined by a length,  $L$  (m), and maximum depth, or depth of closure  $h_d$  (m), beyond which sediment transport is not considered to occur. The additional cross sectional area of sand on the bed is taken from the dry beach and dune of height,  $f$  (m), resulting in a recession of  $R$  (m). The results of the Bruun Rule analysis are presented in Table 3-2 along with the estimated active beach slope which was derived from existing topographic data and extrapolated to the depth of closure.

**EQUATION 3-1 BRUUN RULE EQUATION**

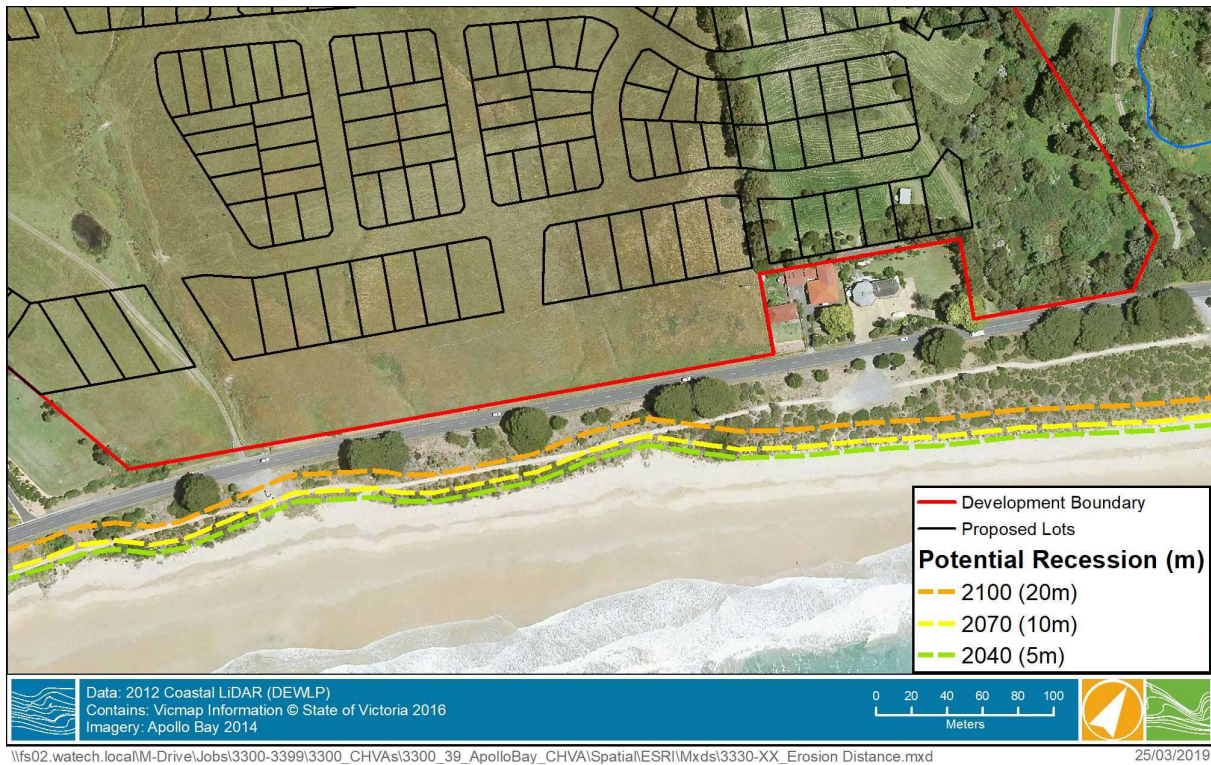
$$R = (S.L)/(h_d + f)$$

**TABLE 3-2 RECESSION DUE TO SEA LEVEL RISE (METRES)**

Recession (m)	Scenario and Year		
	2040 High	2070 High	2100 High
Active Profile			
Active Beach Slope = 1:21 (V:H)	5	10	20

A graphical representation of the Bruun Rule results is presented below within Figure 3-1.

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**FIGURE 3-1 BRUUN RULE – POTENTIAL FUTURE SHORELINE RESSION \**

These results should also be considered within the limitations in the application of the Bruun Rule (from Mariani et al, 2012):

1. The rule assumes that there is an offshore limit of sediment exchange or a 'closure depth', beyond which the seabed does not rise with sea level.
2. The rule assumes no offshore or onshore losses of sand.
3. The rule assumes instantaneous profile response following sea level change.
4. The rule assumes an equilibrium beach profile where the beach may fluctuate under seasonal and storm-influences but returns to a statistically average profile (i.e. the profile is not undergoing long-term steepening or flattening). This being stated, the precise configuration of the profile is irrelevant provided it is maintained as the water level changes (SCOR, 1991).
5. The rule does not accommodate variations in sediment properties across the profile or profile control by hard structures such as substrate geology or adjacent headlands or engineered structures such as the Great Ocean Road.

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### 3.2 Astronomical Tide

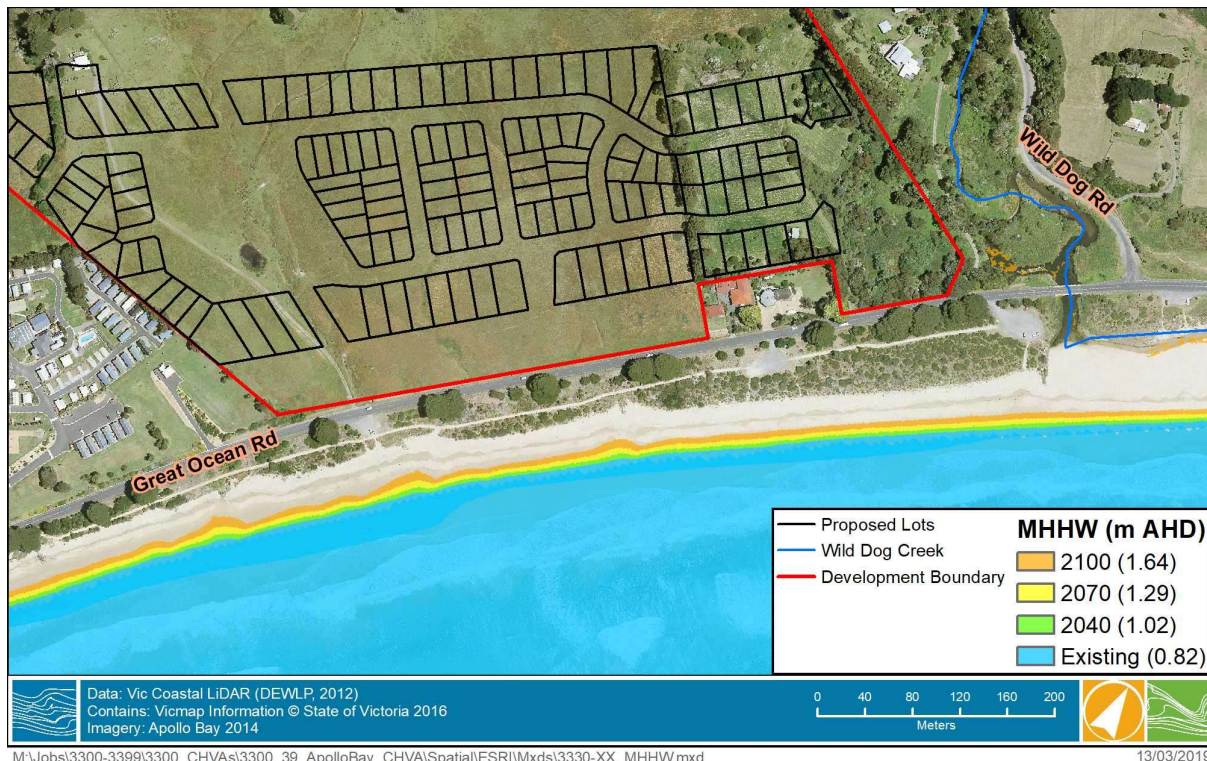
Astronomical tide refers to the rise and fall of the sea surface due to the gravitational attraction between Earth, Moon and Sun. Water level variations in coastal areas due to the astronomical tide can be reliably predicted provided a reasonable length of continuous water level observations is available.

Tidal plane information from Apollo Bay was adopted as listed in the Victorian Tide Tables (VRCA, 2018). The Mean High High Water (MHHW) and the Highest Astronomical Tide (HAT) have been combined with the applied sea level rise scenarios for 2040, 2070 and 2100 shown in Table 3-1 and are listed in Table 3-3.

**TABLE 3-3 ESTIMATE OF HIGH WATER LEVELS FOR DIFFERENT SEA LEVEL RISE SCENARIOS (M AHD)**

m AHD	Existing	2040	2070	2100
HAT	1.09	1.29	1.56	1.91
MHHW	0.82	1.02	1.29	1.64

The predicted extent of the MHHW tidal planes under existing, 2040, 2070 and 2100 sea level scenarios on the Victorian Coastal LiDAR (2012) topographical elevation for the proposed development site are presented below in Figure 3-2. Note that these are still water inundation extents, and can be considered as indicative only, as the extent of inundation will depend on the shape of the beach profile, which evolves and fluctuates over time.



**FIGURE 3-2 PREDICTED MHHW EXTENTS AT THE PROPOSED DEVELOPMENT FOR VARIOUS SEA LEVEL RISE SCENARIOS (EXCLUDING WAVE RUN-UP)**

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### 3.3 Storm Tides

The term storm tide refers to coastal water levels produced by the combination of astronomical and meteorological ocean water level forcing. The meteorological component of the storm tide is commonly referred to as storm surge and collectively describes the variation in coastal water levels in response to atmospheric pressure fluctuations and wind setup. The storm tide components are presented in Figure 3-3.

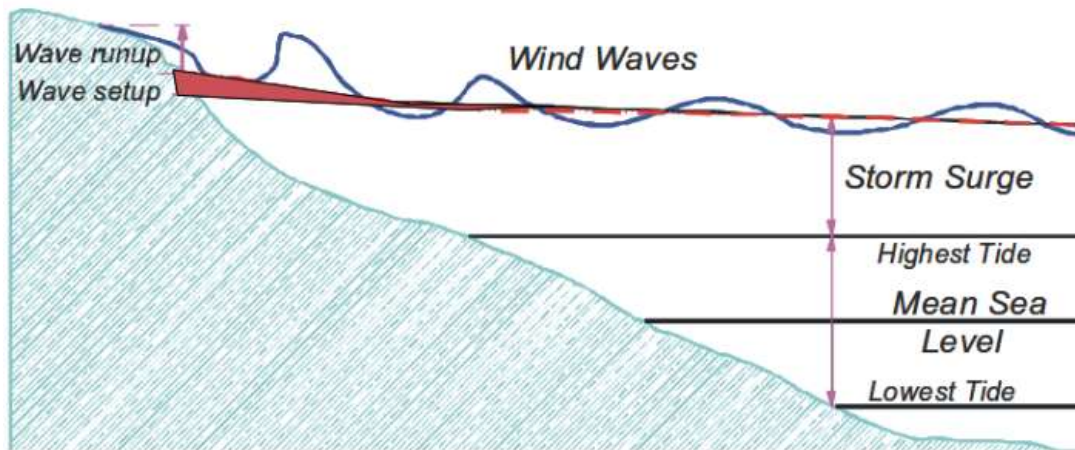


FIGURE 3-3 STORM TIDE COMPONENTS (CSIRO, 2009)

Estimates of extreme coastal water levels (storm tides), including the impact of the projected sea level rise within Table 3-1, have been developed for the Victorian coastline by the CSIRO (2009) for different planning and sea level rise scenarios. The storm tide levels for Apollo Bay that have been adopted for this study and are presented in Table 3-4.

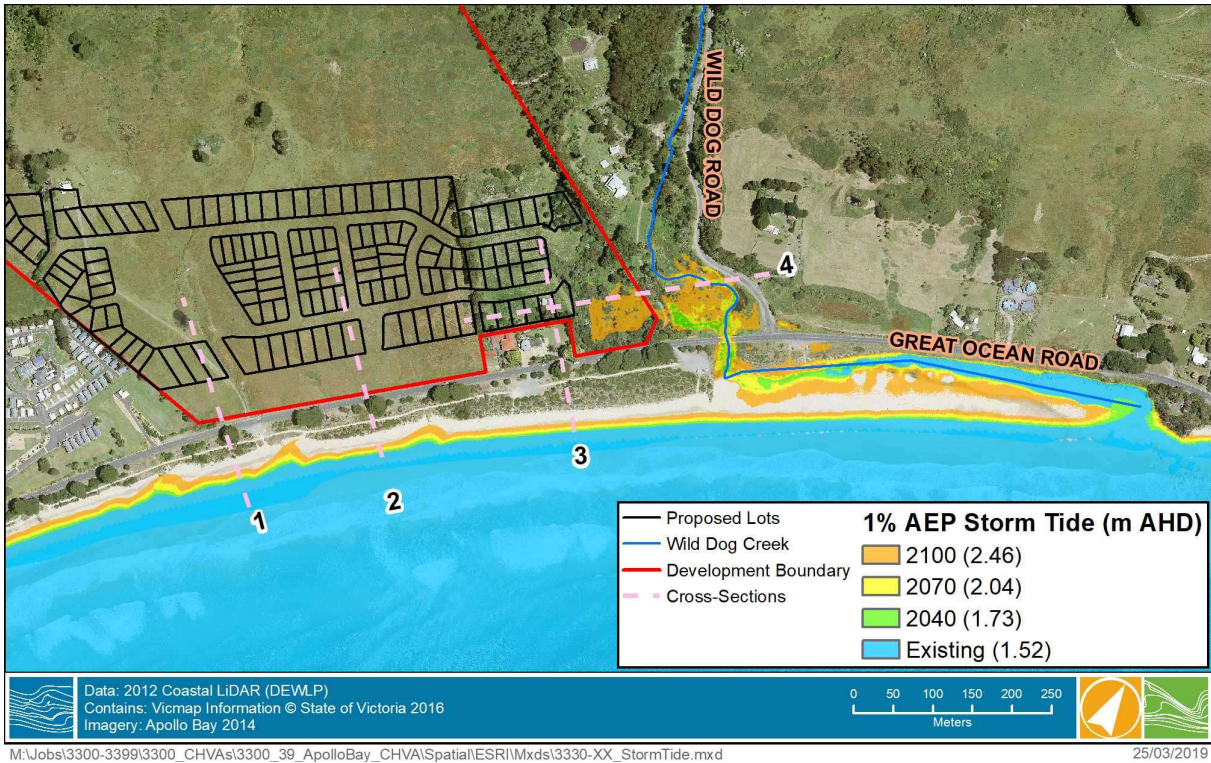
Levels for existing (2019) and 2040 are interpolated from the existing at the time of the report (2009), 2030, and 2070 values. Note that the future scenarios increase by values larger than the sea level rise projections given in Table 3-1 as they also include an additional allowance for future storm intensification. Wave setup and runup values are not included within these storm tide levels and are addressed within Section 3.4.

TABLE 3-4 CSIRO STORM TIDE LEVELS INCORPERATING MEAN SEA LEVEL RISE SCEANARIOS

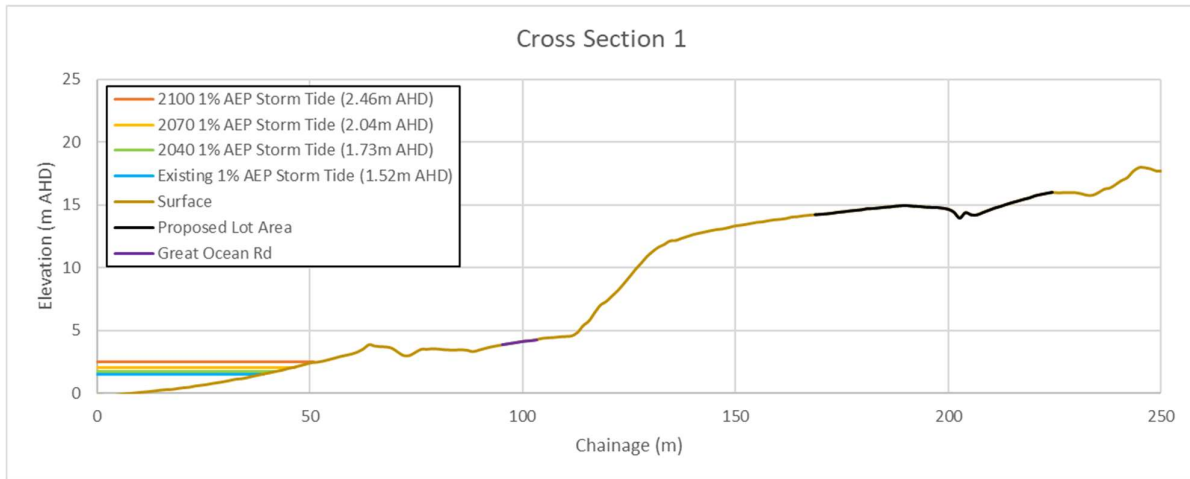
AEP (%)	Existing (m AHD)	2040 High (m AHD)	2070 High (m AHD)	2100 High (m AHD)
10	1.20	1.40	1.71	2.13
5	1.33	1.53	1.82	2.25
2	1.44	1.65	1.95	2.36
1	1.52	1.73	2.04	2.46

The estimated inundation extents from the 1% AEP storm tides are displayed in Figure 3-4. The locations of the cross sections shown in Figure 3-5 to Figure 3-8 are indicated by the pink dotted line within Figure 3-4. The cross sections illustrate the variations in topography across the site. These figures indicate that the projected still water level storm tide does not extend beyond the vegetation line along the site’s south-eastern boundary on top of the dune system. However, areas in the north-eastern section of the property along Wild Dog Creek are below the 2100 1% AEP storm tide levels. The storm tide inundation in this area is due to the rising sea levels overtopping the banks of Wild Dog Creek for the 2100 1% AEP storm tide.

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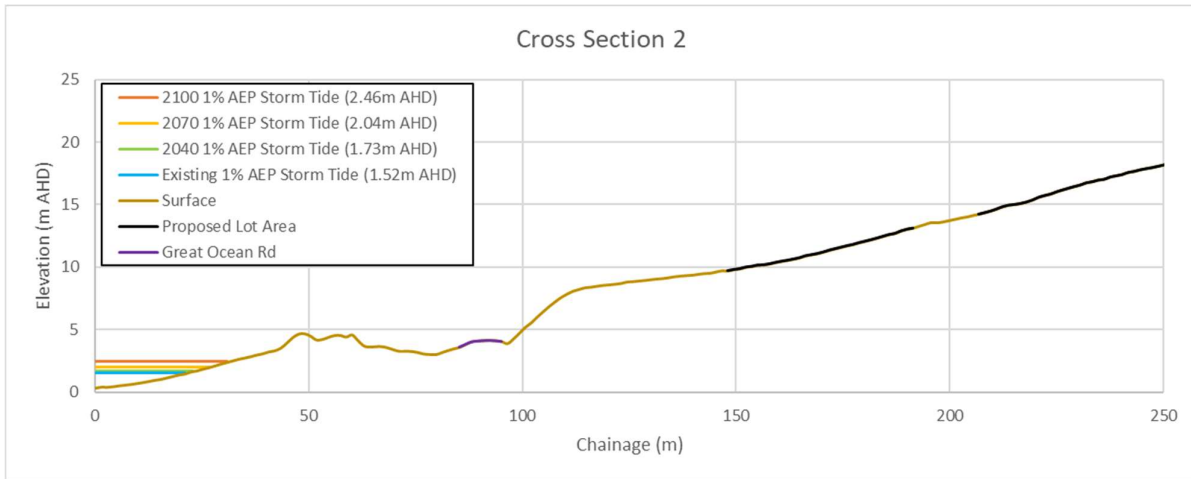


**FIGURE 3-4 1% AEP STORM TIDE LEVELS AND CROSS SECTION LOCATIONS**

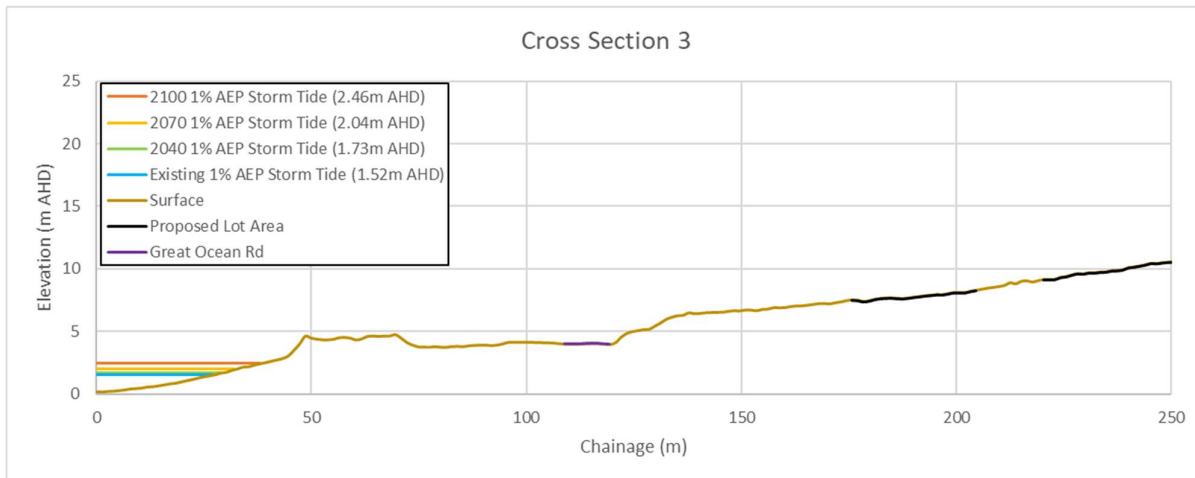


**FIGURE 3-5 CROSS SECTION 1 PROFILE AND 1% AEP STORM TIDE LEVELS**

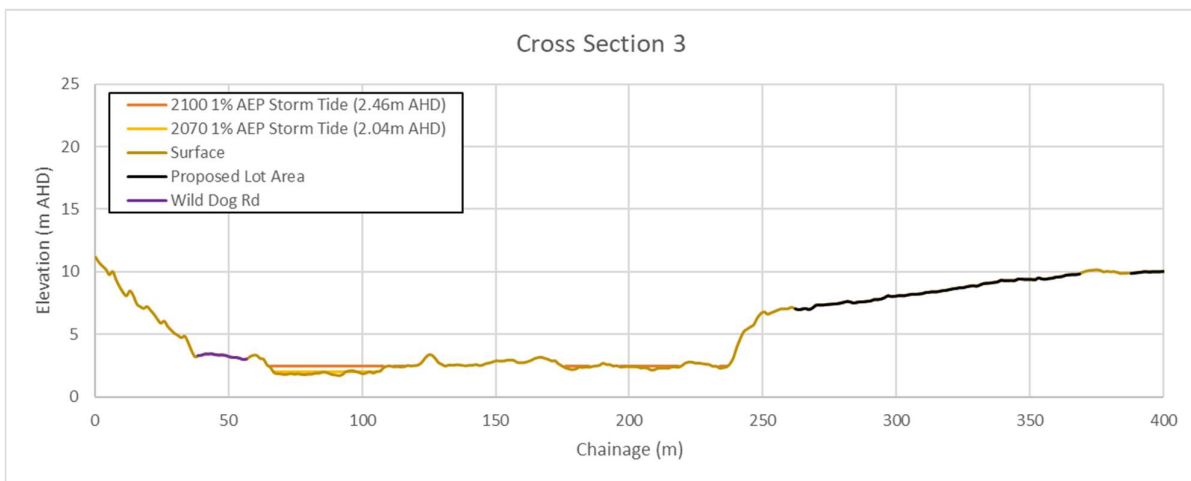
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**FIGURE 3-6 CROSS SECTION 2 PROFILE AND 1% AEP STORM TIDE LEVELS**



**FIGURE 3-7 CROSS SECTION 3 PROFILE AND 1% AEP STORM TIDE LEVELS**



**FIGURE 3-8 CROSS SECTION 4 PROFILE AND 1% AEP STORM TIDE LEVELS**

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### 3.4 Waves & Wave Run-up

The main sources of wave energy within Apollo Bay are south-westerly Southern Ocean swell waves, as well as shorter period swell and local sea waves generated within Bass Strait - as shown in Figure 3-9. Additional (less energetic) wave sources include swell waves from the Great Australian Bight, and the Tasman Sea, all of which are significantly attenuated by the time they round Cape Otway or Wilsons Promontory.

GHD (2018) showed that south-westerly is the dominant wave direction offshore of Apollo Bay with waves propagating from this direction around 94% of the time. South easterly and easterly waves were less frequent and occur approximately 5% of the time. More than 70% of the waves are long period swell waves with a peak spectral wave period of 16-20 seconds.



**FIGURE 3-9 WAVE SOURCES AND DIRECTIONS AFFECTING VICTORIAN COASTLINE**

GHD (2018) assessed the offshore wave climate near the study area and determined design significant wave heights for a range of average exceedance probabilities – as shown in Table 3-5. That study showed that storm events from E and SE directions have a typical wave periods of 8 to 12 seconds, whilst storm waves from the SW have typically have longer associated wave periods, in the range of 10 to 20 seconds.

**TABLE 3-5 OFFSHORE SIGNIFICANT WAVE HEIGHTS**

AEP (ARI)	H <sub>s</sub> off (m)
63% (1 year)	5.2
10% (10 years)	6.3
5% (20 years)	6.6
2% (50 years)	7.0
1% (100 years)	7.2

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The section of Apollo Bay main beach located just north of the harbour and west of the site is sheltered from the dominant south-westerly swell wave energy by the harbour and Point Bunbury. The development, however, is located roughly 3km to the east of Point Bunbury which is more exposed and experiences a high energy wave environment leading to significant wave setup and run-up. Water Technology (2012) estimated wave setup and wave run-up along the Apollo Bay Main Beach in the vicinity of Wild Dog Creek for a series of storm tide scenarios which are presented within Table 3-6, the resultant wave run-up water levels are presented within the same table. The probability associated with the 5m and 8m wave events are considered unlikely and rare respectively.

Water Technology (2012), estimated wave run-up hazards for three different levels of probability:

- Almost certain to occur in a 10 year time frame (10% AEP storm);
- Unlikely to occur in a 10 year time frame (1% AEP event); and
- Rare - worst case scenario for a combination of factors (<1% AEP)

The analysis also includes future wave run-up levels under the adopted sea level rise scenarios.

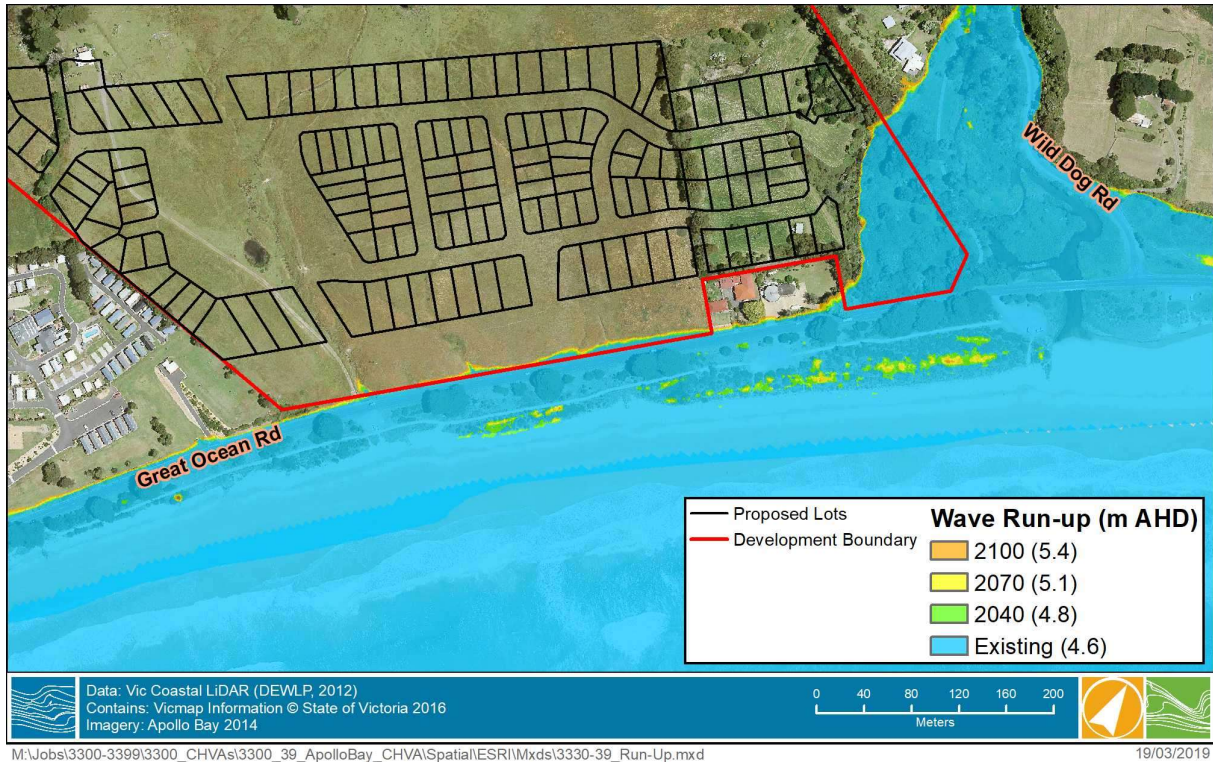
**TABLE 3-6 WAVE RUN-UP**

Probability	Scenario	Existing# (m AHD)	2040 High (m AHD)	2070 High (m AHD)	2100 High (m AHD)
Almost Certain	10% AEP Storm Tide + $H_{s\ off} = 5m, T_p = 14s$	3.6	3.8	4.1	4.4
Unlikely	1% AEP Storm Tide + $H_{s\ off} = 5m, T_p = 14s$	3.9	4.1	4.4	4.7
Rare	1% AEP Storm Tide + $H_{s\ off} = 8m, T_p = 14s$	4.6	4.8	5.1	5.4

# adopted from Water Technology (2012)

The resulting wave run-up inundation extents for the “rare” scenario are provided in Figure 3-10 below. This figure shows that the impact of the existing, 2040, 2070 and 2100 wave run-up inundation scenarios on the development are similar due to the steep topography of the site. Across the site there is only a small distance between the existing and 2100 wave run-up inundation extents which is in the order of 1-8m. None of the scenarios impede on the proposed residential lots, the most exposed residential lot located above the Wild Dog Creek drainage area in the north eastern section of the site is positioned 14m landward of the 2100 wave run-up level.

Site access, however, is greatly affected by wave run-up with the existing “rare” run up level of 4.6m AHD completely inundating the Great Ocean Road along the developments south eastern boundary. It should be noted that inundation of this nature is expected to persist for only a few hours at a maximum – i.e. the duration of a high tide.



**FIGURE 3-10 ESTIMATED “RARE” WAVE RUN-UP EXTENTS FOR VARIOUS SEA LEVEL RISE SCENARIOS**

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## 4 HISTORICAL SHORELINE CHANGE

The longshore sediment transport driven by the wave climate outlined in Section 3.4 was assessed by Costal Engineering Solutions (CES) for a number of beaches within the Apollo Bay region. This modelling verified previous estimates by Vantree (1996) that the net potential sediment transport along the Apollo Bay Main Beach is approximately 80,000 m<sup>3</sup>/y in a north easterly direction (CES, 2005).

Within the vicinity of the proposed development, there exists a groyne located immediately south of the Wild Dog Creek entrance. This groyne was constructed in 1950 (EstuaryWatch, 2018), and has resulted in the coastline accreting as northerly moving sediment is trapped on the groyne's southern side. Mapping of the dune vegetation lines was undertaken by CES (2005) for a number of historical aerial photographs taken between, 1952 and 2004, which verifies this accretion trend (see Figure 4-1). The accretion rate between 1952 and 2004 just south of the groyne was approximately 0.9 m/year, Shoreline accretion further south was less pronounced and around 0.5 m/yr (CES, 2005). That study also showed stabilisation of the shoreline between 1997 and 2004.

Inspection of 2018 aerial imagery shows that no significant change in vegetation line has occurred since 2004 which indicates that the stability of the shoreline observed between 1997-2004 has likely continued. Based on this, it is likely that the groyne compartment at Wild Dog Creek is now full, and sand is likely to be bypassing around the groyne such that ongoing advancement of the shoreline is considered unlikely. The groyne itself is now largely buried in the local dune.

The existing dune and beach system provides a significant erosion buffer to the site with the smallest buffer between the development and lot boundaries to the 2018 vegetation line being approximately 40m and 90m respectively.

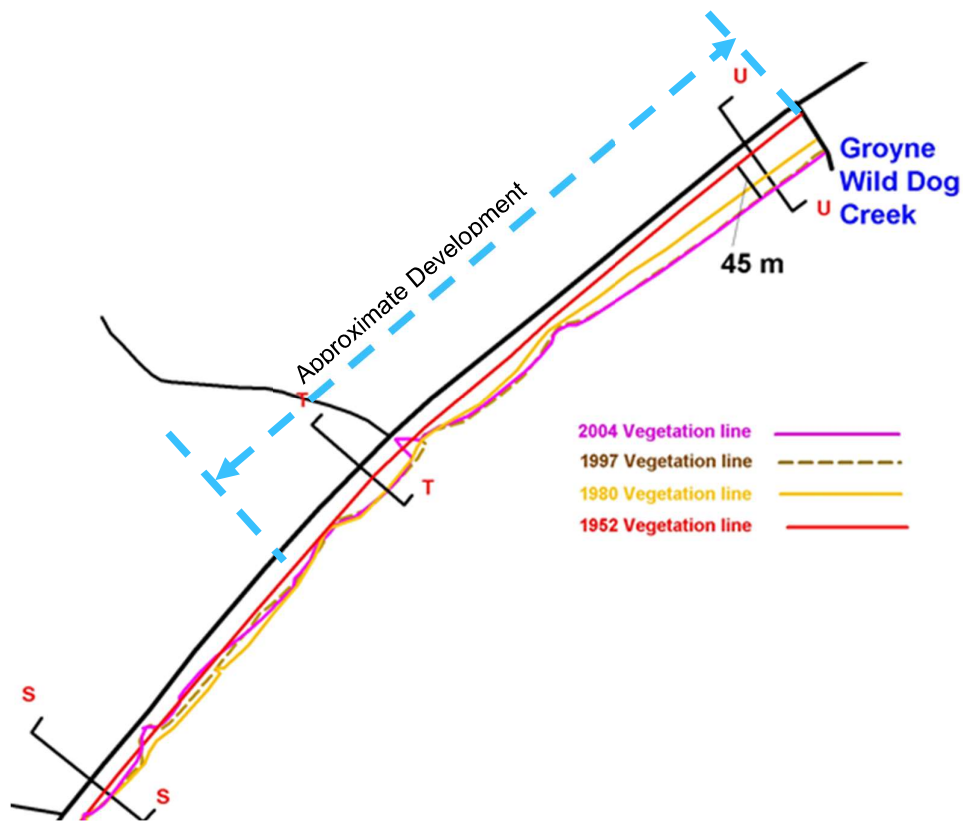


FIGURE 4-1 VEGETATION LINES 1952, 1980, 1997, 2004 (CES, 2005)

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## 5 COASTAL HAZARDS

### 5.1 Coastal Erosion

Historical coastal hazards within the Apollo Bay coastline have generally be associated with large storm tide events in combination significant wave energy impacting the shoreline. These events have resulted in significant shoreline erosion with large volumes of sediment being moved offshore by the waves, combined with inundation of low-lying areas caused by wave overtopping. In particular, the region of open coastline (the section of coast that is not sheltered by Point Bunbury and the Harbour) has experienced a greater severity and occurrence of these events. However, the increased beach volume in front of the development site due to the presence of the Wild Dog Creek groyne has reduced the impacts of these events within the immediate vicinity of the development.

At nearby locations within Apollo Bay (approximately 550m south of the development) storm erosion along the beach has resulted in repeated loss of sections of the foreshore and walking track near Marriners Lookout Rd (see Figure 5-1). Coastal inundation of the Great Ocean Road has also been observed within this area in 2005 as shown in Figure 5-2.



**FIGURE 5-1 COASTAL EROSION IMPACTING CAR PARKS AND WALKING PATHS IN APOLLO BAY IN 2005.**

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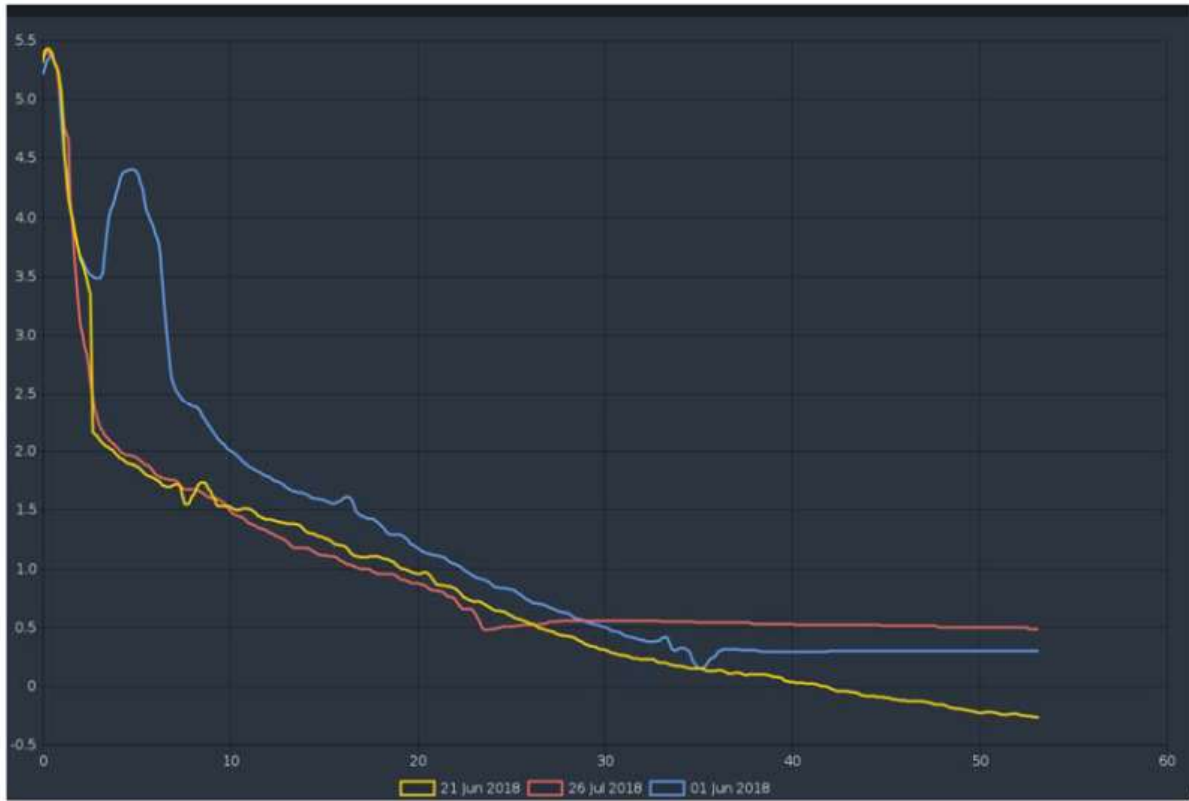


**FIGURE 5-2 COASTAL INUNDATION IMPACTING THE GREAT OCEAN ROAD IN APOLLO BAY (G. MC PIKE 2005)**

The foreshore at Apollo Bay experienced significant erosion in a series of storms during June and July 2018, and these events are discussed in the Apollo Bay Coastal Protection Study (GHD, 2018).

Erosion distances were not reported immediately in front of the site however they were surveyed for the area located between Milford St and Marriners Lookout Rd, approx. 550m south of the site. At that location, around 2 m of horizontal erosion was measured as a (cumulative) result of those storms, with a corresponding storm erosion volume of the order of 2-3 m<sup>3</sup>/m. The worst erosion observed occurred between Milford St and Joyce St where the maximum measured erosion distance was 5m as shown within Figure 5-3. The coastal dune measured on the 1<sup>st</sup> June 2018 (blue) can be observed to have shifted offshore resulting in a shallower offshore bed by 26<sup>th</sup> July 2018 (pink).

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**FIGURE 5-3 SURVEYED CROSS SECTION COMPARISON - APOLLO BAY BETWEEN MILFORD ST & JOYCE ST (IMAGE SOURCE: GHD,2018)**

GHD (2018) updated the design storm erosion results of Water Technology (2012), using additional data from the erosion observed during the June 2018 storm events. Results are provided in terms of storm cut width (also known as storm bite) - which refers to the horizontal retreat of the erosion escarpment. Results are provided for three probability scenarios – as discussed in Section 3.4.

**TABLE 5-1 STORM EROSION AT APOLLO BAY (GHD, 2018)**

Probability	Storm Cut Width (m)
Almost Certain	3
Unlikely	5
Rare	8

**Site Significance**

The existing dune and beach system adjacent to the development site provide a significant erosion buffer. Given the width of the existing dune system at the study area (i.e. the distance between the back of the beach and the Great Ocean Road), which increases from a width of around 25 m at the southern end of the development to around 60 m at the northern end of the development - it is highly unlikely that the residential development will be affected by short term storm erosion at any time during its proposed design life. Individual lots within the development are provided further protection in the form of a 50 m wide drainage reserve, and most individual lots are set back around 90m or more from the existing foreshore.

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Despite this, the Great Ocean Road may become increasingly exposed to coastal erosion risk over 2070 and 2100 timeframes at the southern end of the development. It is expected that such erosion would be managed by the relevant authorities into the future.

## 5.2 Coastal Inundation

As discussed in Section 3.4, it is expected that the Great Ocean Road and associated access point to the development will become inundated under the “Almost Certain” (to occur within a nominal 10 year timeframe) wave run-up scenario for present day conditions. It is therefore also likely to be inundated under more severe events and future sea level scenarios. Consequently, under such conditions the alternate access points at the south-western corner of the development should be used and maintained.

The two alternate access points to the development are located on the south-west boundary that connects to the neighbouring Mariners Vue Estate – see Figure 5-4 . These access points above any potential storm surge inundation and will provide sufficient access points for all the proposed lots where the Great Ocean Road accessway is inundated. The access available provides residents both a route to the town centre, as well as an inland route away from Apollo Bay in case of emergency – see Figure 5-5.

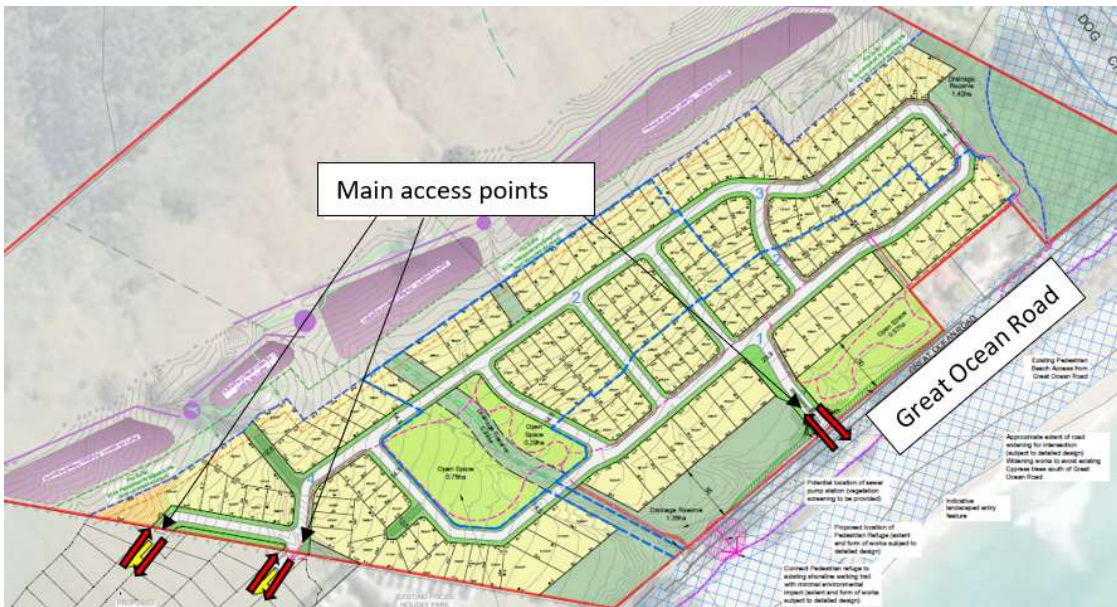


FIGURE 5-4 DEVELOPMENT ACCESS POINTS (IMAGE COURTESY OF BEVERIDGE WILLIAMS, 2019)

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FIGURE 5-5 DEVELOPMENT ACCESS ROUTES (IMAGE COURESTY OF BEVERIDGE WILLIAMS, 2019)

### 5.3 Stormwater & Runoff

The hydrological sub-catchments that traverse the subject site are expected to generate a considerable volume of stormwater runoff during intense rainfall events, as the relatively steep terrain of the upper reaches of the sub-catchments may not permit much infiltration of rainfall. This runoff will be required to be discharged from the site through a network of culverts.

The topographical contours and overland flow paths shown at the site are depicted in Figure 5-6 (as adopted from Beveridge Williams, 2016). This figure shows that overland flow at the proposed development will discharge to four locations. Three overland flow paths discharge to the stormwater drains at the Great Ocean Road – which subsequently discharge to culverts on the study area foreshore (the fourth overland flow path is directed into the wetlands in the lower eastern corner of the development). During a storm event, elevated ocean levels may restrict the discharge of such stormwater - resulting in excess runoff at Great Ocean Road and the developments proposed drainage reserves.

Consequently, it is recommended that the proposed development adopt best practise water sensitive urban design (WSUD) in order to adequately redirect and store excess stormwater runoff. Such mechanisms would be needed to adequately address overland flow runoff & flooding concerns, whilst also minimising the impact of excess runoff on beach erosion at the stormwater culverts/outlets.

It should be noted that the development site also contains a number of storm water storage basins (farm dams) located above the site along the toe of the steep terrain at, an elevation of around 40m AHD. These farm dams are located within the network of overland flow paths and would likely reduce the runoff discharge from the subject site during an intense rainfall event.

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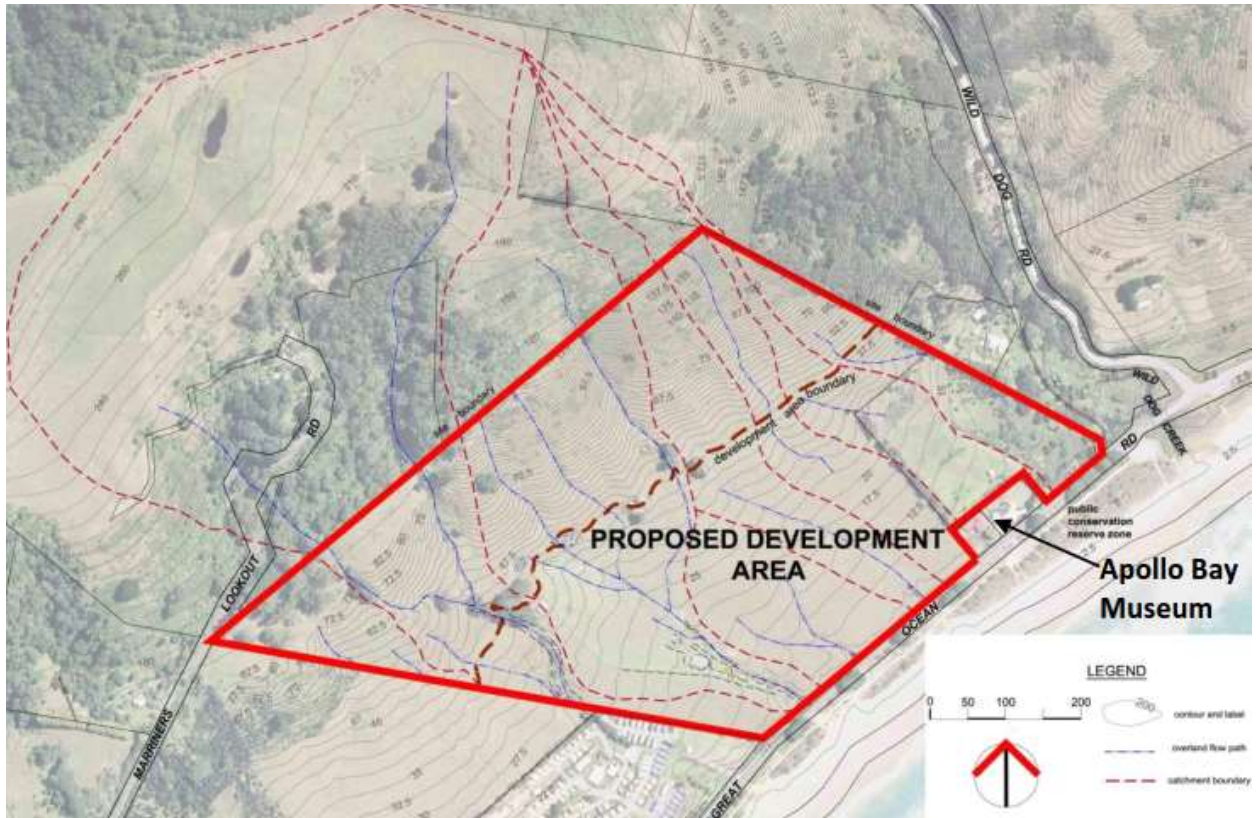


FIGURE 5-6 SITE CONTOURS AND DEVELOPMENT DRAINAGE NETWORK (BEVERIDGE WILLIAMS, 2016)

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## 6 COASTAL HAZARD RISK ASSESSMENT

### 6.1 Overview

Risk Management is the term applied to a logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating the risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise opportunities (Standards Australia, 2009). Risk is identified as the product of the likelihood and consequence of an event impacting on an asset or objective.

Risk profiles have been developed by assigning scores to the consequence of each relevant coastal hazard and the likelihood of this coastal hazard impacting the site over a range of relevant timeframes this century. The risk profile is determined by applying the scores to a risk matrix such as the one shown in Table A-3, Appendix A. The risk profile assists with the identification and analysis of priority risks for subsequent decision making and planning.

Table A-1 within Appendix A displays a description and semi-quantitative score that has been assigned to the range of coastal hazard likelihoods.

Table A-2 within Appendix A displays a description and semi-quantitative score that has been assigned to the range of coastal hazard consequences.

Table A-3 and Table A-4 within Appendix A display the resulting risk matrix and risk profile definitions respectively.

### 6.2 Coastal Inundation Hazard

The likelihood and consequence of the coastal inundation hazards impacting the site has been assessed based on the review of the storm tide levels and existing topography. Risks ratings for the coastal inundation hazard are provided in Table 6-1 (residential lots) and Table 6-2 (access roads).

The key justifications for the risk ratings assigned for this hazard are provided below:

- The proposed lots of the development are located at a minimum level of 6.5m AHD or higher which is:
  - 4.0m above the 2100 1% AEP storm tide level; and
  - 1.1m above the rare wave run-up level for 2100 sea level rise.
- The 2100 1% storm tide will result in inundation of the proposed drainage zone - at the north eastern corner of the property.
- Site access via the Great Ocean Road is likely to be affected when ocean inundation levels equal or exceed approximately 3.5m AHD. As a result, access via the Great Ocean Road will become inundated under the “Almost Certain” (to occur within a nominal 10 year timeframe) wave run-up scenario for present day conditions. It is therefore also likely to be inundated under more severe events and future sea level scenarios. Consequently, under such conditions the alternate access points at the south-western corner of the development should be used and maintained in preparation.
- Site access via the proposed side roads on the south-western boundary of the site are in excess of 20m above the 2100 rare wave run-up scenario.



**TABLE 6-1 COASTAL INUNDATION RISK ASSESMENT RESULTS (RESIDENTIAL LOTS)**

Coastal Hazard	Specific Impact	Timeline	Likelihood	Consequence	Risk Rank
Coastal Inundation	Inundation of proposed <u>residential lots</u> by elevated storm tide and additional elevated water levels associated with wave action on the coastline.	Existing	Rare	Insignificant	<b>Low</b>
		2040	Unlikely	Minor	<b>Low</b>
		2070	Unlikely	Minor	<b>Low</b>
		2100	Unlikely	Minor	<b>Low</b>

**TABLE 6-2 COASTAL INUNDATION RISK ASSESMENT RESULTS (ACCESS ROADS)**

Coastal Hazard	Specific Impact	Timeline	Likelihood	Consequence	Risk Rank
Coastal Inundation	Inundation of development <u>property grounds</u> and/or <u>access road</u> by elevated storm tide and additional elevated water levels associated with wave action on the coastline.	Existing	Likely	Minor	<b>Medium</b>
		2040	Almost Certain	Minor	<b>Medium</b>
		2070	Almost Certain	Minor	<b>Medium</b>
		2100	Almost Certain	Minor	<b>Medium</b>

### 6.3 Coast Erosion (including Short Term & Long-Term Coastal Recession)

The likelihood and consequence of long-term coastal recession hazards at the site has been assessed based on the review of the coastal and oceanographic processes expected to impact the property this century. The key justifications for the risk ratings assigned for this hazard in Table 6-3 (residential lots) and Table 6-4 (access roads) are provided below:

- The coastline in front of the proposed development area has seen an accretion trend since 1952 of up to 45m in in the vicinity of the Wild Dog Creek Groyne, though it is noted that this accretion has ceased and the beach position has stabilised over the past decade.
- Sea level rise may result in coastal recession around the site if no further coastal management or protection works are implemented.
- It is expected (based on State Government comments) that protection works will be undertaken by relevant authorities if the Great Ocean Road is threatened by erosion over future planning horizons.
- The Great Ocean Road, car parks and walking tracks have impacted the natural shape of the dune system with a likely reduction in dune volume and elevation.
- The development boundary is located landward of the Great Ocean Road with a minimum buffer of 40m from the 2018 vegetation line. This is a buffer of 20m from the potential 2100 shoreline recession distance associated with sea level rise.
- The lot boundaries have a minimum buffer of 87m from the 2018 vegetation line. This is a buffer of 67m from the potential 2100 shoreline recession distance associated with sea level rise.
- Due to the steep nature of the development site there is a significant volume of material (sediment) between the coastline and the lot boundaries.

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**TABLE 6-3 COASTAL EROSION RISK ASSESSMENT RESULTS (RESIDENTIAL LOTS)**

Coastal Hazard	Specific Impact	Timeline	Likelihood	Consequence	Risk Rank
Short-term beach erosion	Dynamic, short-term recession or breach of the dune or barrier system by wave action and elevated water levels that impacts the residential lots at the site.	Existing	Rare	Moderate	Low
		2040	Rare	Moderate	Low
		2070	Rare	Moderate	Low
		2100	Rare	Moderate	Low

**TABLE 6-4 COASTAL EROSION RISK ASSESSMENT RESULTS (ACCESS ROADS)**

Coastal Hazard	Specific Impact	Timeline	Likelihood	Consequence	Risk Rank
Short-term beach erosion	Dynamic, short-term recession or breach of the dune or barrier system by wave action and elevated water levels that impacts the development <u>property grounds</u> and/or <u>access road</u> at the site.	Existing	Rare	Moderate	Low
		2040	Rare	Moderate	Low
		2070	Unlikely	Moderate	Medium
		2100	Possible	Moderate	Medium



## 7 MITIGATION OPTIONS

There is a wide array of potential mitigation options that can be employed in response to climate change and sea level rise risks to coastal infrastructure and assets.

The National Committee on Coastal and Ocean Engineering (Engineers Australia, 2017) endorses a simple set of three broad strategic options for mitigating the impact of sea level rise as presented by the IPCC (2014). These options are considered to provide a basic framework for the assessment of potential mitigation strategies for the site if and when they are required.

The three broad strategic options are retreat, accommodate and protect. These broad strategic options have been used to provide the suggested pathways listed in Table 7-1 to adapting to the coastal hazard risks identified at the site and in the general vicinity.

**TABLE 7-1 POTENTIAL CLIMATE CHANGE ADAPTION PATHWYAS**

Planning Horizon	Suggested Response Strategy	Suggested Mitigation Measures
Existing	Accommodate / Protect	<p>Ensure the proposed <u>finished floor levels</u> are above the planning frame 1% AEP storm tide for the planning horizon.</p> <p>Ensure the proposed <u>access roads</u> on the south-western boundary are maintained into the future.</p>
2040		
2070		
2100		



## 8 CONCLUSION

This report documents the updated coastal hazard vulnerability assessment (CHVA) undertaken for the proposed development “The Beach” at Apollo bay.

The following conclusions relating to the coastal hazard vulnerability assessment of the proposed development can be drawn:

- The assessment of coastal inundation at the property indicates:
  - The existing, 2040 and 2070 1% AEP still water storm tide levels will not inundate the property boundary.
  - The 2100 1% AEP storm tide will inundate the south eastern section of the development boundary which is a designated drainage zone.
  - Residential lots are not expected to be affected by wave run-up during the proposed development design life.
  - Access to the site via the Great Ocean Road may become restricted during large wave setup and wave run-up events – both under present day conditions and into the future. However, inundation of the access road is expected to be short lived (the length of a high tide – that is a few hours). Access to the site via the proposed roads on the south western side of the property will not be restricted under any foreseeable coastal inundation event and evacuation of the site and Apollo Bay township is possible.
- The assessment of coastal erosion at the property indicates:
  - Comparison of vegetation lines in aerial imagery between 1952, 1980, 1997 and 2004 by CES (2005) indicates an underlying accretion estimate of 0.9 m/year for the vegetated dune just south of the Wild Dog Creek groyne. This coastline has now stabilised but has resulted in a significant erosion buffer in front of the development.
  - The minimum erosion buffer between the 2018 vegetation line and the property boundary is 40m. This is 20m landward of the potential 2100 shoreline recession distance associated with sea level rise.
  - The minimum erosion buffer between the 2018 vegetation line and the proposed lot boundaries is 87m. This is 67m landward of the potential 2100 shoreline recession distance associated with sea level rise.
  - Residential lots are not expected to be affected by erosion during the proposed development design life.
- The Great Ocean Road and the access point via this road to the development may become increasingly exposed to coastal recession over 2070 and 2100 timeframes (due to future shoreline recession). However, monitoring and management of the long term erosion at this site is expect to be able to identify and address such issues if they occur well into the future.





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## 10 DEFINITIONS AND DISCLAIMERS

The information contained in this report is subject to the disclaimers and definitions below.

1. The area referred to in this report at the development “site” or “property” or “development” is the land that Water Technology believes most closely represents the location identified by the client. The identification has been done in good faith and in accordance with information given to Water Technology by the client.
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# APPENDIX A RISK ASSESSMENT DEFINITIONS





TABLE A-10-1 LIKELIHOOD RANKING

Likelihood Level	Description	Annual Exceedance Probability
1 – Rare	Risk will occur in exceptional circumstances.	1:10,000
2 – Unlikely	Risk not likely to occur within the period.	1:1,000
3 – Possible	Risk may occur within the period.	1:100
4 – Likely	Risk likely to occur within the period.	1:10
5 – Almost Certain	Risk will occur within the period.	1:1

TABLE A-10-2 CONSEQUENCE RANKING

Consequence Level	Description
1 – Insignificant	Minimal impact in a localised area within existing natural variability.
2 – Minor	Low impact in a localised area with minimal impact to the site or its function. Flood depths <0.3m.
3 – Moderate	Medium impact in a broad area with minor, local consequences to the site or its function. Flood depths 0.3 – 0.6m.
4 – Major	High impact in a broad area resulting in significant consequence to the site or its function. Flood depths 0.6 – 1.2m.
5 – Extreme	Very high impact with broad and significant consequences to the site and its function. Flood depths > 1.2m.

TABLE A-10-3 RISK ASSESSMENT MATRIX

Likelihood	Consequence				
	1 – Insignificant	2 – Minor	3 – Moderate	4 – Major	5 – Extreme
5 – Almost Certain	Medium	Medium	High	Extreme	Extreme
4 – Likely	Medium	Medium	Medium	High	Extreme
3 – Possible	Low	Medium	Medium	Medium	High
2 – Unlikely	Low	Low	Medium	Medium	Medium
1 – Rare	Low	Low	Low	Medium	Medium

TABLE A-10-4 RISK PROFILE DEFINITION

Risk Profile	Definition
Low	Tolerable risk. A level of risk that is low and manageable without intervention.
Medium	A level of risk that may require intervention to mitigate.
High/Extreme	A level of risk requiring significant intervention to mitigate.

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