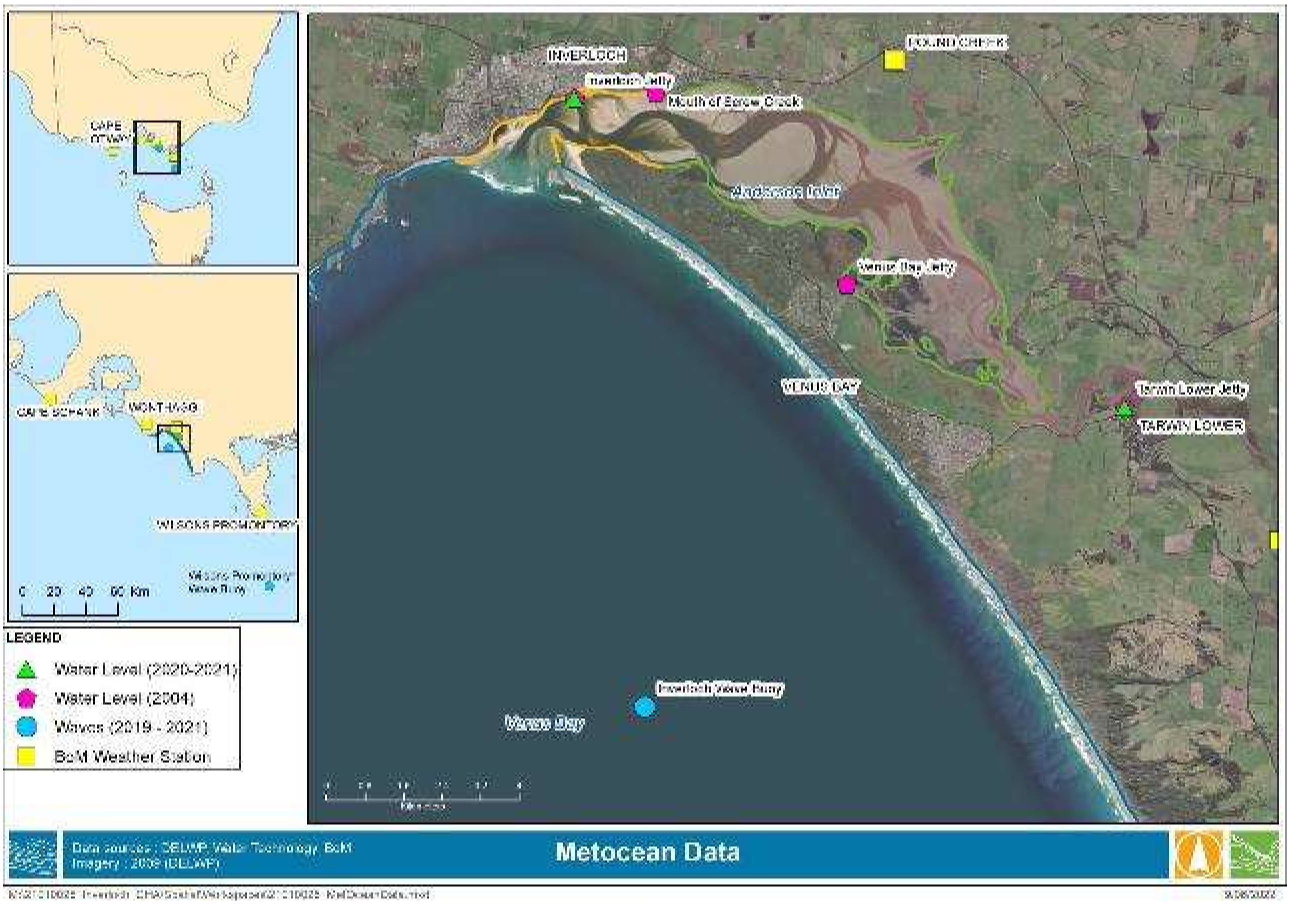

Figure 2-46 Location of Wind and Wave Data Sources

2.3.2.2 Long Term Wind Climate

Pound Creek

Wind roses based on wind data recorded at the Pound Creek Bureau of Meteorology (BoM) weather station (station number: 085099) are presented in Figure 2-47. The Pound Creek wind station is relatively protected, being on the northern side of Anderson Inlet and sheltered from direct ocean winds by the Venus Bay spit sand dunes. Winds are generally less than 10m/s and conditions are regularly calm with winds less than 2m/s. Stronger winds are more common from the southwest although strong north westerlies can occur in winter.

Summer conditions are dominated by southwest and easterly winds compared with a high proportion of northwest in winter (Figure 2-47). Conditions in spring and autumn (not shown) are a relatively even spread of the combined winds observed in the summer and autumn, although both have a bias to the easterly winds observed in the summer months. Daily variation at Pound Creek is also observed with typical movement of winds offshore from the land to the sea in the morning (driven from the faster heating of the ocean surface at day break) followed by movement of winds onshore as the land mass temperature rises above the ocean surface temperatures. Afternoon sea breezes are notably stronger than morning conditions with less than 5% of the winds below 2m/s.

Wilsons Promontory

For comparison, winds at the extremely exposed Wilsons Promontory Bureau of Meteorology (BoM) weather station (station number: 085096) are presented in Figure 2-48.

The Wilsons Promontory weather station is located at the Lighthouse and as such is exposed to winds which impact the coastline. The wind speeds are also influenced by the elevation of the Promontory – the station is located on the coastline at 95m AHD and as such there are updraft acceleration forces local to the weather station location presented in the data.

Regardless, the different pattern in wind conditions can be observed at the Wilsons Promontory station. The record of data is extensive, with reasonable quality measurements from 1957 onwards. Winds are much stronger than at Pound Creek, rarely dropping below 2m/s and regularly (~50% of the time) exceeding 10m/s.

Winds are predominantly from the west or west-southwest with some north-easterly wind conditions noted. The north-easterly component is more prevalent in the summer, which does correlate to similar conditions at Pound Creek. Whilst westerly winds also dominate conditions in winter there is a reasonable spread of winds from the southwest through north to northeast. This seasonality is a common pattern of conditions across Victorian waters and as with Pound Creek the autumn and spring winds (not shown) present a combination of winter and summer winds with a greater proportion of north-easterly conditions than the winter. It is possible southerly and southwesterly conditions at Wilsons Promontory are underestimated due to the location of the anemometer in the lee of the lighthouse and other buildings.

ERA5 Modelled Winds

Wind data extracted from the European Centre for Medium-Range Weather Forecasts ERA5 model (ECMWF, 2022) in the area covering Venus Bay are presented as speed and direction roses in Figure 2-49. The spatial resolution of the ERA 5 model is 30km and single cell covers the Venus Bay waters.

Offshore wind speeds hindcast by the ERA model are higher than those measured at Pound Creek and lower than those measured at Wilsons Promontory. The modelled winds show a closer correlation with the measured data at Pound Creek in seasonal and annual patterns whilst minimum wind speeds are more in line with those observed at Wilsons Promontory.

A peak hourly wind speed of 20.4m/s is predicted by the hindcast model, as shown in Figure 2-50, generated during a significant winter storm event in 1991. The same storm event is recorded at the BoM stations (also shown in Figure 2-50), with the peak wind speed at Wilsons Promontory during the event close to 35m/s. The measured wind data shows similar patterns to the modelled hindcast. (Note. The event occurred before the Pound Creek gauge began in 2007).

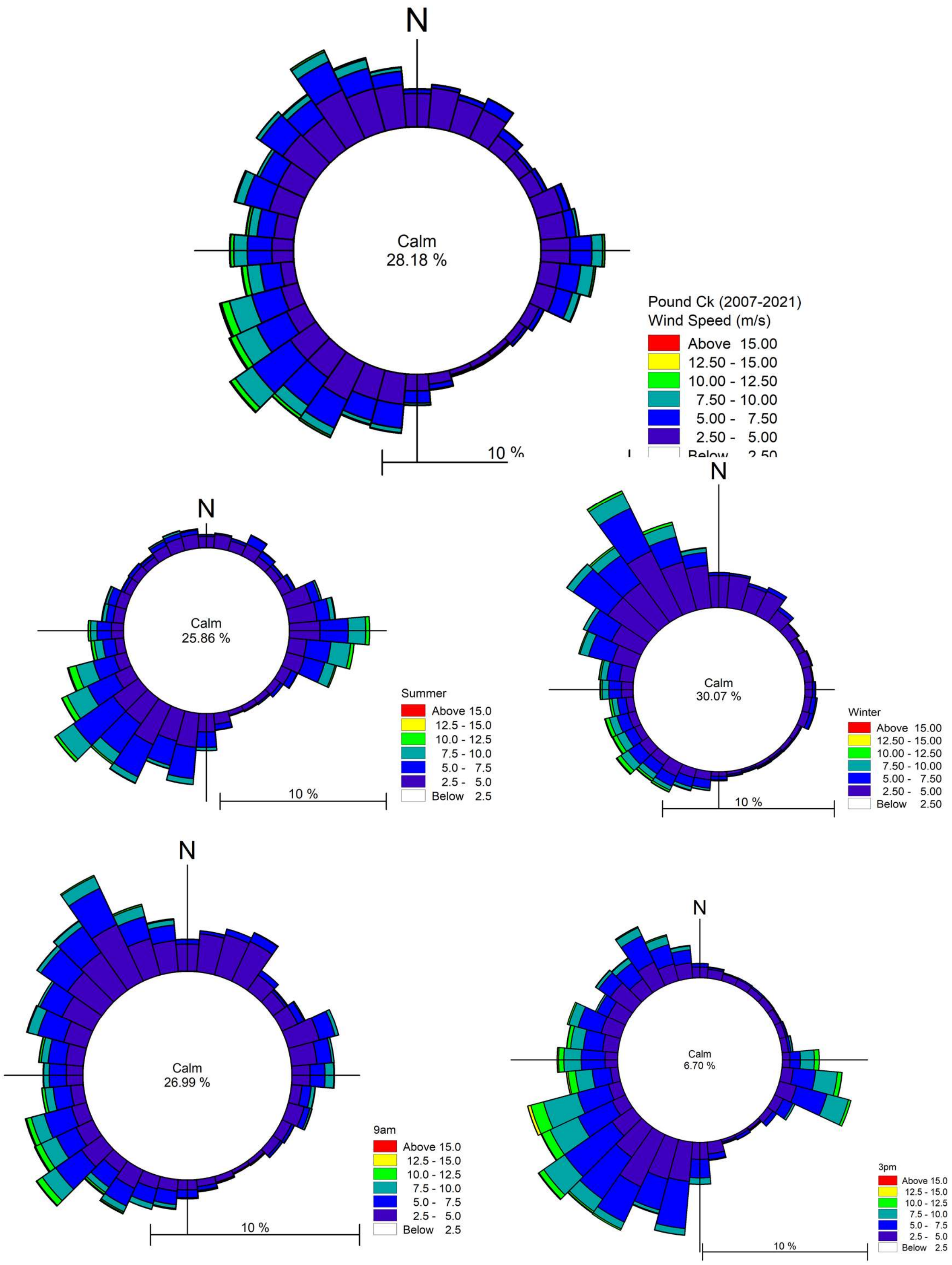

Figure 2-47 Wind Climate at Pound Creek (BoM, 2007 – 2021)

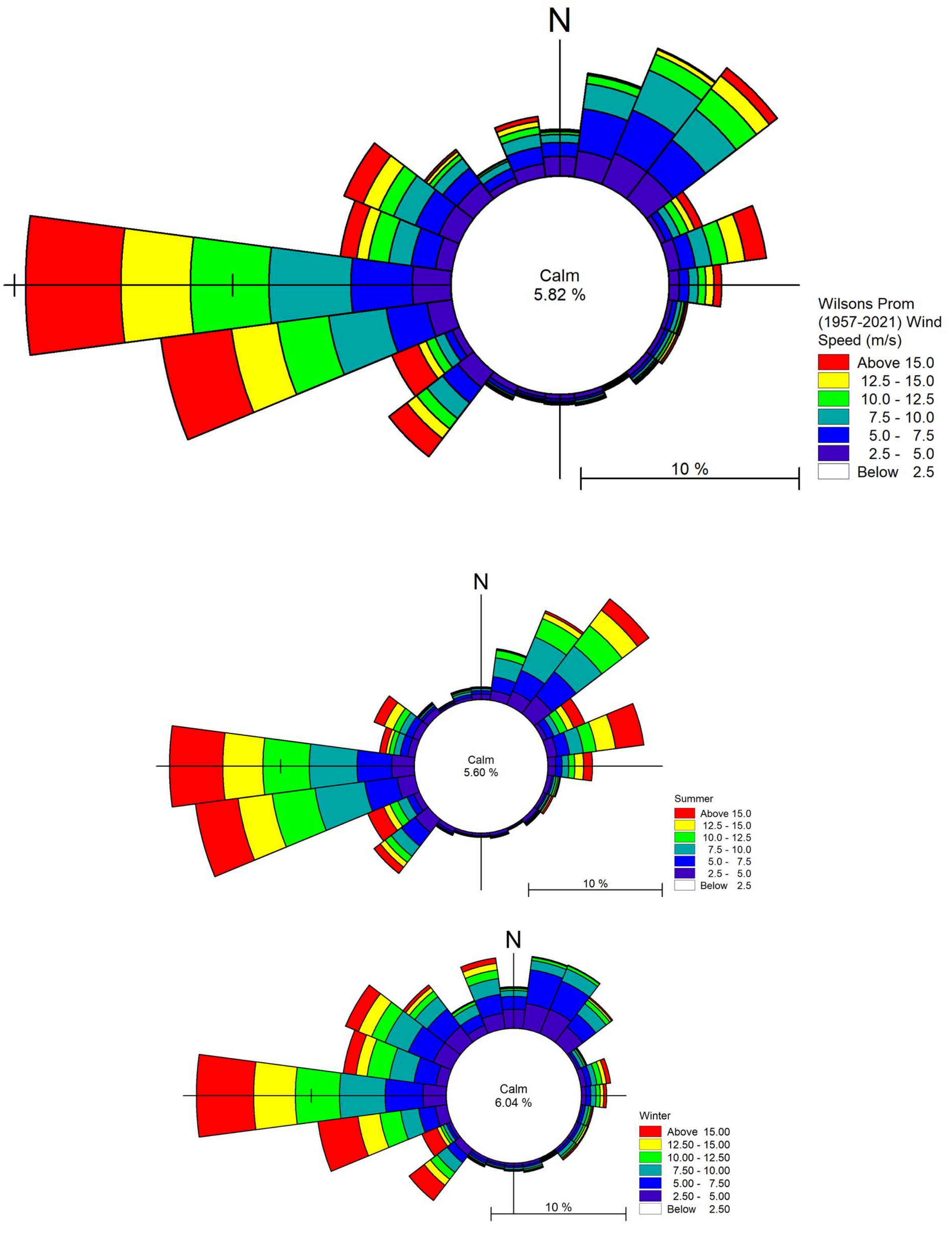

Figure 2-48 Wind Climate at Wilsons Promontory (BoM, 1957 – 2021)

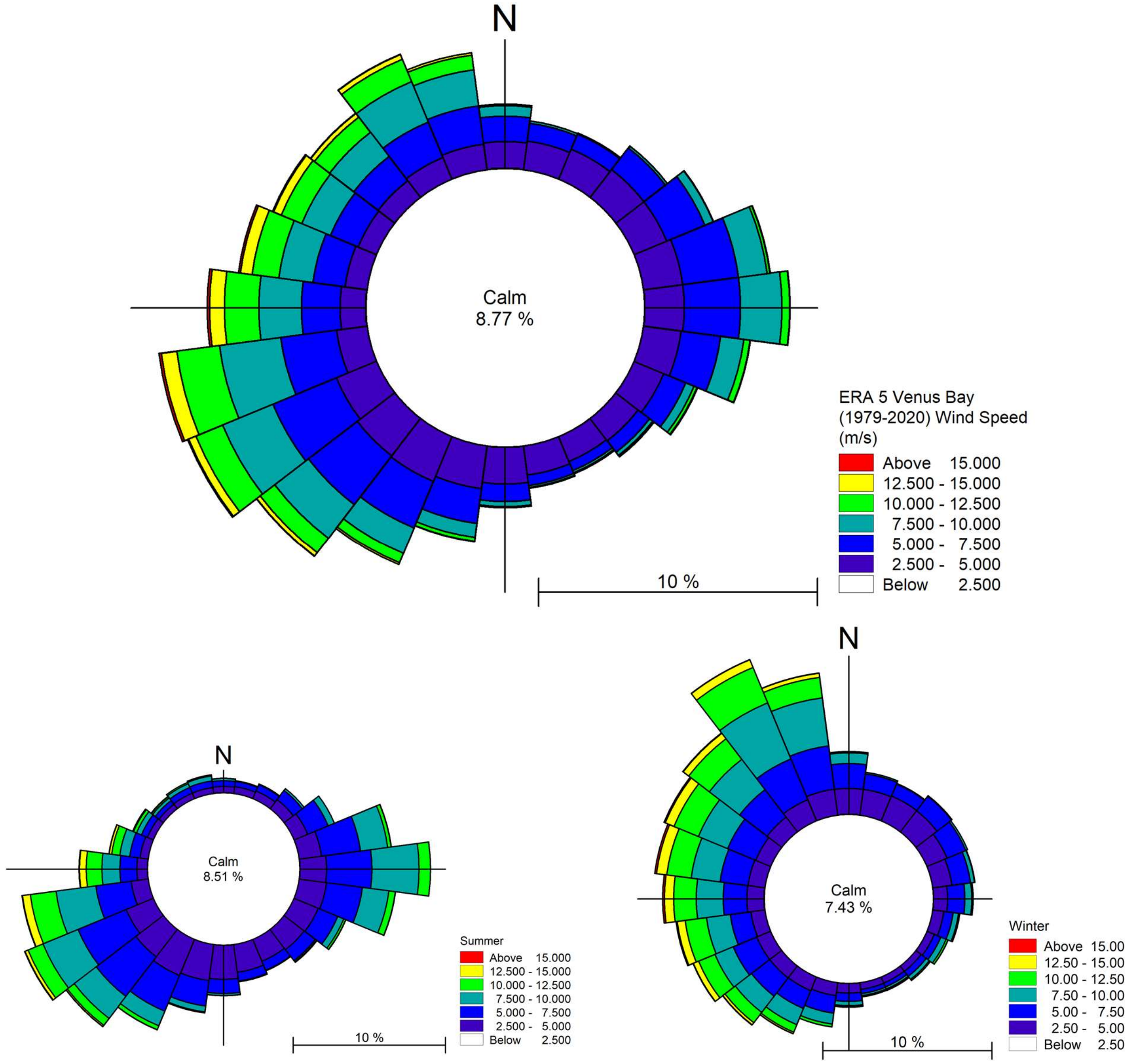

Figure 2-49 Wind Climate at Venus Bay (ERA5 model, 1979 – 2021)

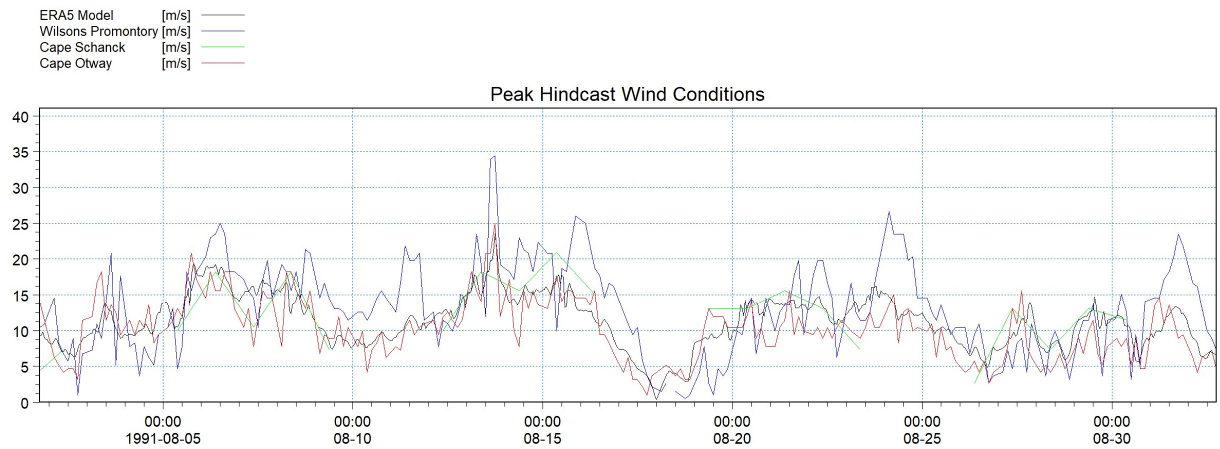

Figure 2-50 Peak hindcast wind speed – 13/08/1991

2.3.2.3 Interannual Variation & Recent Trends

A review of the longer term wind climate has been completed to assess any significant annual, decadal or longer period changes in the measured data. The recorded data at Pound Creek, Wilsons Promontory, Cape Schanck and Cape Otway was analysed to identify the extreme wind conditions and the frequency of which they occurred, the average wind speeds at different times and the average wind direction through the day. In general, the following key points were observed across the datasets:

- 1980s characterised by higher wind speeds and more storm events at all stations where data available
- More storm events also noted in the 1990s at the Wilsons Promontory gauge
- A decrease in storm events from 2010 onwards at Pound Creek is observed (noting measurements only began in 2007, so these early years may have represented a higher incidence of storm events)
- Measured wind speeds at the longer period of record coastal stations (Cape Otway and Wilsons Promontory) have decreased below the long term average since the early – mid 2000s
- Wind direction at these stations have also measured more southerly (from south-westerly) from the mid 1990s.

Whilst the wind datasets cover a wide temporal and spatial range, there is little consistency in the data recording frequency or measurement period. Specific trends which affect the oceanographic conditions into the Study Area are difficult to define with certainty based on the measured data. The measured datasets however confirm that wind conditions vary significantly on a wide range of timescales from daily through to decadal in both average and storm conditions.

2.3.2.4 Extreme Wind Conditions

Australian Standards

The Australian / New Zealand Standards (AS/NZ S 1170.2:2011) provides instruction on how to derive wind speeds for different return periods, directions and locations. The Standards have been used to derive design wind conditions offshore and within Anderson Inlet by varying the terrain category multipliers. The design wind conditions for present day conditions (and relevant directions) are presented in Table 2-11.

Table 2-11 Australian New Zealand Standard Design Wind Conditions

Wind Speed (m/s) (hourly average speed)	Direction							
	N	NE	E	SE	S	SW	W	NW
Within Anderson Inlet (TC 1)								
10%			16.2	16.2	17.2	19.2	20.2	
5%			17.2	17.2	18.3	20.4	21.5	
1%			19.7	19.7	21.0	23.4	24.7	
Anderson Inlet northern floodplains (TC 2)								
10%	16.8	14.9					18.6	17.7
5%	17.8	15.8					19.8	18.8
1%	20.4	18.1					22.7	21.5
Offshore / Open Coast (TC 1.5)								
10%			15.5	15.5	16.5	18.5	19.4	
5%			16.5	16.5	17.5	19.6	20.6	
1%			18.9	18.9	20.1	22.5	23.7	

[1] TC1 for exposed terrain across Anderson Inlet
[2] TC1.5 for open offshore water
[3] TC2 for the floodplains around Anderson Inlet

Measured Winds

For comparison with the Australian Standards, the measured wind data records were used to establish design wind conditions. The data records were analysed to identify storm events where the peak wind speed was at least 2 standard deviations from the mean of the data record. This external population was then assessed using a range of probability distributions to determine the most robust statistical fit and the design AEP established.

The results of the analysis should be considered noting the following:

- Pound Creek has the shortest data record of 13.5 years and thus could only reliably provide the AEP for the 10% AEP event. The 5% AEP event is provided for guidance and comparison with the Australian Standard wind AEPs only.
- The Wilsons Promontory gauge is located at the Wilson Promontory Lighthouse, 95m above sea level on an exposed coastal cliff. Whilst being very exposed, the lighthouse station is also subject to significant updrift and other topographical forces which result in high wind speeds which may not be representative of the general wind climate. The hourly data recorded since 2000 has been used in the analysis below.
- The Cape Otway data is based on the last 34 years of data (1987-2021) where more consistent 3 hourly data is available. Utilising the entire 120 year Cape Otway data results in significantly higher wind speeds but also much larger uncertainties.

Table 2-12 Extreme Value Analysis Design Wind Conditions

Wind Speed (m/s)	AS 1170∞	Pound Creek	Wilsons Promontory	Cape Schanck	Cape Otway
10%	20.2	18.5	31.1	25.7	22.5
5%	21.5	*19.1+*	32.6	27.0	23.6
1%	24.7	- *	33.2	29.8	26.1

+1% not supplied as period of measured data at Pound creek is too short to reliably determine 1% AEP
* 5% (indicative only)
∞Peak wind speed derived from AS1170 shown here only. Directional winds speeds are shown in Table 2-11

The design winds from the Australian Standards are around 10% higher than those generated from the measured data at Pound Creek. The design wind conditions derived from the open coast data stations are significantly higher than the design conditions based on Pound Creek measured data.

The design winds have been used in generating coastal water levels within the Inlet as wave conditions along the open coast have been derived from the University of Melbourne wave hindcast (Section 2.3.3.3). To provide some conservativeness, also noting the limited duration of Pound Creek winds to generate extreme values, the Australian Standard design wind conditions have thus been adopted for use in the study.

2.3.3 Wave Conditions

2.3.3.1 General Wave Conditions

Waves comprise the principal source of energy for mobilising the sediments on the open coast of the Study Area. Waves and wave driven processes (such as sediment mobilisation and alongshore currents) both result in constructive barrier building and destructive barrier erosion processes. The relative difference between these two opposing processes subsequently influences coastal evolution and the potential extents of coastal hazards along the open coast of the Study Area.

The wave climate in Venus Bay is dominated by deep-water waves generated by large-scale weather systems over the Southern Ocean. The island of Tasmania and King Island, located within Bass Strait, limit the direction of waves which approach Venus Bay, as presented in Figure 2-51, to those from the southwest and west. Some wave energy can be experienced during the passage of an East Coast Low diffracting around Wilsons Promontory to the study area.

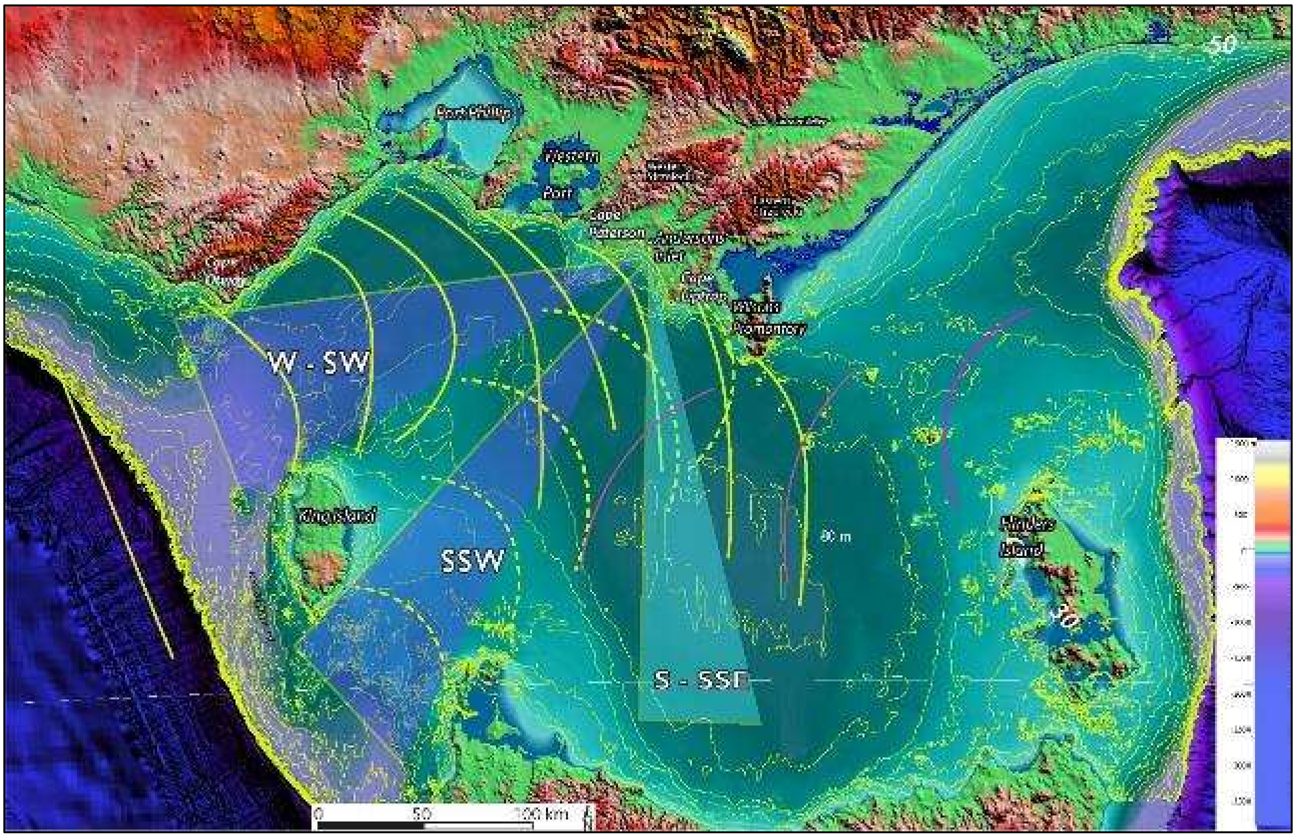

Figure 2-51 Wave generation to Venus Bay (Rosengren, 2021)

The entrance channels and bars at Inverloch greatly modify the passage of ocean swell from Bass Strait into Anderson Inlet. Figure 2-52 displays the peak wave conditions when the 1% AEP offshore wave is simulated over a spring tide into Anderson Inlet. The steep seaward face and shallow bathymetry of the entrance bar described in Section 2.2.3 significantly limits ocean swell penetration into the Inlet. The significant wave height of 3.0m just seaward of the bar (reduced from 6.6m offshore) is reduced to less than 1.0m by the Ayr Creek/Point Smythe line, 0.25m at the Inverloch Jetty and less than 0.05m at Screw Creek.

Strong tidal flows also cause wave-current interactions through the channels and ocean swells are reduced during ebb tides both within the entrance channels and in the offshore tidal jet, although to a much lesser extent than the effect of the varying depth across the channel. Numerical modelling shows a reduction in the wave height in the approach to the Flat Rocks – Point Norman coast, driven by the Flat Rocks platform and the diffraction of the incoming wave around Point Norman.

Strong winds can generate waves within Anderson Inlet, however the duration and fetch are limited by the wide intertidal banks which are exposed below MSL, or less than 55% of the time (Figure 2-41) and for a short duration (Figure 2-40).

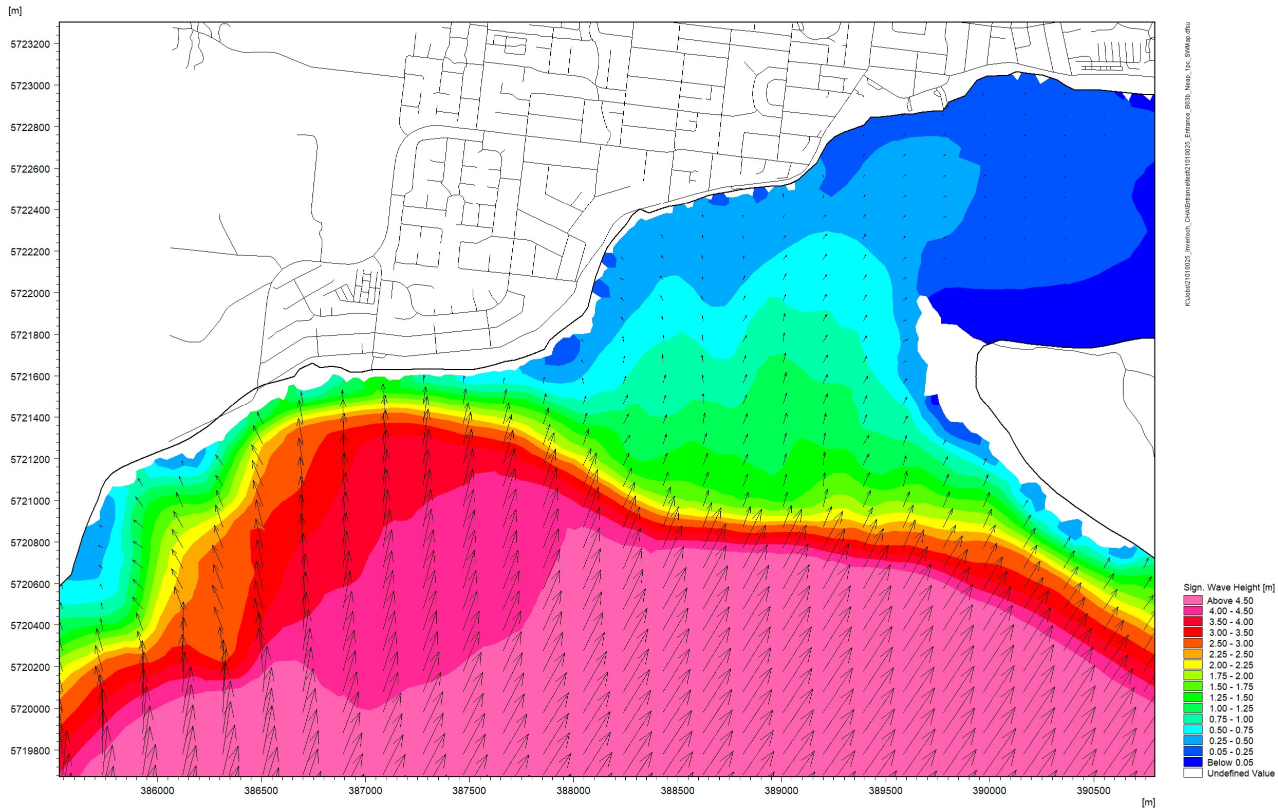

Figure 2-52 Peak Wave Penetration to Anderson Inlet (1% AEP + Spring Tide)

2.3.3.2 Measured Wave Data

Wave data has been measured as part of the Victorian Coastal Monitoring Program (VCMP) since January 2020 within Venus Bay and since December 2019 offshore of Wilsons Promontory (Figure 2-46 & Table 2-13). Wave height, mean and peak period and mean direction roses for Venus Bay and Wilsons Promontory are presented in Figure 2-53 and illustrate the different exposure patterns for each site. The buoy at Venus Bay shows waves approaching from primarily the southwest, with a smaller proportion from the west-southwest, whilst at Wilsons Promontory, waves are predominantly from the west-southwest. A small amount of waves are measured from the south-southeast at Venus Bay, with additional southeast and northeast components measured at Wilsons Promontory.

Table 2-13 Measured Wave Data in Study Area

Location	Source	Data period, frequency
Venus Bay	VCMP	08/01/2020 – ongoing, hourly
Wilsons Promontory	VCMP	18/12/2019 – ongoing, hourly

Mean wave period at Venus Bay are generally between 6 and 10 seconds, whilst peak wave periods range from 8 to 14 seconds, with median wave periods of 7.0 and 11.8 seconds respectively. Wave periods measured at Wilsons Promontory show a higher proportion of shorter wave periods, both with mean period (generally 4 to 6 seconds) and peak period (higher proportion of waves where Tp < 10 seconds).

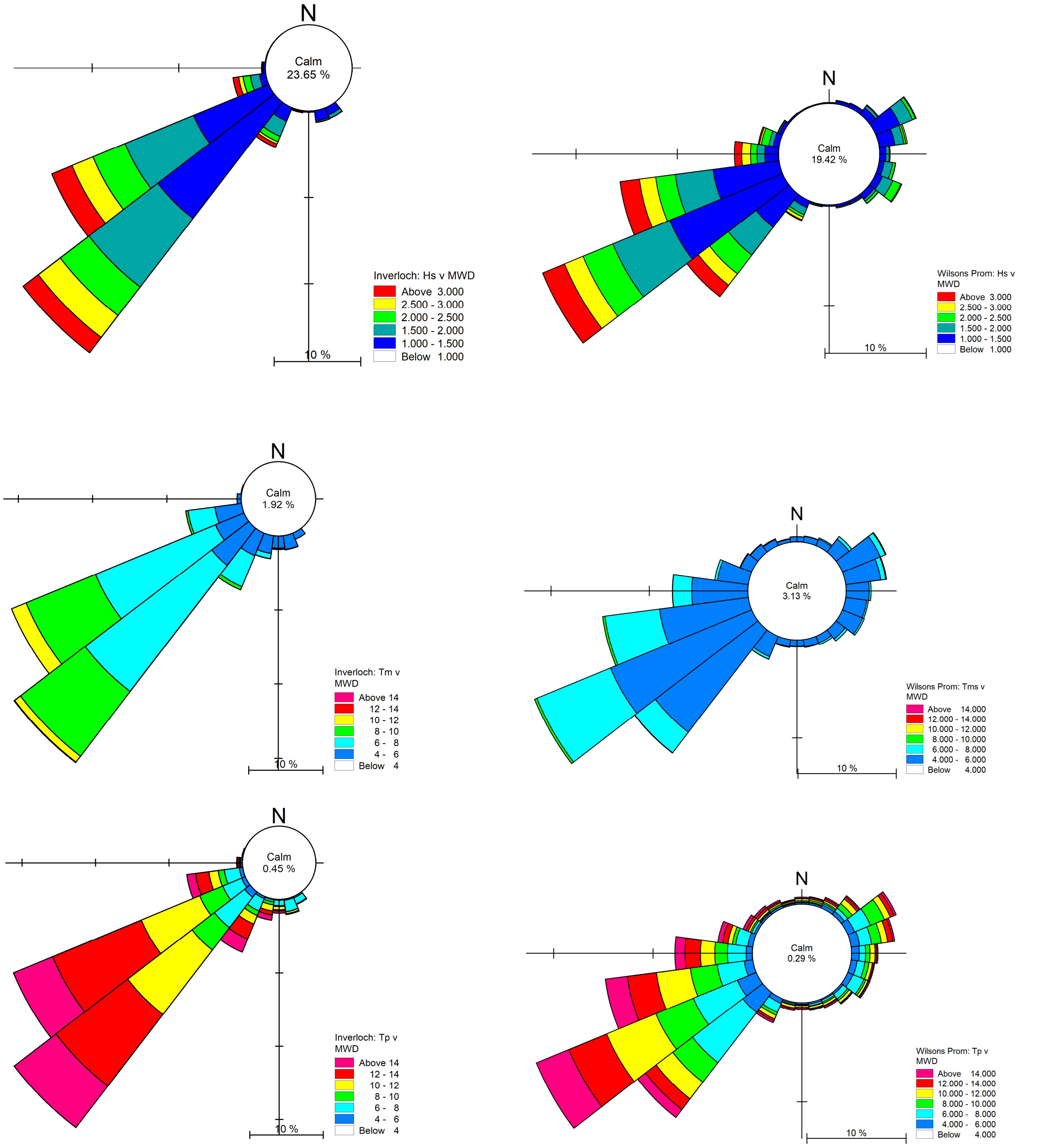

Figure 2-53 VCMP Measured Wave Data at Venus Bay (left) and Wilsons Promontory (right)

Further review of the measured data in Venus Bay shows the narrowing of directional spread towards 225 degrees (southwest) as wave height and period increases. This corresponds to the largest fetch length into the Southern Ocean (Figure 2-51) and the refraction of waves from the southwest towards the coast. Wave period, both mean and peak, trends towards around 7 – 12 seconds as wave height increases in Venus Bay.

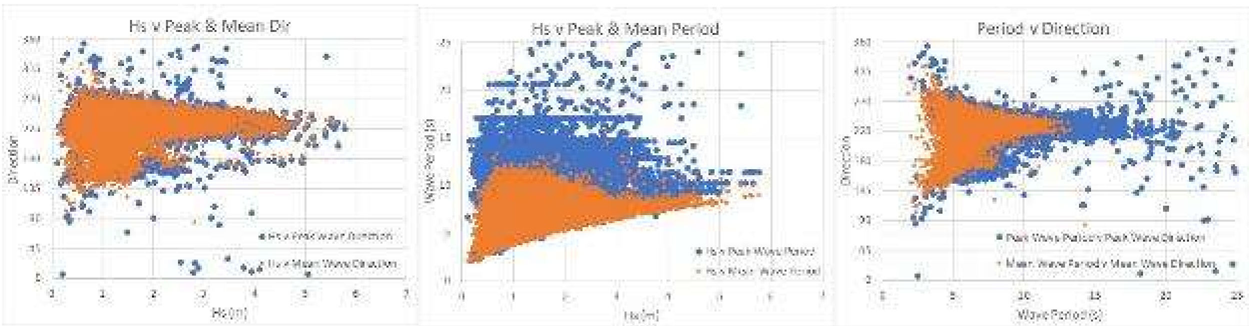

Figure 2-54 Measured Wave Data Venus Bay (2020 – 2021)

Peak wave heights measured by the Venus Bay wave buoy include significant storm events as presented in Table 2-14. The wave periods for each of the storms are relatively consistent at ~9.0s seconds mean period and 10-11s peak period. The short duration and short peak period of the April 2021 storm indicates this was likely to be a local wind storm event rather than a distant swell wave storm. Wave direction during a storm generally changes from more southwest to south as the storm progresses.

Table 2-14 Significant Storm Events Measured in Venus Bay (2020 – 2021)

Date	Significant Wave Height (m) (hours above 5m)	Peak Wave Period (seconds) Mean / peak	Mean Wave Direction (degrees) Beginning – end of storm
11 April 2020	5.64m (5h)	8.5s/ 10.2s	247 - 223
2 May 2020	5.82m (8h)	9.0s / 11.4s	235 - 230
11 April 2021	5.25m (1h)	9.0s / 9.3s	225
29 October 2021	5.68m (5h)	9.2s / 11.4s	215 - 205

2.3.3.3 Hindcast Model Wave Data

Further information on the wave climate over time can be established through review of a wave model hindcast completed by researchers at the University of Melbourne as part of the VCMP. Detail on the model and model parameters can be found in the PhD Thesis being prepared by Jin Lui (publication expected 2023) and via published papers of Liu (Liu 2020, 2021) and others in the VCMP wave modelling project (Young, Medici, etc).

The wave hindcast model by Lui, referred to herein as the "University of Melbourne wave model", or the "UoM" model/data, has been used to establish the long term wave climate within the Study Area. The significant wave height (Hs) has been provided on an hourly timestep, hindcast from 1980 through to 2020 and provided at the location of the VCMP buoy in Venus Bay and at nearshore points along the Study Area open coast (Figure 2-46).

Detailed review of the model hindcast data in Venus Bay at the VCMP buoy location has been completed as part of the project. The following points summarise the important aspects of the wave climate with respect to coastal processes in the Study Area:

- Waves are primarily from the southwest, with 62% of waves at the VCMP buoy location coming from a narrow direction around southwest (213.75 – 236.25) (top row, Figure 2-55).

- More waves are from the west of southwest (37% from 225 – 236.25 degrees) than south to southwest (24% from 213.75 – 225 degrees (inclusive)) indicating a slight skew of waves to the west of southwest.

- The median wave height is 1.5m and the 95th percentile wave height is 3.2m. The peak modelled wave height offshore is 6.51m (6/11/1994).

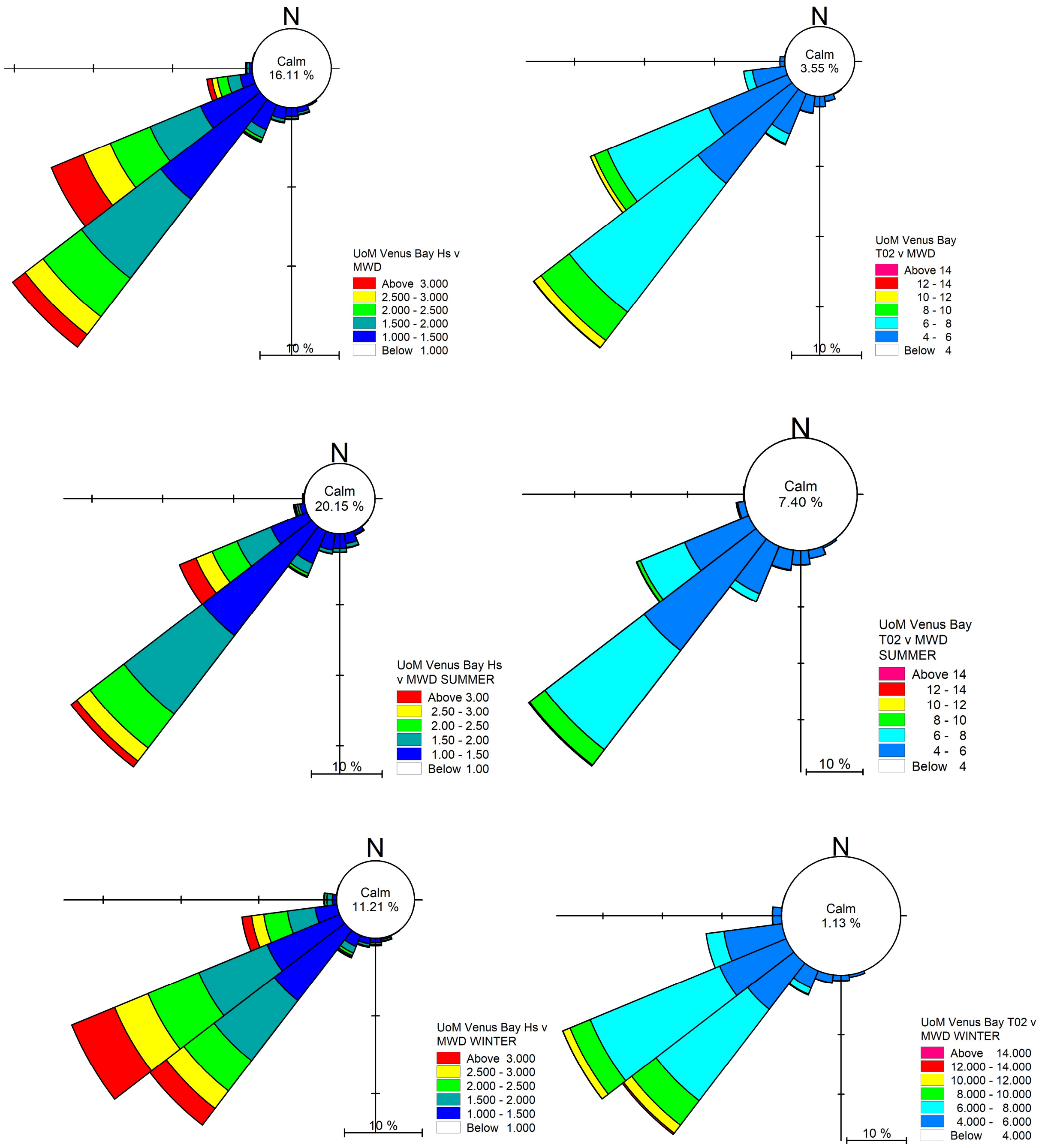

Figure 2-55 Hindcast wave roses of Hs and T02 for the full hindcast (top row), summer months (middle row) and winter month (bottom row)

- The median mean wave period is 6.0 seconds compared to the median peak wave period of 13.2 seconds. The 95th percentile of the mean wave period is 8.9 seconds and 16.1 seconds for the peak wave period.
- Seasonal variation is observed in the hindcast data:
  - Hindcast waves during the summer months, shown in the middle row in Figure 2-55, have lower energy than the year round mean conditions. They are:
    - Smaller in height than year round mean conditions
    - Lower in period than year round mean conditions
    - More southwest (and less west-southwest) than year round mean conditions.
  - Waves hindcast during the winter months are shown in the bottom row in Figure 2-55, have higher energy than the year round mean conditions. They are:
    - Higher in height than year round mean conditions, with a lower proportion of wave heights less than 1.0m
    - Longer in wave period, especially in the proportion of waves greater than 14 seconds
    - More west-southwesterly (less southwest) than year round mean conditions
  - Autumn and Spring are transitional seasons, shown in Figure 2-56, where conditions shift from the typical summer to typical winter conditions. Autumn is notably calmer than Spring, with many larger wave events occurring in September. Despite this, large storm events are still common in the transitional seasons.

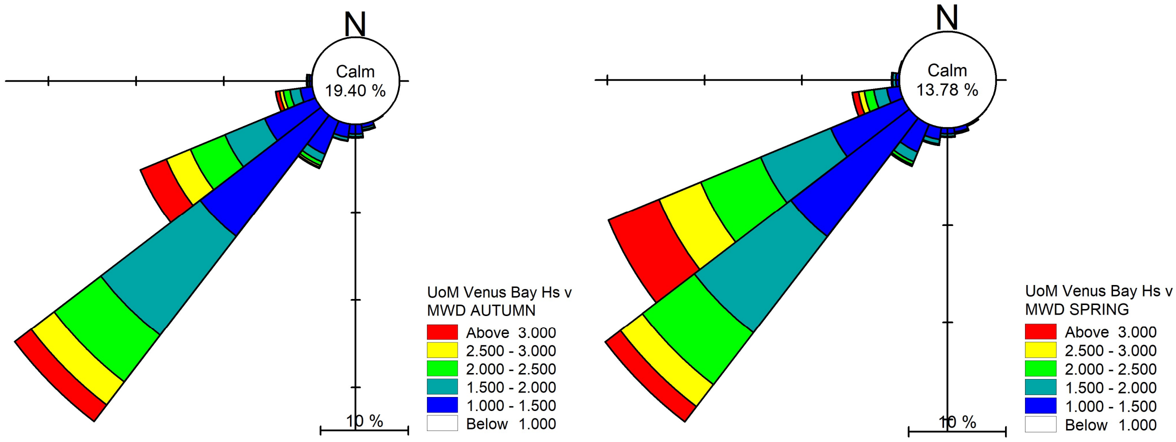

Figure 2-56 Hindcast wave roses of Hs during the months of Autumn (left) and Spring (right)

- Annual variation is also noted in the hindcast data, with a **recent trend towards stronger waves and stormier conditions** noted. The median and 90th percentile exceedance wave height for each year is presented below in the top chart of Figure 2-57 along with the most frequent annual wave direction (shown in blue in the bottom chart of Figure 2-57) and the direction with the highest average wave height (shown in gold in the bottom chart of Figure 2-57).
  - The median and 90th percentile exceedance (i.e. wave height exceeded 10% of the time per year) have been increasing during the 40 year hindcast from a Hs of 1.5m and 2.7m respectively in 1983 to Hs of 1.6m and 2.9m respectively in 2018 (as the 5 year rolling average significant height).
  - The 5 year rolling average of both the median and 90th percentile significant wave height oscillates around the linear trend line over an increasing cycle of 4-7 years.

- Higher waves are noted in the early 1990s, followed by lower waves during the late 1990s and early 2000s. Wave heights increased in the early 2000s before falling in the late 2000s and early 2010s, followed higher waves in the mid-late 2010s.
- The 90th percentile exceedance significant wave height also shows periods of high energy followed by below average conditions. High peak significant waves are observed in the 1994 data, and low peak significant wave heights are noted in 1999. Peak significant wave heights were relatively stable through 2006 to 2015, after which a trend of increased high significant waves through 2018 and 2019 is clear.
- The year 2020 saw below average high and median significant wave heights.
- The dominant wave direction is trending more southerly across the 40 year hindcast, from a 5 year average of 230 degrees in 1983 to 228 in 2018. However, as with the wave height data, there are peaks and troughs in the hindcast directions. In 2010 and 2011 the main wave direction was significantly more southerly than the long term average, whilst in 2012-2013, the direction was notably more west than the long term average.
- The main wave direction is variable on a year to year basis, and the 5 year rolling average shifts from above (more westerly) to below (more southerly) the long term average frequently.
- The direction which has the highest average wave height (i.e. the direction coincident with the peak hourly Hs, not a storm event as discussed below) over the year shows less of a southerly trend through the hindcast (from 246 to 247 degrees). The high wave direction oscillates around the long term average similar to the wave heights on a similar increasing 5 – 7 year cycle.

Figure 2-57 Analysis of annual significant wave height and direction

- Storm events have been assessed in the dataset, with the following noted and presented in Figure 2-58:
  - The year 2019 is considered the stormiest year of the hindcast (top chart, Figure 2-58), with more hours where the significant wave height was above 2.0m, 2.5m, 3.0m and 3.5m than any other year. This is in line with the highest 90th percentile wave height in the hindcast in 2019 and the highest median wave height.
  - The 5-year running average (top chart, Figure 2-58) of the number of storm events shows a similar pattern to the 90th percentile exceedance of significant wave heights, with more storms during 1994-1997, 2004-2007, and an increasing trend from 2011 to present.
  - The annual number of storm events where the significant wave height is above 2.0m, 3.0m and 4.0m increases over the hindcast period, especially in storm events with a Hs greater than 4.0m.

- The duration of the wave storm event is increasing (middle chart, Figure 2-58), most notable in the smaller height storm events, although all thresholds indicate an increase in duration.
- The average storm direction is more westerly for the higher the storm waves, i.e. for a storm where Hs > 1.5m the wave direction ranges between 224 – 234 degrees, however where the significant storm wave is greater than 3.5m, the direction ranges between 228 – 237 degrees.
- The average direction of the extreme storm events (i.e. storms where Hs > 3.0m, 3.5m or 4.0m) is presented in the bottom chart of Figure 2-58 and shows the direction varies over the hindcast more notably than the average wave direction. Large storm events are more typically from the west or southwest, with a direction between 230 and 236 degrees. The trend of significant storm wave conditions is more westerly across the 40 year hindcast, although this does change year to year. As with the general wave climate, the storm wave direction for the years between 2010 and 2015 changes from being more south to more west and are now returning to more south in the higher storm events.

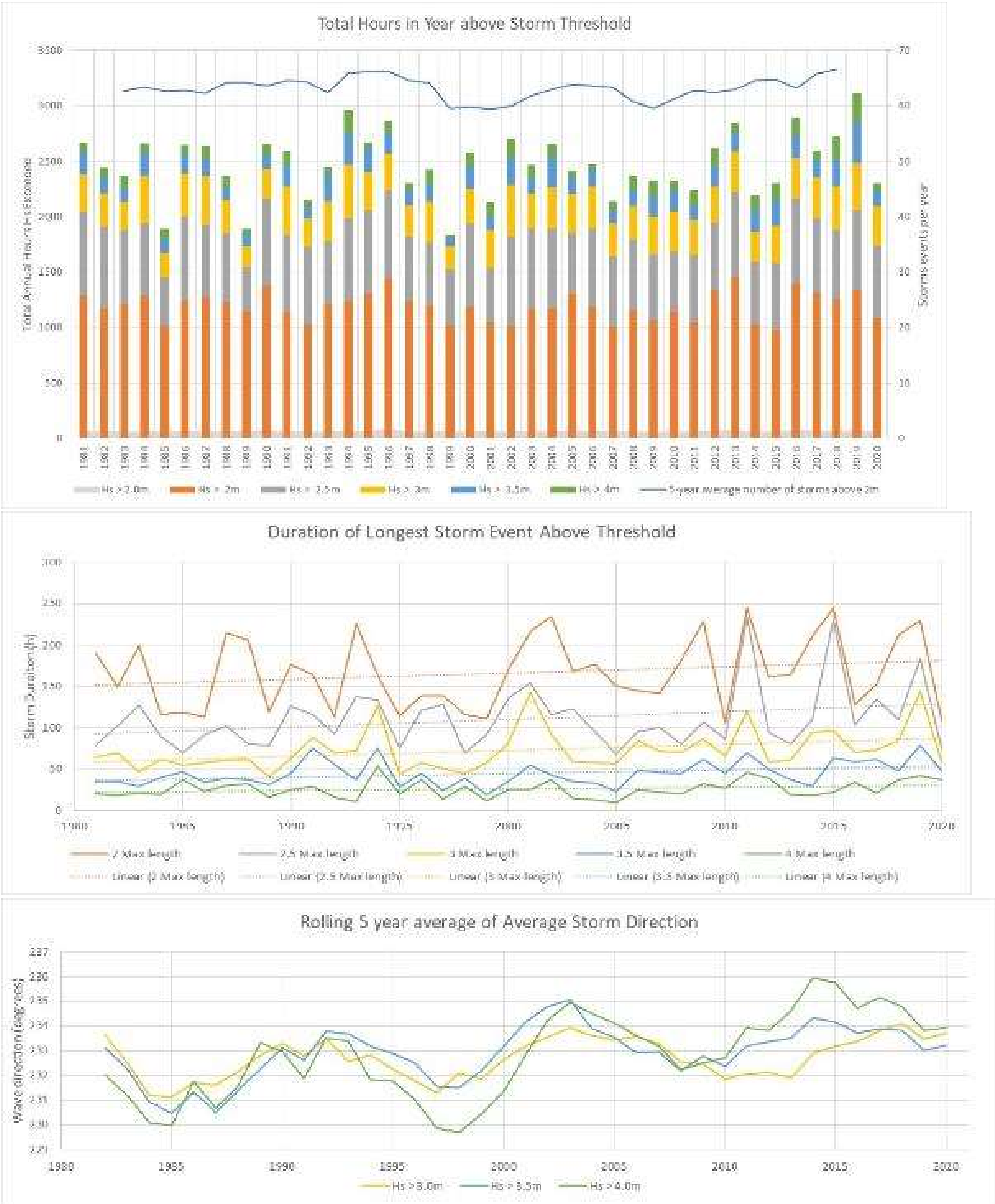

Figure 2-58 Analysis of hindcast wave storm conditions

- Change in the past decade and a quarter (2008 – 2020) are summarised below with consideration of the changing conditions at the entrance.
  - Annual average significant wave heights were smallest in 2011, increasing to a peak in 2016 and trending downwards to the end of 2020.

- The highest waves were higher in 2018 – 2019, with the highest 90th percentile annual Hs wave being 3.17m in 2019.
- Main wave directions were notably more southerly in 2011 (223°) compared with the long term linear average of 228°, before shifting significantly through 2012 to 2013 (to 231° and 234° respectively) to be more westerly than the long term average direction.
- From 2014 – 2020 main wave directions were similar to the long term direction (approximately +/- 1°), with the exception of 2019 where conditions shifted west to a more south-westerly mean direction (233°).
- The direction of the higher waves also swung from more southerly than the 5 year average in 2011 (239° compared to 244°) to more westerly in 2012 (249° compared to 245°) before following the long term average trend slightly westward each year, with the exception of 2015 where there were more higher southerly waves (240° compared to 245°).
- There is a notable cycle and stepped rotation westward in the average storm direction, with the storm direction in the last decade more westerly than the previous cycle.
- Assessment of conditions since 2009 indicate a trend to more westerly conditions, both in the main wave direction and the direction with the highest average waves.

Nearshore Waves

The above analysis describes the offshore conditions in the centre of Venus Bay. As the waves approach the coastline, there is significant refraction of the wave across the seabed, and diffraction of the waves in the nearshore areas, especially along the Bunurong Road coastline where rock platforms and outcrops significantly alter wave conditions.

The UoM model data along the coastline has also been analysed and the variation in median hindcast wave height and direction are presented in the arrows in Figure 2-59. The wave direction varies from 216 to 239 degrees (SSW – WSW), with larger waves (1.4 – 1.6m Hs) from SW refracting around Cape Paterson towards the entrance as SSW waves with a smaller wave height (1.2 – 1.3m Hs). Along Venus Bay, the direction gradually turns from SSW through to the most WSW at Cape Liptrap as the wave height also gradually increases from 1.2m through to 1.45m.

The median of the mean period (T02) and the 95th percentile exceedance of the significant wave height (95th%ile Hs) are also shown in the figure through colour varying triangles and circles respectively. The average wave period is highest offshore of Cape Paterson, reducing towards the entrance and remaining fairly constant along the open coastline. The extreme waves follow a similar pattern to the median heights, being highest at Cape Paterson, reducing significantly in the lee of the Cape seaward of Surf Beach and the entrance, increasing as greater exposure to the incoming wave occurs towards Cape Liptrap.

Seasonal and annual variation, as well as trends in wave height, direction and storminess along the coast are reflective of the conditions offshore described above.

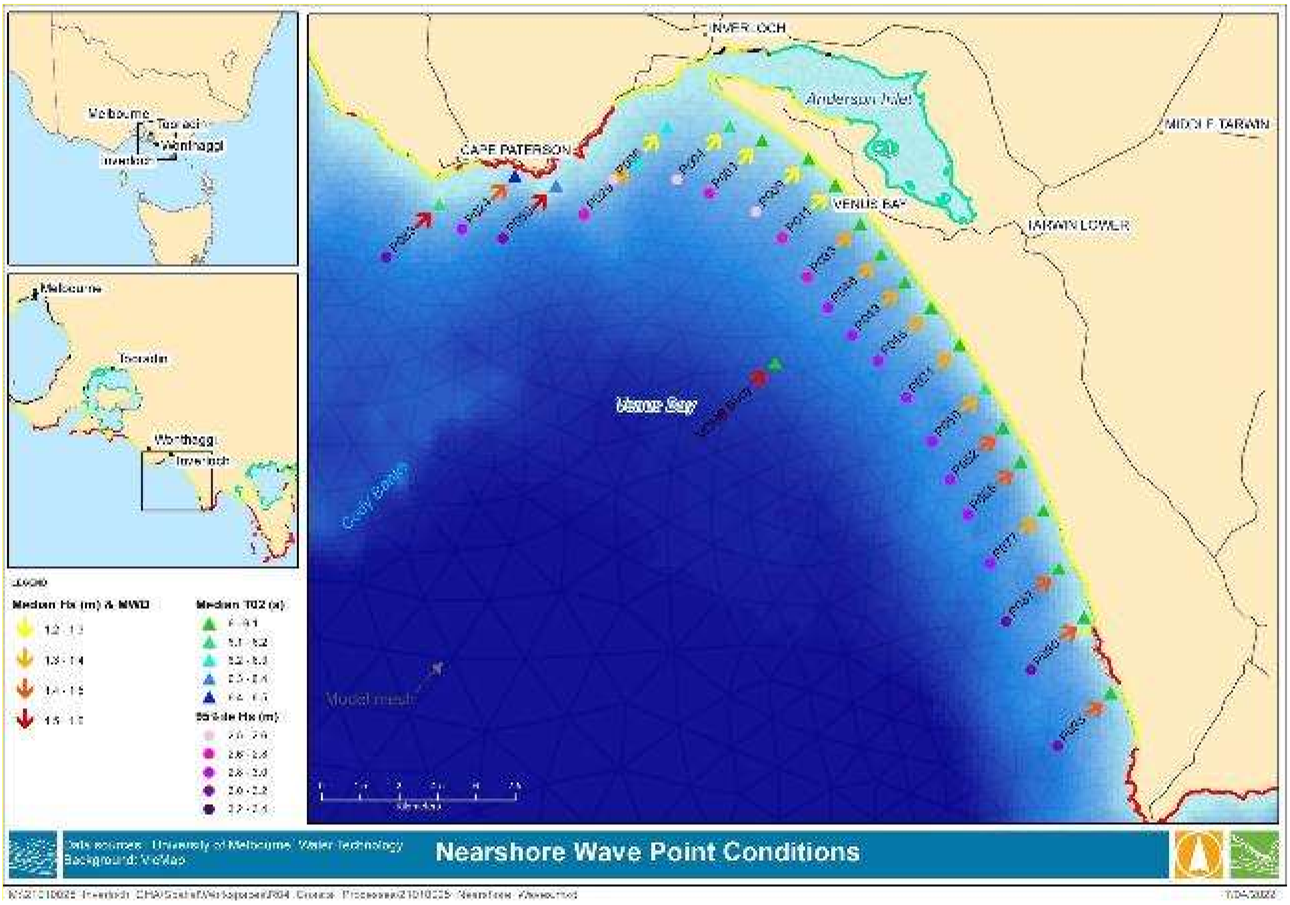

Figure 2-59 Nearshore Wave Hindcast Conditions

The rocky capes at either end of Venus Bay help to anchor the coastline in response to the wave climate with Cape Paterson and the Cody Banks in particular acting to diffusing wave energy on the Surf Beach and Point Smythe coastlines.

The wave conditions shown above are the nearshore conditions in 18-25m of water. Waves further refract and dissipate in height as the depth decreases and wave height reduces further as waves enter the surf zone.

2.3.3.4 Extreme Wave Conditions

An extreme value analysis (EVA) of the 1981-2020 hindcast UoM wave data was undertaken to establish design storm wave events, as described in Appendix D, Report 3. Design storm waves offshore of the Study Area at the VCMP wave buoy are presented below in Table 2-15.

As noted in Report 3, there was some variance in the wave heights when comparing the measured and model hindcast data with measured data 5 – 8% higher than hindcast data for the large storm events. For non-extreme, "normal", wave energy the model and measured data calibrated well. However, when considering the extreme value analysis, this under representation of high wave events could be significant. The measured data period is too low to generate a reliable estimate of low probability events and the hindcast has been used to generate the design conditions presented. Further calibration of the model with the extended period of measured data, particularly considering some larger storm events occurred in 2021, could be undertaken to improve confidence in the results. Sensitivity testing has reviewed higher wave conditions in erosion and inundation mapping.

Table 2-15 Extreme Offshore Wave Conditions based on Hindcast Wave Data (1981-2020)

Design Event	Offshore Significant Wave Height (m)	Offshore Peak Wave Period (s)
1% AEP	6.6	14.6
5% AEP	6.1	14.2
10% AEP	5.9	13.9
20% AEP	5.7	13.7
Maximum wave height *(6/11/1994 21:00)*	6.5	11.6
Maximum wave height since entrance change *(26/04/2009 17:00)*	6.0	11.5
Maximum wave height comparable with VCMP buoy, i.e. 2020 *(2/05/2020)*	5.8	11.4

Of the four storm events noted in Table 2-14 which occurred in the past few years and were measured offshore, using the UoM hindcast EVA, the exceedance probability of the storm events can be considered as follows:

- 11 April 2020 (Hs 5.64m) < 20% AEP
- 2 May 2020 (Hs 5.82m) 10 - 20% AEP
- 11 April 2021 (Hs 5.25m) << 20% AEP
- 29 October 2021 (5.68m) ~ 20% AEP

Nearshore Waves

The design wave conditions have been used to establish the potential for storm erosion along the open coast and the wave setup in a design storm event. To provide nearshore wave inputs for coastal modelling, the EVA was also completed for the nearshore wave hindcast points shown in Figure 2-59. A summary of the design wave heights and periods for the nearshore points are presented in Table 2-16. The extreme waves in the lee of Cape Paterson at Point Smythe and Venus Bay 2nd settlement are notably lower in wave height than the more exposed nearshore climate along Cape Paterson and Venus Bay and towards Cape Liptrap.

Table 2-16 Nearshore Extreme Wave conditions

Nearshore Point	1% Hs	1% Tp	5% Hs	5% Tp	10% Hs	10% Tp
P024 Cape Paterson	5.8	14.9	5.5	14.5	5.4	14.3
P006 Entrance	5.2	14.2	4.8	13.7	4.7	13.2
P004 Point Smythe	4.9	14.7	4.7	14.5	4.6	14.3
P009 Venus Bay 2	4.6	14.0	4.5	13.9	4.5	13.8
P033 Venus Bay 1	5.5	13.5	5.3	13.2	5.1	13.0
P045 Venus Bay	5.3	13.6	5.1	13.3	5.0	13.2
P050 Venus Bay	5.5	13.5	5.3	13.2	5.2	13.1
P055 Venus Bay	5.8	13.8	5.6	13.6	5.5	13.4

Nearshore Point	1% Hs	1% Tp	5% Hs	5% Tp	10% Hs	10% Tp
P087 Venus Bay	6.0	13.7	5.7	13.4	5.6	13.2
P093 Cape Liptrap	6.0	13.7	5.8	13.4	5.7	13.3

2.3.4 Currents

Coastal currents also help drive sediment movement along the coast. Within the Study Area, currents are driven by tidal water levels, winds, waves and fluvial inputs.

2.3.4.1 Open Coast

Tidal currents on the open coast are relatively weak with a small net easterly flood and westerly ebb tide observed in the hindcast hydrodynamic model. Tidal currents reduce in strength from west to east as they approach the tidal divide around Waratah Bay, as pictured in Figure 2-39.

The numerical model developed for the Study shows a very low (less than 0.05m/s net current eastward along the Venus Bay coast, with very, very low (less than 0.01m/s) return westward eddies spinning off Cape Paterson and Cape Liptrap (Figure 2-60).

Current roses extracted from the numerical model offshore of Point Norman are presented in Figure 2-61. Current roses show the speed and direction of the astronomical tide offshore Point Norman to the west of the main flow channel as noted in Figure 2-60. The ebb, flood and full tide roses are shown. The ebb tide shows a strong west-southwest and southwest movement of water away from the entrance and across Surf Beach during the ebb tide. However, this is notably overshadowed by the dominant flood tides which are influenced by the entrance tidal channel draining water from Venus Bay into Anderson Inlet. The combined “all tide” rose shows the dominant flood/eastward tidal currents. Current speeds vary notably across both flood and ebb tides due to the diurnal inequity of the tidal heights (i.e. one tide is much higher/lower than the next high/low tide). The lower range spring tide results in current speeds half that driven by the subsequent higher spring tide flood.

The modelling has been calibrated to water levels only as limited measured data is available to verify current speed or directions within Bass Strait, particularly along the Victorian coastline. Local currents will be affected by land topography and bathymetric features not resolved in the model however general patterns are considered reasonable.

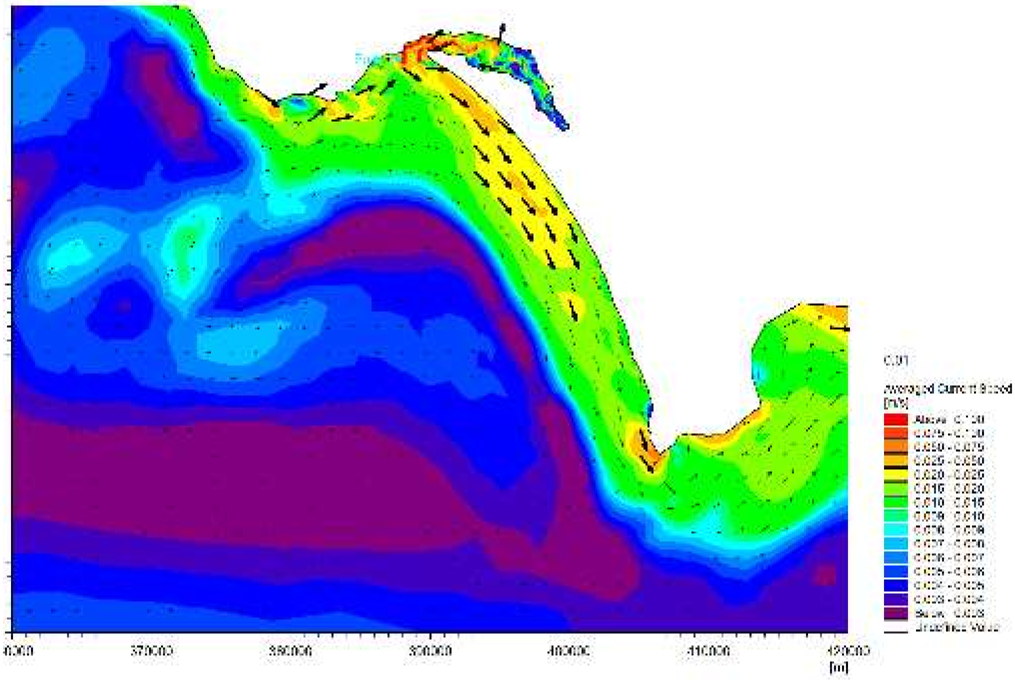

Figure 2-60 Venus Bay Net Average Astronomical Tidal Currents (larger arrows indicate higher current speeds)

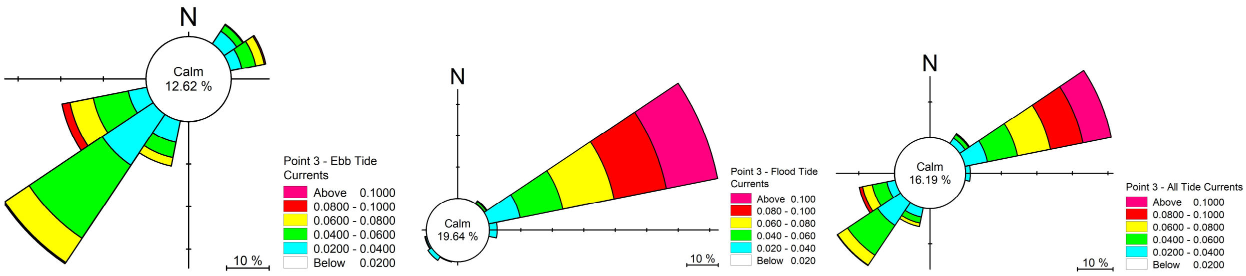

Figure 2-61 Point Norman Current Roses

Wave currents are in sync with the angle of the wave to the coast. The mean wave direction along the coast derived from the hindcast model presented in Figure 2-59 illustrates an average wave direction west of shore normal from the entrance Anderson Inlet to Venus Bay settlements. Around the Venus Bay settlement areas, the wave climate becomes near perpendicular with the coast and then progressively changes to become more south of shore normal with the changed orientation of the coastline. Wave driven currents will follow this pattern, although periods of different current direction will occur with the changing wave climate.

2.3.4.2 Entrance

Both tidal and wave driven currents within the entrance drive the shape and fluctuation of the entrance channels and bars. Numerical modelling has been used to provide information on current speeds under the existing channel and bar configuration, however the location and distribution of current speeds is liable to change with the changing size and extent of channels and bars. Measured current data is not available within the Study Area.

Modelled spring flood- and ebb-tide current speeds are presented in Figure 2-62. Current speeds are in excess of 1.0m/s through much of the channel at the ebb tide from offshore to Townsend Bluff. Current speeds outside of the main channel are low, less than 0.4m/s peak and mainly less than 0.2m/s. The map shown below in Figure 2-62 is the instantaneous current speed and currents are observed to be higher earlier in the flood tide along the Broadbeach Estate and adjacent to the Inverloch boat ramp jetty, although speeds remain under 0.5m/s.

The flood tide current speeds are also high, exceeding 1.0m/s in parts, although the duration and extent of extreme current speeds is much less than the ebb tide.

Current speeds are however higher on the bars with the flood current speed peaking over 0.25m/s across most of the entrance during the incoming tide. The activation of secondary “flood tide” channels in conjunction with the main tidal channel can be seen in the flood tide map, especially connecting the Inverloch Jetty channel to the main channel and east of Point Smythe. In contrast to this, secondary ebb tide channels are more notable across the outer bar, notably to the west of the main channel near Point Norman.

Current roses showing the current direction and speed over a 6-month period at locations A, B and C noted in Figure 2-62 are presented in Figure 2-63. The model results show currents are constrained to a narrow directional band during both flood and ebb tides. Currents show flow “going to”, as opposed to wave roses which show waves “coming from”. Ebb tide flows are stronger as shown by the higher proportion and higher current speeds on the south-southeast and southwest roses for the outer channel and at the mid-channel point adjacent to the Ayr Creek lagoon respectively, and by the dominant and higher north-westward currents in the Inner Channel rose.

These tidal patterns are representative of conditions in January 2021. They include the bathymetry survey collected in November 2020 and April 2021 and are astronomical tide currents only. The shifting entrance channels mean the location and to a lesser extent, the current speed, will vary over time as will the driving tidal fluctuation.

Addition of waves onto the tidal hydrodynamics presented below changes the current speeds and patterns. The changes are comparative to the level of wave energy but differ in their influence with variance of wave direction and period, and the corresponding tidal state and water depth. Any number of combinations of these drivers influence current speeds however the influence is limited to the main area of wave energy, as shown in Figure 2-52. Tidal currents through the entrance and across the bar have a greater influence on the wave climate as noted in Section 2.3.3.1.